Ergonomic Hazards in Local Fireworks Factories

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Abstract: *The objective of this paper is to review the practices, postures and workstations in Maltese fireworks factories which may cause back pain and musculoskeletal disorders to fireworkers. Hazards varying from the toxicity of substances used to produce colours and pyro-effects up to ergonomic adversities that such processes impose upon the workers are present in these factories. At fireworks factories, the ergonomic aspects are not considered important and this is mainly attributed to the financial aspects and traditional methods of manufacturing. Rivalry between local fireworks factories fuels this passion which forces the voluntary fireworkers to increase or maintain their yearly production and hence their exposure to such ergonomic hazards. Literature that specifically discusses ergonomics or fireworks manufacturing is readily available, but literature which combines both topics is difficult to find. Even the local legislation, mainly the Explosives Ordinance (Laws of Malta – Chapter 33) and the Occupational Health and Safety Authority Act (Laws of Malta – Chapter 424), do not cross reference each other to provide fireworkers with suitable and systematic guidelines. For this pilot study a questionnaire was designed for use as an investigative tool, to help understand the cause of fireworkers' complaints of aches and pains (if any) during fireworks manufacturing. Results, gathered from 51 licensed fireworkers indicated that the manufacturing processes are the cause of pains located mainly in the upper part of the body. The respondents reported their pains as being frequent or occasional during an average six hour production day. Further discussion argues that these fireworks enthusiasts (the respondents) consider these reported pains as part of their job at the fireworks factories. These illnesses and ailments may be causes of minor and/or major accidents during the processes. These may even end up in injuries, deaths, news sensationalism and resurfacing protests by anti-fireworks citizens.*

Keywords: *fireworks, fireworkers, ergonomic hazards, work practices, time*

Introduction

Ergonomics

The three basic human sciences anatomy, physiology and psychology converge to forge ergonomics to ensure that human beings and technology function in complete harmony. Although ergonomics is widely used during our daily domestic lives, it is far more involved in work settings. Ergonomics helps to increase efficiency, productivity and health and safety.

Local fireworks factories

Fireworks is a Maltese culture which was born decades ago, after the arrival of the Knights of St. John, and nurtured later during the last century. Village fiestas are organized upon four main pillars – church functions, street decorations, band marches and fireworks. Rivalry between fireworks factories within the same town and also between neighbouring towns holds an important role in the continuous improvement of local fireworks manufacturing.

A total of 38 factories, which are spread across Malta and Gozo, host nearly 1000 licensed enthusiasts. The factories and the manufacturing processes are regulated by the Explosives Ordinance.[1] Each factory is managed by a licensee, who is responsible for the safety of these volunteers and the general manufacturing processes. Maltese fireworks are typical 'Italian type shells',[2] but

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with innovative fireworks and pyrotechnics. The Maltese fireworkers are much renowned for the 'beraq pront', multibreak colour shells and the more complicated 'murtali tal-logħob'.

Literature review

The local fireworks industry

Esteem and acknowledgment from foreign fireworkers proves that Malta is a sort of Mecca for pyro-enthusiasts from all over the world. Mark Lancaster in 'Fireworks – Principles and Practices' describes Malta as a *'unique place, where fireworks in their purest form are enjoyed for their own sake, by some of the friendliest and skilled pyrotechnists I have ever had the pleasure to meet'*.[2]

Fireworks and health & safety

The manufacturing process of fireworks is a slow and rigorous one. Dr Takeo Shimizu in his book 'Fireworks – the Art, Science and Technique' published various flowcharts and tables to break down the processes.[2] Through these the reader can get a glimpse of the variety of tasks which the fireworker will have to undertake once the process of manufacturing has been started.

Although fireworks are part and parcel of our everyday community life, safety in this regard is not inherent in the manufacturing processes. It was only in the last few years that occupational health and safety issues were introduced to the Maltese pyro-community through the courses which have been set up by the Maltese Police Force to grant the A and B licences. But a mere two hour session is really not enough to even introduce the risks associated with the manufacturing of fireworks.

Ergonomic hazards

Although the chemicals at the factories present the highest level of risk and hazards, other risks are omnipresent throughout all the processes. Ergonomic hazards are more prominent at the local factories since these factories are built and run by volunteers. These factories are financed by the money collected from parishioners or fund-raising activities. Investing finance in adequate seating or workstations is considered less important than buying several kilograms of a chemical which will improve the shells' performance. Moreover, studies and writing about the ergonomic hazards in local and foreign firework factories are non-existent. The author's attempts to find literature about ergonomics and fireworks production proved futile. Comparing fireworking activity with catering activities the author was introduced to conditions which may be caused by fireworks production. Repetitive motion disorders (RMDs) are described by http://www.medicinenet.com as 'a family of muscular conditions that result from repeated motions'[2] and research published by the European Agency for Safety and Health at Work in 2000 states that lower back pain 'is any back pain between the ribs and top of the leg that results from any cause'.[2]

The European Agency for Safety and Health at Work states that: 'in a stressful environment people might be more sensitive to pain'.[2] Local firework factories are a stressful environment: all the risks and hazards, the urge to finish the planned works, competition against neighbouring factories and loads of other small issues combine to increase stress upon the workers.

Methodology

The author, being a fireworks enthusiast himself, already had knowledge of manufacturing which helped a lot in the structuring of the questionnaire and discussion of the results. The primary data were collected by means of a survey.* This type of approach helped in presenting insights into the workers' health status during and after fireworks production, the persistence of the ailments and their knowledge of ergonomic hazards at the fireworks factories.

A questionnaire, the most common research instrument, was chosen for the collection of primary data and it consisted of both nominal and ordinal questions. The questionnaire was presented in the Maltese language, so that the respondents would fully understand the technical (on fireworks) questions. The sampling unit consisted of licensed fireworkers irrespective of their age, sex, type of licence and years of experience. Thirteen localities where fireworks factories are located were randomly chosen. Contact points were identified in each locality and through them a sample number of 105 licensed fireworkers was established. Respondents were

* See http://archives.jpyro.com/?p=1042 for a copy of the survey.

Table 1. *Pain reported by respondents.*

Pain	Normal range	Overweight	Obese
Lower back	3	7	4
Lower back and calves		1	
Lower back, calves and ankles		1	1
Lower back, calves and knees		1	1
Lower back and knees	1	2	
Knees		2	
Lower and upper back	1	4	2
Upper back	2	2	2
Lower and upper back, calves and ankles			1

asked to self-administer the questionnaire during the months of November–December 2007. Out of 105 distributed questionnaires, 51 returned the questionnaires. The response rate was 48.6%. The non-respondents were not requested to complete the questionnaire.

Results, findings and discussion

The results presented here are a basic statistical occurrence of pains and aches which result from hours of hard labour on the production of fireworks. Moreover the subjects were asked which tasks cause such ailments. Factors such as stress, production time, medical assistance, sick leave and health & safety knowledge were also surveyed.

Profile of sample: age distribution and gender of sample (Q1 & 2)

72.5% of all the subjects, 51 in number, who returned the questionnaire, were under 45 years of age. Male workers are much more common in firework factories than females; this is in accordance with the fact that only one female returned the questionnaire.

Height of sample (Q3)

The subjects were asked about their height, since the benches where these persons work are not adjustable according to height. This information can be used for further studies and experimentation. The single female respondent fell in the lowest height group.

Weight of sample (Q4)

The exact height and weight of each individual in the study was not asked. The interviewees could choose between different group limits so the approximate body mass index could be calculated for the sample. The sample replies were sorted on an Excel sheet and compared to a body mass index graph and then related to pain reported in the back and lower limbs during fireworks manufacturing. These results indicate that most persons are either overweight or obese and this could be an added complication resulting in back and lower limb pain. However the sample size for normal body mass index was too small to deduce any conclusive results.

Type of licence and years of experience (Q5 & 6)

The type of licence that gives a person the right to perform fireworks is important. 76.5% of the sample hold a B licence, whilst the other 23.6% hold an A licence. Licence A holders are more experienced than Licence B holders; this can be deduced from the fact that all the 12 licence A respondents have placed themselves in the range of 11 years to over 50 years of experience. Positively enough none of the respondents had worked in a fireworks factory for less than one year. This means that their reply is based on at least a year's experience, hence they have come across all the processes at the factories.

Professional or volunteer (Q7)

All the respondents declared that they do not earn their living from manufacturing fireworks. This is consistent with the voluntary work, dedication and passion these men and women put into this art all year round. The main concern at the factories, which are run on a voluntary basis, is the quality and quantity of the shells. Tools and work practices

are not substituted unless the shells produced are better and more numerous even though the systems presently being used are causing ailments due to factors such as repetitive motion, bad postures and restricted work space. Since the work is done on a voluntary basis it takes place during free time (after a normal 40 hour a week job) and this may cause a build up of stress especially during the months of preparation and assembly of the shells.

Employment sector or status (Q8)

The respondents' employment sector or status is here listed in decreasing order: 23 services sector, 15 manufacturing and construction sector, 9 pensioners, 2 in the agriculture and fisheries sector and 2 unemployed. Since 78.4% of the respondents could be exposed to ergonomic hazards such as repetitive work, bad posture at the office, prolonged seating and manual handling during their employment period, and so compromise questions 18a, 18bi, 19, 20 and 21 (where the respondents were asked if any musculoskeletal pains were caused by fireworks manufacturing), question 9 was intended to isolate fireworking activity pain from employment/sports/free time activity pain.

Work, free time or sporting activities related to musculoskeletal pain (Q9)

63% of the respondents do not perform heavy lifting or other work that causes musculoskeletal pain during their work, free time or sports activity. Added to this, the workers could specify at what time the aches or pains are felt, whether it is fireworks production, during salary based work, or during any other activity such as sports or hobbies. This renders the answers for questions 18a, 18bi, 19, 20 and 21 more plausible.

The manufacturing processes and the workers' health

Jobs performed (Q10 & 11)

The subjects were asked to write down the most common three pain-causing jobs from their already marked list. When analyzing the most performed jobs versus the most pain-causing jobs the top five jobs are as follows.

Body movements during tasks (Q12 & 13)

The majority of the workers reported repetitive hand movements using small muscles such as gripping (88.2%), squeezing tightly with the

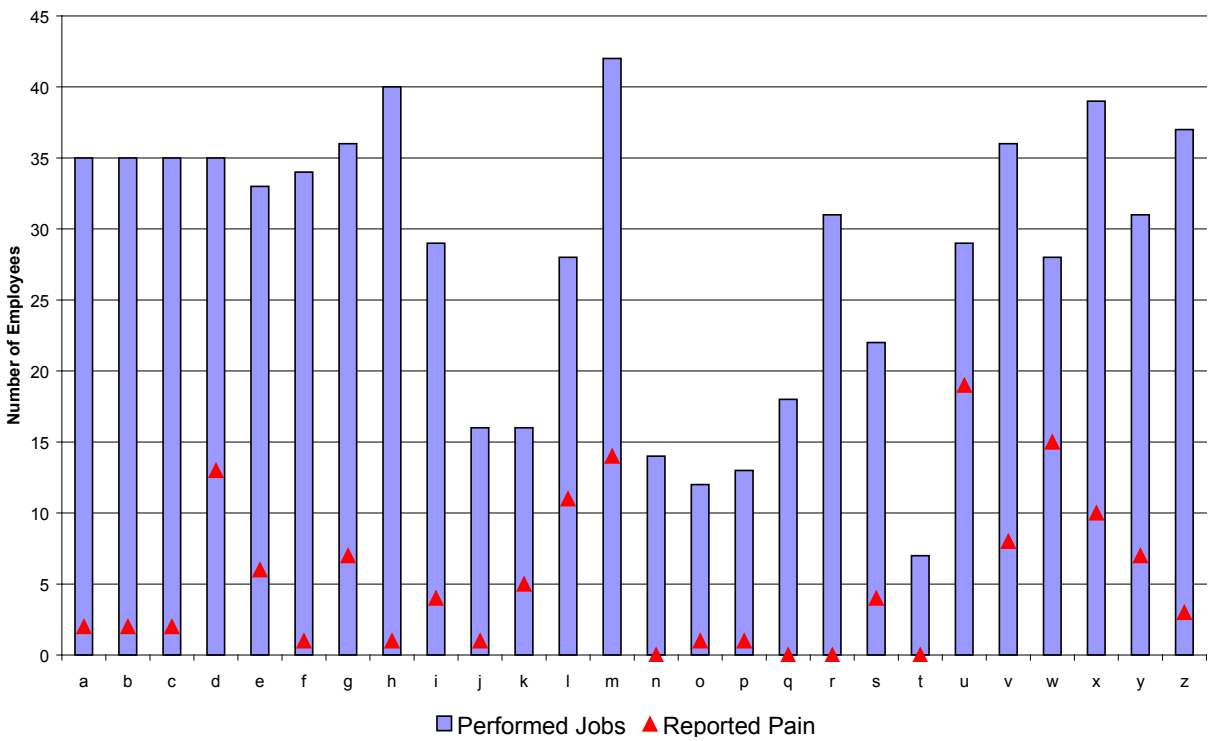

Figure 1. *Rate of jobs performed and pain reported for each job. See Appendix for definitions.*

Table 2. *Table showing most painful job by the most performed.*

Code	Job	%
U	Spiking of shells (5" in diameter and bigger)	65.5
W	Assembly of shells	53.6
L	Sieving of black powder	39.3
D	Spiking of beraq casings	37.1
M	Carrying of black powder into sunshine	33.3

fingers (82.4%), and bending of wrist (78.4%). Other tasks require whole body movements such as carrying (76.5%), twisting (72.5%) and bending (54.9%). The least performed task which the subjects recall is pushing (52.9%). This data is very important when collating musculoskeletal ailments to such tasks and also when proposing innovative work processes.

Although there is a balanced reply between reported and non-reported, pain during fireworks manufacturing is mostly reported in finger joints, hands and shoulders. The writer expected a higher incidence of pain in these areas and in the wrist area. However, a psychological factor could be affecting this response; that is the acceptance of such pain as part of their voluntary work.

Stress caused by target date (Q14)

Improving the fireworks' quality and quantity increases stress and tension which may cause the workers to bypass their 'ergonomically safe' work practices and perform undesirable work practices such as working in limited areas on the workbench, working in awkward standing positions and carrying greater loads. These undesirable work practices added to accumulated stress and tension may be the cause of musculoskeletal injuries. Results show that 72% of the sample agrees that the completion of planned fireworks manufacturing processes in due time increases tension and stress.

Workstations (Q15)

It was assumed that the respondents had limited knowledge about the ideal height of their workstations so a question was presented to perceive the respondents' comfort at the workstations in the fireworks factories. 73% of the respondents agreed that their workstations are suitable for their needs.

As already explained in the literature review, the factories are run by donations and such funds are invested in the chemicals, cardboard and other relevant items for the production of shells and not in the workstations. Semi-broken chairs, stools, wooden boxes and other spontaneously invented seating is very common at the factories (Plate 2 and Plate 3). The author recalls a particular factory having a tilted work bench positioned on a slightly sloped concrete platform (Plate 1 below), which implies that the worker has to continuously work in an unlevelled posture. Should the fireworkers be better educated and trained in the best measurements for their workstations, an improvement of the work benches would be definitely seen in the future.

Manufacturing time (Q16 & 17)

Response to these questions can give a glimpse of the average time spent on production during a normal day and total weekly time.

From these results we can derive the exposure time these workers have to ergonomic hazards at their local factories and through further and more

Plate 1. *Wooden blocks used to level a working bench at a local fireworks factory. Source: author's own gallery.*

Plate 2. *Examples of seating at the factories.*

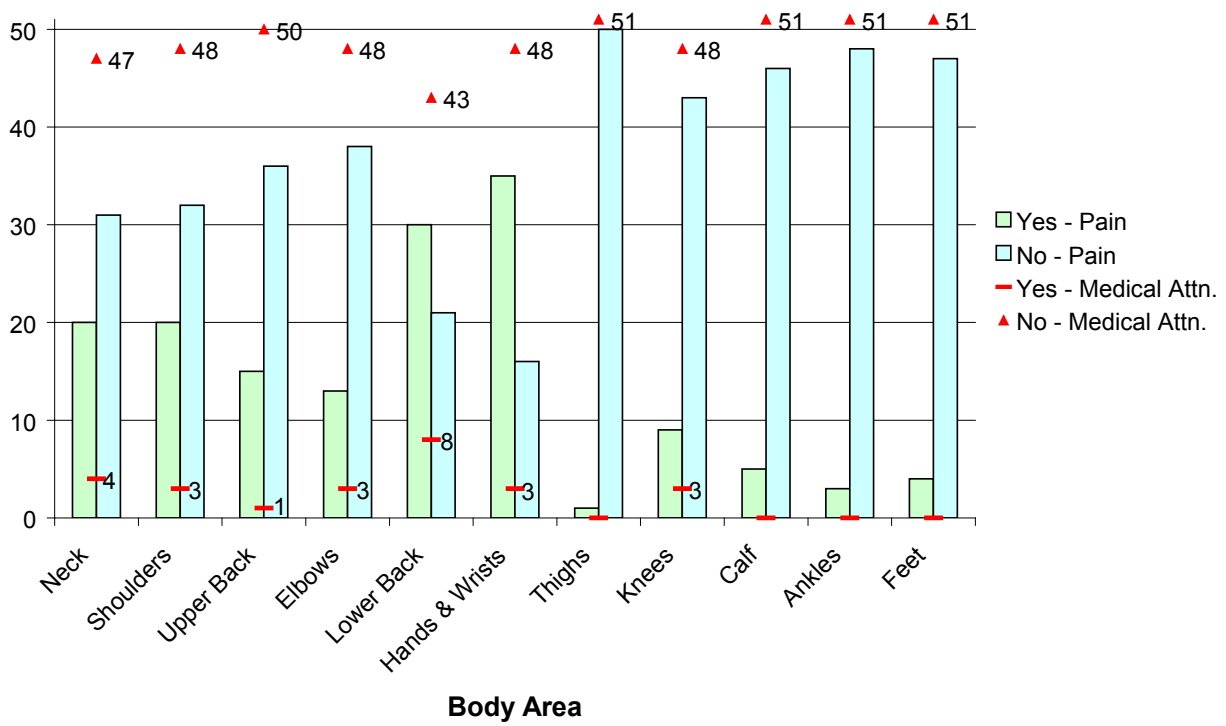

Figure 2. *If pain is reported in particular body areas and if medical attention is sought for such pain.*

detailed studies a threshold limit value (TLV) or short term exposure level (STEL) can be attributed to each task. Taking into account all data retrieved from these questions we can state that the average working period of a normal production day is 5.48 hours per worker.

Musculoskeletal disorders in specific areas (Q18a & 18bi)

The interviewee was asked whether he experienced any musculoskeletal pain during the past year as a result of his fireworking activity and if he has ever asked for medical advice to cure such problems.

Lower limb pain incidence is very low when compared to pain in the upper torso and upper limbs. Notwithstanding that, some subjects reported discomfort, about which they did not seek medical advice, except for a mere 5.9% that suffered knee problems.

Plate 3. *Other examples of seating found at the factories.*

Pain in the hands and wrist was the most highly reported (68.6%) although only 8.6% of these subjects sought medical advice. Here we must reconsider the answers presented in Question 12. In this question the subject is once again being questioned about pain that he/she may recall during certain instances where pain or ache was experienced. The author firmly believes that the answers presented in this question are much more realistic and reaffirm the theory that the voluntary fireworker considers pain as part and parcel of his job.

Figure 2 shows that medical advice is most commonly sought for lower back pain. It is widely known that lower back pain is the major ailment of the European workforce. The findings show that 58.8% of the respondents have suffered some form of lower back pain due to fireworks manufacturing but only 26.7% of these subjects sought medical advice.

The results for elbow pain are more alarming. Although 25.5% of the respondents ticked 'Yes' as their result, 23.1% of these sought professional medical care. This may mean that such aches and pains are much more severe, chronic and annoying than hands and wrist pains. The author recalls mild lower back pain and mild elbow tiredness during the shell spiking process. The author also states that his production time was very low when compared to the long hours of production his comrades used to spend. The most alarming result comes from knee pains. Nine subjects reported knee discomfort and three of them asked for medical advice related to such problems. It is unclear what causes such problems since all three respondents come from different age groups and have different height and weight combinations. When referred to the BMI graph two of the three subjects were found to be overweight and the third one obese. As for the working hours the two overweight respondents reported working from 11–20 hours per week whilst the obese respondent reported working from 6–7 hours per week.

Quantifying aches and pains (Q18bii & 18c)

The subjects were then asked to be more specific on the frequency of their aches. Almost all of the subjects reported 'occasional' or 'frequent' pain.

More specific questions (Q19, 20 & 21)

The subjects were asked if they had experienced any back pain these last three months due to their fireworks manufacturing.

68.6% of the respondents reported negatively, the rest gave a positive answer. This may be due to the fact that during the period this survey was distributed, the processes at the factories did not involve the spiking and/or mounting of the shells, now deemed as the most pain causing jobs at the factories. But other tiring jobs such as sieving black powder and carrying it into the sunshine are regularly conducted throughout these months.

The sample was than asked a further two questions:

- If these tasks have caused severe pain which forces them to stop the production.
- If, even though they suffered severe pain, they have persisted in their production.

The results to both questions are as follows:

- 13.7% of the respondents had to stop the manufacturing due to pain.
- All 7 subjects that 'had to stop due to pain' responded negatively when asked if they have ever persisted on working although in pain.
- 27 subjects responded negatively to both questions.
- 17 subjects noted that they have kept on their production although in pain, but never wanted to stop.

The author once again puts forward the theory that pain is considered by the volunteers as part of their job, hence they accept the muscular pain and keep on persisting with their production. In fact only a small percentage decided to stop work due to their pain.

Sick leave (Q22 & 22a)

In the following question the subjects were asked if they have ever benefited from sick leave due to pain caused during fireworks manufacturing and the duration of such leave.

Four subjects gave a positive answer. Three subjects of these formed part of the sample that had to stop their production because of the pain. The fourth subject who took sick leave previously reported having kept on working although suffering pain.

The sick leave duration of 50% of the subjects was not longer than 3 days whilst the other 50% were absent from work from 4 to 10 days.

Education – occupational health & safety principles and manual handling (Q23 & 24)

The subjects were asked if they ever received occupational health & safety and/or manual handling training in the context of fireworks production.

It can be clearly noted that the lack of training is spread across all the manufacturing years. A concentration of 'OHS trained' is found in less experienced manufacturers. The author realised that the only official training these fireworkers get on fireworks production is during a special course held prior to the granting of licences A or B.

During this 12 hour course a 2 hour session is allowed for occupational health and safety. During this very short session very basic OHS principles are explained to the attendees and the lecturer almost completely bases his talk on the toxicity of chemicals. He only spends 15 minutes dealing with ergonomics and no training in manual handling at fireworks factories is ever practised.

As previously stated the short course, which is meant to grant a licence for fireworks production, does not include any manual handling training. 56.9% of the sample gave a negative response to the question, thus confirming that they were never given any training in manual handling during fireworks production.

As previously stated the short licence granting course does not include any manual handling training and since the questionnaire was self administered the 22 respondents who chose 'Yes' as their answer must have been misled by the question and confused other manual handling training undertaken at any other place. Hopefully they are putting this training into practice during their fireworks manufacturing. A quick review of these subjects shows that 10 out of 22 perform lifting of heavy items at their place of work in the manufacturing and construction industries.

Conclusion

The manufacturing of fireworks is a local culture which is highly esteemed by the international fireworks community. Nearly 1000 licensed predominantly male voluntary fireworkers put into practice their artisan capabilities at the local fireworks factories across Malta and Gozo. Rivalry between these enthusiasts drives them into strenuous manufacturing processes, which results in spectacular fireworks shows during the summer period. In the attempt to manufacture better shells, these enthusiasts put into practice riskier tasks, in an already hazardous workplace.

The selected sample showed a median height of 1.61–1.70 m (41.18%) with an average weight of 71–80 kg (33.33%) and a very wide range (18 to >65) in age distribution. The majority worked in demanding employment sectors prior to their voluntary tasks (5.48 hours per worker of average extra working time) at the fireworks factories. All of these factors play an important part in the musculoskeletal conditions reported by those voluntarily employed in fireworks factories.

Further studies would be required to provide the statistical significance of the origin of musculoskeletal complaints amongst those 'employed' in such activities following a full day's work in these sectors, although 63% of the respondents did not admit to aches, pains or sporting activities. Firework manufacturing processes require a large number of hand, wrist and upper arm movements. These involve whole body movements such as twisting, bending and both carrying and pushing loads

From an ergonomic perspective the levels of risk from the tasks performed at the fireworks factories increases when conditions such as time and workspace are considered. Reported results show that on an average working day the voluntary workers spend several hours working on a myriad tasks at the factories. The carrying of black powder in the sunshine and spiking of shells larger than 5 inches in diameter were tagged as being the most frequent job and the most tiring job at the factories respectively. Results show that fireworks manufacturing causes most pain in the upper body parts, mainly in the hands and wrists, and this is all attributed to repetitive motions and continuous forces exerted with hands, arms and upper torso. 72% of the respondents agreed that all of this is made worse due to stress imposed by the multitude of tasks which is to be completed within defined timeframes, the limited time available for manufacturing the fireworks and ever increasing pressure by supporters and sponsors.

Training in posture, manual handling and an improved working environment would go a long way to reducing work-related musculoskeletal conditions at fireworks factories.

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Appendix

List of processes as given on the questionnaire

A Rolling of beraq casings

B Rolling of shells casings

C Filling up and closing of beraq casings.

D Spiking of beraq

E Priming of beraq

F Placing of beraq inside shell casings

G Cutting of cardboard discs by hand

H Cutting of cardboard discs by motorized blade

I Carrying of materials from vehicles to stores

J Carrying of material from stores to barrel room

K Putting in and/or taking out material from he barrel

L Sieving of black powder

M Carrying of black powder filled trays into sunshine

N Mixing of colour and/or flash compositions

O Pressing of stars

P Priming of stars

Q Placing of stars inside shell casings

R Closure of shells

S Pressing of spoulettes and/or drivers by hand.

T Pressing of spoulettes and/or drivers by pressing machine

U Spiking of big shells (5 inches and over in diameter)

V Spiking of small shells

W Mounting of multi-break shells

X Paper gluing of shells

Y Placing in of lifting charge, shock absorbers and leaders onto shells

Z Placing of lifting charge and leaders to finale shells

AA Manufacture of quickmatch

AB Charging of lances

AC Preparation works on ground fireworks.

AD Sieving of charcoal

AE Others