



# Risk assessments of work-related musculoskeletal disorders among the TFT-LCD manufacturing operators



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## ABSTRACT

The thin film transistor liquid crystal display (TFT-LCD) industry is one of the major industries in Taiwan, yet few studies addressed its work-related musculoskeletal disorders (WMSDs). Thus, this study aims to evaluate the risk of WMSDs among the operators of a TFT-LCD manufacturing company in Taiwan by using the subjective questionnaire and ergonomic assessment tools. First, the NMQ survey was conducted among 393 operators, accounting for 94% of all operators in the TFT-LCD plant. The results showed that the prevalence of WMSDs was 31.8%. Among the various body parts, the highest prevalence of WMSDs was found in neck and shoulders (20.4%), while upper limbs were with the lowest prevalence (9.2%). Besides, the prevalence of WMSDs tends to be affected by both work factors and operator factors. Those who were more experienced, working in day shift and involved in the Array process tend to have a higher prevalence of WMSDs. Further, female and domestic operators reported a higher prevalence of WMSDs than male and foreign operators. Moreover, the jobs of 50 employees were analyzed using ergonomic assessment tools including OSHA MSDs, BRIEF, OWAS, 3D SSPP, and NIOSH lifting equation. The findings indicated that inadequate working height, restricted working space, awkward postures, overweight load, and high repetition were the major risk factors of WMSDs. Thus, countermeasures such as redesigning the workstations and material handling carts, proactive training of manual material handling, and providing safety clearance are recommended to enhance the occupational health and safety of the TFT-LCD operators.

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## 1. Introduction

With the rapid development of the optoelectronics technology, the Thin Film Transistor Liquid Crystal Display (TFT-LCD) industry becomes one of the two major industries in Taiwan. In 2013, the production value of TFT-LCD products approached NT\$ 944.7 billion (US\$ 31.5 billion), holding around 26% of the global market (Liu, 2014). As the production increases, the demand for labor also rises. In the meantime, the occupational health of the employees in the TFT-LCD industry needs to be addressed.

In order to investigate the work-related musculoskeletal disorders (WMSDs) among TFT-LCD operators, the first step is to obtain a clear understanding about the manufacturing processes, as well as the job functions of the human operators. The manufacturing

processes of TFT-LCD involve the Array process, the Cell process, and the Module process. The Array process is similar to the manufacturing process of semiconductors, with thin-film deposition followed by photolithography and etching. The difference is that the thin-film transistor is fabricated on glass substrate instead of silicon wafer. Subsequently, in the Cell process, the arrayed back substrate and the front color filter substrate are joined together by filling liquid crystal in between. After polarizer attachment, it proceeds to the Module process for the assembly of driver IC, backlight unit and PCB with the TFT-LCD panel. As the final inspection is completed, the TFT-LCD panels become finished products.

In spite of the high degree of automation in the Array process, human involvement is required in tasks such as carrying WIPs (work in progress) with carts between workstations and moving WIPs into or out of machines. In these manual operations, similar as in the semiconductor industry, the issue of WMSDs among operators needs to be highlighted. According to the survey conducted by

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Li et al. (1997) among 810 employees of nine semiconductor manufacturers in Taiwan, shoulders (42.0%), ankles and feet (33.1%), and low back (30.9%) were found to be the body parts with high prevalence of WMSDs. In addition, the prevalence of WMSDs in operators was higher than that in engineers, implying that more attention should be paid to operators. Further, the WMSDs in low back seem to increase with job experience, and hence this cumulative trauma disorders need to be managed as early as possible.

From the product point of view, the substrate size becomes smaller as moving from the Array process to the Cell process. Thus, the Array process requires more automated material handling and machine operation, while the demand for manual handling increases in the Cell process. As for the Module process, it involves assembly, visual inspection, and packaging, with prolonged standing postures. In general, the focus of WMSDs among TFT-LCD operators may vary from process to process, so an in-depth ergonomics investigation would be necessary. Nevertheless, few studies addressed the WMSDs issues of the TFT-LCD operators. Twu et al. (2010) focused on evaluating the visual fatigue problems suffered by operators handling light-on test inspection in the Cell Process. They found no significant effect of illumination level on the operator's visual fatigue. Besides, Lu et al. (2012) applied questionnaire and ergonomic checklists to evaluate the workplace design in the Module process and reported that musculoskeletal disorder symptoms are frequently complained in shoulders (59.8%), neck (49.5%), wrists (39.5%), and upper back (30.6%). Apparently, more efforts are required to investigate the WMSDs among TFT-LCD operators in the Array process and the Cell process.

Therefore, the purpose of this study is to evaluate the WMSDs among the TFT-LCD operators in the Array process and the Cell process by using different ergonomic job assessment tools. Based on the identified risk factors, intervention strategies are proposed to improve the WMSDs problems in the TFT-LCD manufacturing workplace.

## 2. Method

### 2.1. Selected working areas

This study was conducted in a 3.5th generation (G3) plant (substrate size: 600 mm × 720 mm) of a TFT-LCD manufacturer in Taiwan. Table 1 lists the seventeen selected working areas in the Array process and the Cell process.

### 2.2. The NMQ survey

In order to understand the prevalence of subjective symptoms associated with WMSDs, the Nordic Musculoskeletal Questionnaire (NMQ) was prepared in both Chinese (for domestic operators) and English (for foreign operators). The NMQ is a close-ended questionnaire developed for epidemiological studies covering the subjective discomfort feelings occurred in neck, shoulders, upper back, elbows, low back, wrist/hands, hips/thighs, knees, and ankles/feet (Kuorinka et al., 1987). It has been applied to a wide range of occupations to identify musculoskeletal problems (Cook et al., 2000; Macdonald and Waclawski, 2006). The reliability ranges from 0.77 to 1.00, and the validity ranges from 0.80 to 1.00 (Deakin et al., 1994).

The contents of the questionnaire consist of personal information and symptoms of WMSDs. There are twenty questions about personal information, such as gender, age, ethnicity, working area, work shift, job experience, and general complaints about discomfort. It can be used to not only investigate the affecting factors of WMSDs but also keep track of each employee's health condition. In the second part, the respondent was asked to report the symptoms

**Table 1**

The selected working areas and corresponding number of participants.

Process	Working area	Task description	Number of participants
Array	UNPACKING	Unpacking glass substrate	2
	TF	Thin-film deposition	2
	PHOTO	Photolithography	1
	ETCH	Etching	2
	INT	Testing	2 <sup>a</sup>
Cell	F1	1st cut & color filter cleaning	4 <sup>a</sup>
	F2		2
	F3	Polyimide film printing	4
	F4	Rubbing	4
	F5	Assembly	3 <sup>a</sup>
	F6	Jig press	1
	ODF	One-Drop-Filling inspection	5 <sup>a</sup>
	B1	2nd cut	4 <sup>a</sup>
	B2		4
	B3	Polarizer attachment	4 <sup>a</sup>
	B4	Testing	4 <sup>a</sup>
	PACKING	Packing TFT-LCD panel	2

<sup>a</sup> Including one operator on night shift.

of WMSDs including the feelings of pain, stiffness, soreness, tingle and numbness in his/her neck, shoulders, upper back, elbows, low back, wrists/hands, hips/thighs, knees, and ankles/feet over the past six months.

If a symptom occurred one to two times a week or even more with the level of discomfort reaching 5 or higher (out of 10), it is defined as being with self-perceived WMSDs. The prevalence of WMSDs is calculated as a percentage by dividing the number of people identified with self-perceived WMSDs by all individuals within the specified group.

The questionnaire was distributed to all operators in the TFT-LCD plant except those who were on vacation or sick leave during the one-month survey. The total number of valid samples was 393 (accounting for 94% of all operators), with a 100 percent return rate.

### 2.3. Ergonomic job assessments

#### 2.3.1. Participants

In order to assess the risk levels and factors associated with the WMSDs, the operations performed in the seventeen working areas in the Array and Cell processes were recorded and analyzed. Considering time and cost efficiency, the policy was to observe 50% of the operators during a day/night shift in each working area. After a pilot study of the Ovako Working posture Analysis System (OWAS, details provided in section 2.3.3) analysis for one operator in each working area, the levels of risk were roughly identified. Subsequently, the number of participants was increased for the working areas with higher levels of risk or in which more types of operations were involved, while the number of participants for other working areas was decreased. Following this logic, as shown in Table 1, there were totally 50 operators (accounting for 48.5% of the total number of 103 operators in a day/night shift) participating in the analysis, covering both day-shift and night-shift ones.

#### 2.3.2. Descriptions of the job functions

In order to analyze the levels of WMSDs risk in the selected seventeen working area systematically, the typical job functions performed in the Array and Cell processes were presented in ten categories. They are described as follows:

- (1) Load/Unload (L/U): loading cassettes from the rack to the machine or unloading cassettes from the machine to the rack, as shown in Fig. 1(a);

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