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Case Reports

Review of a Case of Chronic Obstructive Pulmonary Disease in Workers Exposed to Synthetic Fibers

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ABSTRACT

Objectives: Objectives of this study were: 1) to introduce industrial situation and health hazards of synthetic fiber, 2) to review a case of chronic obstructive pulmonary disease in a worker exposed to synthetic fiber reported to the Korea Occupational Disease Surveillance Center, and 3) to suggest supplementary measures for the occupational health system for workers exposed to synthetic fibers.

Methods: Respiratory exposure, health hazards, and exposure standards for synthetic fiber dust in Korea and other countries were reviewed. In addition, a case of chronic obstructive pulmonary disease due to exposure to nylon dust reported to the Korea Occupational Disease Surveillance Center was reviewed and summarized.

Results: The worker was a 53-year-old non-smoking male who had been involved in the nylon weaving process for 26 years. He had shortness of breath from three years ago. He was diagnosed with chronic obstructive pulmonary disease. PM1.0, $PM_{2.5}$, and PM10 were measured at 26.6 $\mu g/m^3$, 48.2 $\mu g/m^3$, and 91.7 $\mu g/m^3$, respectively. Fiber components estimated as nylon fiber were detected in the microscopic examination of a solid sample.

Conclusions: For workers exposed to synthetic fiber dust, special health examinations of the respiratory system, regular work environment measurement, and work environment management through workplace health management should be performed. It is necessary to research on health effects of synthetic fibers.

Key words: chronic obstructive pulmonary disease, pulmonary disease, synthetic fiber, nylon fiber, weaving

I. Overview

Technical textile refers to a fiber with lighter weight, higher strength, higher elasticity, higher heat resistance, and higher chemical resistance than general textiles. They can improve the added value and competitiveness of various industries such as automotive, aviation, electrical and electronic, civil engineering and construction, medical devices, shipbuilding, and machinery. The industry is highly capital-intensive. As the industry is seen as a technology converging future growth engine, global leading companies, mainly those in advanced countries, are establishing oligopolistic systems to create clusters and cross-stream and cross-industry cooperation systems for the industry and increasing investment in its technology development as part of policy (Park, 2021). Accordingly, the number of workers in the industry is predicted to increase. Thus, there is an urgent

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need to establish a system for synthetic fiber-related work environment management and occupational health management and to improve treatment for workers.

Dust generated from synthetic fibers like nylon is not classified as a hazardous substance. There are no publicly established estimates of its potential harm. Several studies have shown that exposure to synthetic fibers such as nylon is associated with lung disease (Eschenbacher et al., 1999; Porter et al., 1999; Nordness et al., 2003; Kern et al., 2011). Therefore, this study aimed to introduce industrial status and health hazards of synthetic fibers not classified as hazardous substances needing mandatory special medical examinations and work environment measurements so that we could collect information about industrial status and health hazards of synthetic fibers through a literature survey. Another purpose of this study was to suggest additional rules for the occupational health system for workers exposed to synthetic fibers based on a case of chronic obstructive pulmonary disease caused by exposure to nylon fibers reported to the Korea Occupational Diseases Surveillance Center (KODSC) (Ministry of Employment and Labor, 2022).

II. Methods

This study conducted a literature review on respiratory health hazards caused by exposure to synthetic fibers, explored current Occupational Safety and Health Act's exposure limits for fiber dust. Furthermore, a case of a nylon weaving factory worker diagnosed with chronic obstructive pulmonary disease (COPD) and referred to the occupational disease safety center was investigated for the association between nylon dust exposure and the occurrence of COPD. The investigation was conducted through an examination by an occupational medicine physician, a job history survey, pulmonary function tests, blood tests, chest computed tomography (CT) scans, and workplace environment measurements.

Air measurements of nylon fibers in the workplace were conducted on January 31, 2023 specifically in the area where the patient worked. It was used for three weaving processes in the weaving workshop. The relative humidity at the time of measurement was about 45-50%. The workload was about the same as usual. For the measurement of total dust, two GilAir plus personal Air Sampling Pumps were installed for a personal sample and four were used for regional samples. All samples were subjected to gravimetric analysis. Of the two personal samples, one was used for total dust measurement and the other was used for respirable dust measurement. Of the four regional samples, two were for total dust measurement and the remaining two were used for respirable dust measurement. For the total dust measurement, a 37 mm closed-face cassette with a PVC membrane filter (37 mm, 5 μm pore size) was used. The flow rate was calibrated to 1.0 L/min. As for the respirable dust measurement, a 37 mm closed-face cassette equipped with an Aluminum Respirable Dust Cyclone capable of measuring particles below 1 0μm (with an average diameter of 4 μm) was used along with a PVC membrane filter (37 mm, 5 μm pore size). The flow rate for the respirable dust measurement was calibrated to 2.5 L/min. In addition, one Blatn BR-smart-126s air monitor, a digital instrument, was installed as a regional sampling method to measure PM10, $PM_{2.5}$, and PM1.0 separately to determine the level of nylon fibers.

Two pump of the personal sampling was fixed on the breathing zone of the patient's work clothes. For regional sampling, two pumps were installed at the head of the weaving machine and the others were installed at the opposite end with digital measurement equipment installed in the middle of the machine. Measurements were taken for three

hours in the morning and two hours in the afternoon for a total of five hours.

Ⅲ. Findings

1. A case of nylon dust exposure reported to the Korea Occupational Disease Surveillance Center

A case of COPD caused by exposure to nylon fibers reported to the KODSC was reviewed and summarized. The KODSC is an institution established by the Minister of Employment and Labor to protect and promote health of workers by identifying the occurrence of occupational diseases and investigating their causes in a timely manner in accordance with Article 12.2 of the Ministry of Employment and Labor Notice 2022-33. Accordingly, the KODSC provides essential support, including detection of suspected occupational diseases, health counseling, and medical treatment for workers suspected of developing occupational illnesses. Additionally, the KODSC supports occupational safety and health supervisors by offering advice and conducting on-site investigations of diseases.

1) Present medical history

The worker is a 53-year-old non-smoking male stating in an interview with a healthcare provider that he has experienced symptoms of breathlessness since 2019. He has been engaged in the nylon weaving process for 27 years. He did not have any other remarkable occupational careers.

The patient was diagnosed with COPD in 2019 at a primary clinic. At the time of diagnosis, his pulmonary function showed a mixed spirometric pattern. Although lung function decline progresses with aging (Lee et al., 2016), the patient exhibited significantly lower function of lungs compared to men of his age. Imaging findings showed decreased vascularity in the right middle and lower lobes. Thus, pulmonary emphysema was suspected (Figure 1). Taken together, these examinations revealed no other disease to cause mixed

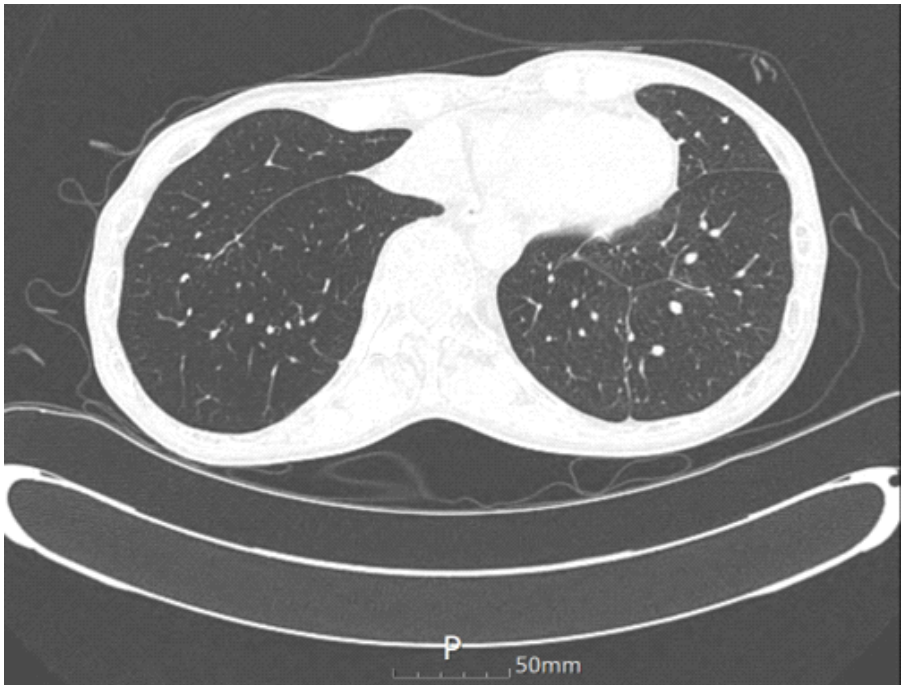

Figure 1. Chest computed tomography image of the patient showing decreased vascularity on the right lower lung field, suspected emphysematous lung (2022.08.04. Kosin university gospel hospital).

pulmonary dysfunction. The patient had voluntarily discontinued hospital care in 2022 because he experienced improvement after receiving treatment.

2) Social, family, and previous medical history

The patient stated that he was a nonsmoker and a non-drinker. He did not have any chronic diseases such as hypertension, diabetes mellitus, or hyperlipidemia. He also stated that he had been told that there were no abnormalities in his medical examinations prior to the onset of symptoms. He stated that he had suffered from tuberculosis 20 years ago. However, after recovering from the disease, he had no symptoms until three years ago when his current illness began. He had not been told that there were any abnormalities in his medical examination.

3) Occupational History

The patient has been employed at the textile factory since March 1996 for approximately 27 years. He works in the weaving process where he makes nylon fibers on a weaving machine. If he connects the nylon thread skeins to the machine, the machine (Endress) automatically makes cloth. If the thread runs out, he connects the thread to the grooved drum to keep the machine running. If the thread breaks due to an accident of the machine, he connects the thread again and monitors the occurrence of defects. The patient works two shifts, day and night. He has not had many remarkable jobs before. He worked at a food company only for three years prior to his employment at the textile factory. At that food company, he worked as a dough cutter (operating a machine that takes the shape of food products).

4) Special medical examination results

The exposure hazard which could be identified in the current system was only noise. Results of his general and special medical examinations conducted by a special medical examination institution on September 27, 2022 showed no other abnormalities except for emphysematous changes on chest X-ray. Thus, the worker has been classified as a group of patients who have probable occupational disease.

5) Work Environment Measurement

The total dust measured was at 0.17507 mg/m^3 in the personal sample, 0.21309 mg/m^3 in the part of the head, and 0.16032 mg/m^3 on the other side of the head (Table 1). Respirable dust was measured at 0.08874 mg/m^3 in personal samples, 0.04377 mg/m^3 in the respirator headpiece area,

Table 1. Particulate Matter Measurement

	Measurement time (min)	Results(mg/m^3)	Results (microg/m^3)
Personal sample*	270	0.17507	175.1
Personal sample†	270	0.08874	88.7
Local sample‡	270	0.21309	213.1
Local sample§	270	0.04377	43.8
Local sample‖	270	0.16032	160.3
Local sample¶	270	0.03477	34.8

*: Measured at the respiratory area, total particulate matter
†: Measured at the respiratory area, respiratory particulate matter
‡: Measured at the loom head, total particulate matter measurement
§: Measured at the loom head, respiratory particulate matter measurement
‖: Measured at the opposite of the loom, total particulate matter measurement
¶: Measured at the opposite of the loom, respiratory particulate matter measurement

and 0.003477 mg/m^3 on the opposite side of the respirator headpiece (Table 1). In addition, the average concentration of particulate matter measured by a digital meter was 26.6 μg/m^3 for $PM_{1.0}$, 48.2 μg/m^3 for $PM_{2.5}$, and 91. 7 μg/m^3 for PM_{10}, equivalent to 'very bad' according to the particulate matter standard. They were significantly higher than average concentrations in the area where the factory is located on the same date (the average concentration of fine dust in Deokpo-dong, Sasang-gu, Busan, Korea, where the workplace is located, was 16 μg/m^3 for PM_{10} and 12 μg/m^3 for $PM_{2.5}$). In addition, a solid sample was taken from the dust accumulated on the head of the weaving machine and submitted to the Korea Asbestos Environment Research Institute for microscopic examination. As a result, fiber components other than asbestos were detected. The fiber type was individual fibers rather than bundles. These fibers were identified as artificial chemical fibers rather than natural fibers. The fiber percentage was about 3% and the approximate size was about 20 μm. Since other fibers except for nylon were not detected in the workshop and there were no sources of other fibers in the process, it was assumed that these fibers detected in test results were nylon fibers. This suggests that nylon fibers are likely being scattered during the weaving process on the machine.

There is no exact exposure limit for nylon dust. However, for similar cotton dust, a total dust level of 0.2 mg/m^3 has been published as an exposure limit (Ministry of Employment and Labor, 2020). The dust level was measured at 0.17507 mg/m^3 in the personal sample of the worker and 0.21309 mg/m^3 in the regional sample of the machine head. These values were 87.5% of the exposure limit for cotton dusts in the personal sample. However, they exceeded the exposure limit for cotton dusts in the regional sample.

6) Clinical review

In conclusion, the patient was diagnosed with COPD based on clinical information, pulmonary function tests, imaging findings of emphysematous lung, and diagnosis of a pulmonologist. Given that the patient was a non-smoker without exposure to any other toxic substances for respiratory organs in his living environment and lifestyle, it was concluded that his COPD was caused by fugitive nylon fibers and other particulate matter from the weaving machine during the process.

Ⅳ. Discussion

1. Respiratory and other diseases caused by exposure to synthetic fibers

Many studies have suggested toxicity of synthetic fibers such as nylon with an effect on respiratory organ. The study of Pimentel et al. reported that seven patients exposed to synthetic fibers developed various bronchopulmonary diseases such as asthma, exogenous allergic alveolitis, chronic bronchitis with bronchiectasis, spontaneous pneumothorax, or chronic pneumonia(Pimentel et al., 1975). Development of interstitial lung disease in a female worker working with rotary-cut polyethylene for seven years has been reported (Barroso et al., 2002). Asthma-like symptoms, bronchitis with bronchiectasis, and so on have also been identified in animal studies with nylon. The study of Eschenbacher W.L. et al. have reported 12 cases of interstitial lung disease in workers of a nylon fiber factory. Lung tissues of patients showed lymphocytic bronchitis, peribronchial inflammation, and lymphoproliferation(Eschenbacher et al, 1999). Study of Nordness M.E. et al. have reported a case of a nylon factory worker diagnosed with hypersensitive pneumonitis (Nordness et al, 2003). The National Institute for Occupational Safety and Health (NIOSH) in the United States has analyzed a total of nine cases of interstitial

lung disease diagnosed among workers in a nylon flock factory from 1992 to 1996 (Burkhart et al., 1999). When these cases were subjected to bronchoalveolar lavage analysis, they all showed active alveolitis. This suggests that synthetic fibers might cause respiratory diseases such as chronic bronchitis, asthma, pneumothorax, interstitial lung disease, and chronic pneumonia.

2. Review of the current Occupational Safety and Health Act related to fiber dust at home and abroad

The Occupational Safety and Health Act mandates special medical examinations and work environment measurements for works involving seven agents: grain dust, mineral dust, cotton dust, wood dust, welding fume, glass fiber, and asbestos dust. Synthetic fiber dust, which is the subject of this study, is not currently subject to work environment measurement. Both NIOSH in the U.S. and the Health and Safety Executive (HSE) in the U.K. only specify exposure limits and precautions for synthetic mineral fibers (like glass fibers and rock wool). There is no mention of chemical synthetic fibers such as nylon or polyester in their regulations (CDC, 2023; HSE, 2023). This could lead to under-reporting of adverse health effects on workers exposed to them, which could hinder their access to adequate healthcare.

3. Suggestions about occupational health regulations related workers exposed to synthetic fiber

This case suggests that health impairments of workers exposed to synthetic fibers are underreported due to insufficiencies of the current occupational health management and special medical examination. Under the current system, synthetic fibers-related workers are only subject to general medical examination without receiving specific tests such as pulmonary function test. Thuss, the assessment of decreased lung function is missed.

Despite adverse effects of synthetic fibers such as nylon on respiratory health, this case reported to the KODSC shows that workers in this industry are not protected due to inadequacies of the domestic occupational health and safety system.

Work environment measurements and special medical examinations are important to identify chronic diseases of the respiratory system for workers. Nevertheless, the true magnitude and severity of effects of synthetic fibers on workers are underestimated due to institutional deficiencies. It should be considered that such institutional deficiencies, not only in preventing respiratory diseases, but also in compensating following occupational accidents, can put workers at a disadvantage (Kim et al., 2020).

V. Conclusions

Special medical examination of the respiratory system for workers exposed to synthetic fibers, regular measurement of the working environment, and management of the working environment through workplace health management might be necessary in the future. In particular, nylon fiber should be designated as an agent subject to special medical examination and work environment measurement in Korea. It should be classified under “other fiber dust,” a term that encompasses similar substances. In addition, as the production of synthetic fibers is expected to increase in the future, it is necessary to continue research on its health effects.

Regarding the present case, the KODSC was able to identify the occupational disease quickly, which allowed an opportunity to prevent the worker's occupational disease from worsening. The KODSC is an institution that can evaluate and respond to patients' occupational predisposition through various channels, including workers, clinicians at hospitals, and health managers at workplaces. It is expected that through the activation of KODSC,

various occupational diseases can be detected early and the potential scale of occupational diseases can be identified.

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