アジアじん肺読影医養成プログラム（AIR Pneumo）認定医の分布状況

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研究要旨

【目的】

本研究の目的は、2008 年から 2023 年までの Asian Intensive Reader of Pneumoconiosis（AIR Pneumo）プログラムに参加した医師の出身国の分布を調べ、AIR Pneumo 試験の成績をまとめて、合格者と不合格者の X 線写真の読影の違いについて述べることである。

【方法】

本研究では、2008 年から 2023 年までに Asian Intensive Reader of Pneumoconiosis（AIR Pneumo）プログラムにより実施された認定試験への医師の参加状況と認定試験の成績を調べ、試験に合格した医師と不合格となった医師の読影結果を比較した。

【結果】

2023 年 12 月までに、20 カ国から 674 人の医師が認定試験を受けており、特に近年は参加者が増加している。参加者の人口統計、参加傾向、合否率、習熟度スコアをまとめ、試験に合格した医師と不合格だった医師のじん肺の X 線写真の読影の違いを評価した。背景となる専門医の専門分野、職務経験は様々であった。合格率と合格者の平均技能スコアは初回の認定試験で 83.4%と 77.6±9.4、再認定試験で 76.8%と 88.1±4.5 であった。試験に合格した医師と比較して、不合格となった医師は、正答では陰性の胸部 X 線写真を陽性と分類し、陰影密度を正答よりも高めに読む傾向があった。また、大きな空孔や胸膜斑を見逃す可能性が高く、小さな空孔の形状を認識する精度が低かった。

【考察】

本研究結果から、不合格となった医師は胸部 X 線写真をじん肺陽性と過剰診断する傾向があり、小陰影の形状を正確に同定することが困難であることが示唆された。

A. 研究目的

じん肺の健康管理のためには、働く労働者に対するじん肺健康診断が重要となる。この健康管理には、国際労働機関が定める国際じん肺 X 線分類（ILO Internatiional Classification of Radiograph of Pneumoconioses）が用いられる。

本研究では、研究代表者らを始めとした日本人専門家らが中心となって、アジア諸国で国際じん肺 X 線分類を用いて読影医を養成する取り組みとして、アジアじん肺読影医養成プログラム（AIR Pneumo）を通じて養成した認定医を、診断・治療に関して一定の技術レベルに達していると思われる者とみなし、その分布状況を調べた。

B. 研究方法

AIR Pneumo 検査は、胸部 X 線写真を分類する医師の熟練度を評価するものであり、医師の正確性と一貫性を評価するために、小空孔、大空孔、胸膜斑の分類が行われる。精度は感度と特異度を用いて測定され、スコアはそれらの組み合わせで計算される。また、専門家パネルとの一致率も評価される。医師の情報が収集され、試験への参加と成績の分析が行われ、合格率や不合格率、平均点などが報告され、医師間の比較も行われる。すべての解析は Stata/MP 17.0 ソフトウェアを用いて行われ、倫理委員会の承認を得ている。

C. 研究結果

2008 年から 2023 年にかけて、AIR Pneumo は 26 回の認定試験をインド、フィリピン、ベトナム、インドネシア、ブラジル、日本、タイで実施した。認定試験には 674 人の医師が参加し、その 6 割はインドネシア、タイの医師であった。認定試験の合格率は 83.4%であり、再認定試験の合格率は 76.8%だった。合格した医師は、再認定試験を受けた医師を除いて、小空孔の同定で偽陽性が偽陰性よりも多い傾向があった。不合格となった医師は、病変の同定における偽陽性率および偽陰性率が高かった。また、profusion の分類では専門家パネルとの比較で有意な違いがあった。認定試験と再認定試験の両方で、合格した医師は小さな混濁の形状を正しく認識する割合が高かったことが示された。

表 1. 2008~2023 年に実施した AIR Pneumo の認定試験に関する情報

国	試験開催頻度
インドネシア	6
タイ	7
インド	1
ベトナム	1
日本	5
ブラジル	5
フィリピン	1

表 2. 2008~2023 年に AIR Pneumo の認定試験を受けた 674 人の医師に関する情報

医師の基本属性	人数 (%)
国	
インドネシア	218 (32.3)
タイ	186 (27.6)
インド	58 (8.6)
ベトナム	56 (8.3)
日本	49 (7.3)
ブラジル†	48 (7.1)
フィリピン	23 (3.4)
マレーシア	22 (3.3)
その他‡	13 (1.9)
不明	1 (0.2)
専門分野	
産業医	195 (28.9)
呼吸器内科医	187 (27.7)
放射線科医	117 (17.4)
総合診療医	59 (8.8)
公衆衛生	27 (4.0)
その他	4 (0.6)
不明	85 (12.6)
性別	
女性	304 (45.1)
男性	282 (41.8)
不明	88 (13.1)

表 2 続き

卒後年数	
中央値 (範囲)	10 (1–41)
≤5	173 (25.7)
6-10	129 (19.1)
≥11	240 (35.6)
不明	132 (19.6)
過去のじん肺胸部X線写真の読影件数（枚）	
なし	144 (21.4)
<10	248 (36.8)
<50	103 (15.3)
≥50	97 (14.4)
不明	82 (12.2)

†アルゼンチン、チリ、ペルーの医師を含む。
‡ブルネイ、カンボジア、香港、ブータン王国、ラオス、モンゴル、台湾の医師を含む。

D. 考察

本研究では、2008 年から 2023 年までの AIR Pneumo 試験の成績を総括し、合格者と不合格者の X 線写真の読影の違いを評価した。約 20 カ国から計 674 人の医師が参加し、多くは ASEAN 諸国出身で呼吸器内科医、産業医、放射線科医のバックグラウンドを持っていた。AIR Pneumo への参加者数の増加は、発展途上国の医師の ILO 分類システムへの関心の高まりを示している。しかし、再認定試験への参加率が低いことから、医師は主に ILO 分類システムの理解やじん肺に関する知識向上に関心を持っている可能性がある。さらに、一部の国からの参加率が低いことから、じん肺の X 線写真の読影と報告の資格に関する具体的な規制の重要性が浮かび上がる。不合格となった医師は、合格者に比べて X 線写真をじん肺陽性と誤って分類する割合が高く、特に小さな混濁を多く読み取る傾向があった。これらの結果は、今後のトレーニングプログラムの改善の必要性を示している。具体的には、医師の肺結核の初期の X 線変化や大きな混濁、胸膜斑を認識し、小さな混濁を分類する能力の向上に焦点を当てる必要がある。また、ウェブベースのトレーニングプログラムの開発や医療用のフラットパネル診断モニターへのアクセスの確保など、新しい技術やリソースに適応する必要がある。

E. 結論

アジア諸国におけるじん肺の X 線診断においては、読影医の訓練プログラムの改善が急務である。特に肺結核や巨大線維化の診断に対する医師の能力向上が重要である。新技術への適応も必要であり、ウェブベースのトレーニングプログラムの開発が進んでいる。ただし、トレーニングプログラムの効果やウェブベースアプローチの他国での適用性については、さらなる検討が必要だろう。

F. 健康危険情報

該当なし

G. 研究発表

1. 論文発表

J-P NA, Susanto AD, Samoedro E, Mansyur M, Tungsagunwattana S, Lertrojanapunya S, Subhannachart P, Siriruttanapruk S, Dumavibhat N, Algranti E, Parker JE, Hering KG, Kanayama H, Tamura T, Kusaka Y, Suganuma N. Asian Intensive Reader of Pneumoconiosis program: examination for certification during 2008-2020. Industrial Health 2024. 62, 143–152. DOI: 10.2486/indhealth.2023-0010

2. 学会発表

［International meeting］

1. Indriyati LH , Eitoku M, Naw Awn J-P , Nishimori M, Hamada N, Sawitri N, Suganuma N
Assessment of Chest Ray Profile in Relation to Prevalence of Silicosis aming Tuberculosis Patients in West Java, Indonesia,34th International Congress on Occupational Health (ICOH), Marrakesh, Morocco, April 2024

［National meeting］

1. Indriyati LH, Eitoku M, Naw Awn J-P, Nishimori M, Hamada N, Sawitri N, Suganuma N
Prevalence of Radiographic Silicosis among Tuberculosis patients in West Java, Indonesia: Preliminary report from Hospital Based Study . The 67th Chugoku-Shikoku Joint Conference on Occupational Health 第67回中国四国合同産業衛生学会本, Ehime, December 2023

2. Indriyati LH, Eitoku M, Naw Awn J-P, Nishimori M, Hamada N, Sawitri N, Suganuma N
Prevalence of Radiographic Silicosis Among Tuberculosis Patients in West Java, Indonesia
94th Annual Meeting of Japan Society for Hygiene, Kagoshima, March 2024

3. Indriyati LH , Eitoku M, Naw Awn J-P , Nishimori M, Hamada N, Sawitri N, Suganuma N
Prevalence of Radiographic Silicosis Cases among MDR-TB and DS-TB patients in Indonesia.
97th Annual Meeting of Japan Society for Occupational Health, 第97回日本産業衛生学会, Hiroshima, May 2024

H. 知的財産権の出願・登録状況(予定を含む)

1. 特許取得
   該当なし
2. 実用新案登録
   該当なし

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Field Report

Asian Intensive Reader of Pneumoconiosis program: examination for certification during 2008–2020

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Abstract: This study examined physicians' participation and performance in the examinations administered by the Asian Intensive Reader of Pneumoconiosis (AIR Pneumo) program from 2008 to 2020 and compared radiograph readings of physicians who passed with those who failed the examinations. Demography of the participants, participation trends, pass/fail rates, and proficiency scores were summarized; differences in reading the radiographs for pneumoconiosis of physicians who passed the examinations and those who failed were evaluated. By December 2020, 555 physicians from 20 countries had taken certification examinations; the number of participants increased in recent years. Reported background specialty training and work experience varied widely. Passing rate and mean proficiency score for participants who passed were 83.4% and 77.6 ± 9.4 in certification, and 76.8% and 88.1 ± 4.5 in recertification examinations. Compared with physicians who

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passed the examinations, physicians who failed tended to classify test radiographs as positive for pneumoconiosis and read a higher profusion; they likely missed large opacities and pleural plaques and had a lower accuracy in recognizing the shape of small opacities. Findings suggest that physicians who failed the examination tend to over-diagnose radiographs as positive for pneumoconiosis with higher profusion and have difficulty in correctly identifying small opacity shape.

Key words: Asian Intensive Reader of Pneumoconiosis (AIR Pneumo), Chest radiograph, International Labour Office (ILO), Occupational health, Pneumoconiosis, Surveillance

Introduction

Pneumoconiosis is an occupational lung disease caused by inhaling mineral dust, such as coal mine dust, silica, and asbestos. It appears as widely distributed nodular or reticular lesions on a chest radiograph. In 2017, there were approximately 60,055 newly diagnosed cases globally, with over half occurring in Asia (32,205 in China and 5,160 in India)[1)]. The risk of exposure to harmful substances increases due to industrialization and the transfer of hazardous processes, such as asbestos processing and ship breaking to developing countries[2–4)]. Early detection through health surveillance programs is crucial[5)]. However, implementing such programs can be particularly challenging in developing countries due to limited resources, a lack of experienced physicians skilled in reading chest radiographs, and various obstacles, including a lack of awareness of pneumoconiosis, poor cooperation from industries, and a lack of policy environment.

Interpreting the radiographic signs of pneumoconiosis is challenging due to subjectivity and inconsistency among readers. To ensure uniform reporting, the International Labour Office (ILO) developed the ILO International Classification of Radiographs of Pneumoconioses (ILO classification system) in 1950[6)]. The ILO classification system uses standardized descriptions, guidelines, and reference radiographs. It classifies radiographic abnormalities into small opacities, large opacities (opacities larger than 1 cm), and pleural abnormalities. Small opacities are further defined as rounded or irregular shapes and categorized based on profusion using a twelve-subcategory scale within four major profusion categories ranging from 0 to 3. Large opacities are encoded as *A, B*, or *C* in increasing order of sizes. Pleural abnormalities are classified as pleural plaques, costophrenic angle obliteration, and diffuse pleural thickening. This system allows readers to report pneumoconiosis using identical descriptions of parenchymal and pleural findings.

However, disagreements persist due to unfamiliarity with the ILO classification system and radiographic manifestations of pneumoconiosis[7)]. To address this, the National Institute for Occupational Safety and Health introduced the B Reader certification program in the United States in 1974[8, 9)]. In 2006, a similar initiative called the Asian Intensive Reader of Pneumoconiosis (AIR Pneumo) project was established[10)]. This project, in collaboration with various institutions and organizations (see the acknowledgment), focuses on providing training and certification programs to occupational health physicians in developing countries. The main goal of the project is to improve their proficiency in utilizing the ILO classification system for classifying and interpreting radiographic findings associated with pneumoconiosis.

Since 2008, AIR Pneumo has been conducting training programs in Thailand, and in 2018, it expanded its reach to Indonesia. The program also provides training upon invitation from governmental agencies of hosting countries. In South America, in collaboration with the ILO, AIR Pneumo has been offering the program as a national training course in Brazil since 2009. These programs contribute to strengthening national systems for workers' health surveillance.

The AIR Pneumo program includes a two-day training course and a three-hour examination, during which physicians classify 60 chest radiographs according to the ILO classification system. To obtain AIR Pneumo-Reader certification, physicians must achieve a score of 60 or higher out of 100. After five years, certified readers are required to take a recertification examination, using the same test radiographs as the initial certification. A score of 80 or higher is required to pass the recertification and demonstrate improvement. However, maintaining AIR Pneumo-Reader status only necessitates a score of 60 or higher. Further details of the AIR Pneumo project have been reported elsewhere[10–12)]. This study aims to summarize physician participation and performance in AIR

Pneumo examinations from 2008 to 2020 and describe the differences in reading radiographs between those who passed and those who failed the examinations.

Subjects and Methods

The AIR Pneumo examination evaluates physicians' proficiency in classifying 60 chest radiographs according to the ILO classification system. A detailed assessment method has been previously reported[12]. In summary, physicians are assessed on their accuracy in classifying the presence or absence of small opacities, large opacities, and pleural plaques, as well as their consistency in classifying the profusion and shape of small opacities. Accuracy is measured using sensitivity and specificity, and the score is calculated as (Sensitivity + Specificity) − 1. Consistency in profusion classification and shape recognition is determined by comparing the percentage agreement with the expert panel's readings. The expert panel consists of 12 B Readers who are recognized experts in the field. They determine the correct answers for each test radiograph. The set of 60 radiographs used in the examination includes 20 without nodular or reticular lesions, 9 boundary cases (which fall into the ILO profusion subcategory 0/1 or 1/0), and 31 radiographs with small opacities (ILO profusion subcategory 1/1 or greater). Among the radiographs with small opacities, 20 have pure rounded opacities, while 4 have pure irregular opacities. Of the 31 radiographs with small opacities, 9 also display varying sizes of large opacities. Additionally, 9 of the test radiographs exhibit pleural plaques.

Since the first certification examination in December 2008, physicians' information, such as country of residence, specialty, years after graduation, and the number of reviewed pneumoconiosis chest radiographs, has been collected through a questionnaire. This information, along with physicians' reading records and test scores, has been maintained in the AIR Pneumo database. By December 2020, the database contained 652 records for 555 physicians who participated in the examinations, including 565 certification records and 87 recertification records. Ten physicians attempted the certification examination twice. For the analysis of participation and performance in the certification examination, 12 physicians who had not classify six or more of the test radiographs (*i.e.,* ≥10% of the total radiographs) in their first attempt were excluded, resulting in 543 physicians included in the analysis. For assessing participation and performance in the recertification examination, records of 69 physicians who took the test for the first time were used.

Using the collected data, first, we observed the trend in taking the examinations from December 2008 to December 2020 and physicians' participation based on their characteristics. We also summarized their performance by examination type (certification or recertification) and pass or fail status. Pass and fail rates, as well as mean scores (with standard deviation), were presented for each component of proficiency assessment, including accuracy in identifying small opacities, large opacities, pleural plaques, and consistency in classifying the profusion and shape of small opacities. Second, we compared physicians who passed and failed the examinations in the following reading assessments: (1) Rates of false positives and false negatives in classifying radiographs for small opacities, large opacities, and pleural plaques. The rates were determined based on sensitivity and specificity in classifying the lesions. (2) Assessment of over-reading or under-reading the profusion of small opacities by comparing with the expert panel's classification. To determine the profusion category for a group of physicians, we analyzed the most frequently reported profusion category by the physicians in that group. (3) Evaluation of small opacity shape recognition by calculating the percentage of physicians with similar descriptions for shape (no small opacities, rounded shape, or irregular shape). The percentage was based on radiographs containing specific shapes (4 with pure irregular opacities and 20 with pure rounded opacities). Comparisons between physicians' groups were performed appropriately using Student's t-test or χ^2 test. Results are presented separately for the pass or fail and for the certification or recertification examination. All analyses were performed using Stata/MP 17.0 software (StataCorp., College Station, TX, USA). This study was approved by the institutional review board of Kochi Medical School (approval number: 31-68). Due to the nature of this study, *i.e.,* using anonymized data from radiograph reading tests, the noninvasive nature of data collection, and no involvement of biological materials, written informed consent from the physicians taking AIR Pneumo examinations was waived.

Results

Between 2008 and 2020, AIR Pneumo conducted certification examinations 23 times in several countries: once in India, the Philippines, and Vietnam; four times in Indonesia; five times each in Brazil and Japan; and six times in Thailand. Figure 1 illustrates the trend and number of physicians who took the certification and recertification

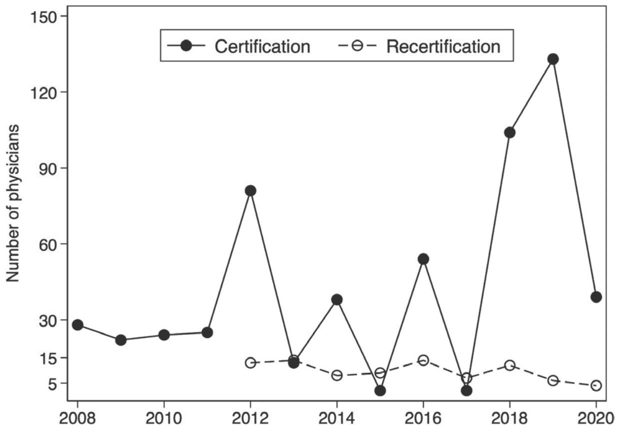

Fig. 1. Number of physicians taking certification examination and recertification examination, 2008–2020.

Table 1. Information on 543 physicians taking AIR Pneumo examination, 2008–2020

Physicians' characteristics	Number (%)
Residing country	
Indonesia	169 (31.1)
Thailand	122 (22.5)
Vietnam	56 (10.3)
India	52 (9.6)
Japan	49 (9.0)
Brazil†	47 (8.7)
Philippines	23 (4.2)
Malaysia	15 (2.8)
Others‡	10 (1.8)
Specialty	
Pulmonology	164 (30.2)
Occupational medicine	147 (27.1)
Radiology	101 (18.6)
General medicine	55 (10.1)
Public health	20 (3.7)
Others	4 (0.7)
Not reported	52 (9.6)
Sex	
Female	251 (46.2)
Male	237 (43.7)
Not reported	55 (10.1)
Time since graduation, yr	
Median (range)	10 (1–41)
≤5	129 (23.8)
6–10	112 (20.6)
≥11	222 (40.9)
Not reported	80 (14.7)
Number of reviewed pneumoconiosis chest radiograph in the past	
None	114 (21.0)
<10 films	194 (35.7)
<50 films	90 (16.6)
≥50 films	95 (17.5)
Not reported	50 (9.2)

†including physicians from Argentina, Chile, and Peru.
‡including physicians from Brunei, Cambodia, People's Republic of China, DR Congo, Hong Kong, Kingdom of Bhutan, Myanmar, Parkistan, Taiwan.
AIR Pneumo: Asian Intensive Reader of Pneumoconiosis.

examinations during the study period. The number of physicians taking the certification examination fluctuated every other year until 2017. In 2018 and 2019, the participation reached its peak, with over 100 physicians taking the examination. On the other hand, the number of physicians taking the recertification remained below 15 throughout the entire period. Table 1 provides a summary information regarding the participating physicians. Over the course of twelve years, physicians from 15 Asian countries, 4 South American countries, and DR Congo took the examination. Indonesia had the highest participation rate at 31.1%, followed by Thailand (22.5%), Vietnam (10.3%), India (9.6%), Japan (9%), and Brazil (8.7%). The reported medical specialties of the participating physicians, in decreasing order of participation, included pulmonary medicine, occupational medicine, radiology, general medicine, and public health. The working duration since medical graduation ranged from 1 to 41 yr. Twenty-one percent of the physicians reported they had never encountered a pneumoconiosis chest radiograph. Table 2 presents the pass and fail rates, as well as the mean scores for the total proficiency assessment and each component, in the certification and recertification examinations. Throughout the study period, the passing rate for the certification examination was 83.4% (453 out of 543), while the recertification examination had a passing rate of 76.8% (53 out of 69). The mean total score for those who passed the certification and recertification was 77.6 ± 9.4 and 88.1 ± 4.5, respectively. Physicians who failed the certification examination scored considerably lower than 60% of the maximum possible score in consistency of classifying profusion of small opacities (mean score: 11.0 out of 25 points), accuracy in identifying small opacities (mean score: 14.9 out of 30 points), and pleural plaques (mean score: 5.7 out of 15 points). Physicians who failed the recertification examination achieved comparable scores to those who passed the certification examination, except for slightly lower scores in accuracy of identifying small opacities (mean score: 21.4 versus 25.0) and consistency of classifying profusion of small opacities (mean score: 13.5 versus 16.1).

Table 2. Pass and fail rates and proficiency score, according to type of examination, 2008–2020

Pass and fail rate % (number of physicians)		Certification (n=543)		Recertification (n=69)	
		Pass 83.4% (453)	Fail 16.6% (90)	Pass 76.8% (53)	Fail 23.2% (16)
Assessment areas	Max score	Proficiency score (Mean ± standard deviation)			
Small opacity					
Accuracy in identifying small opacity†	30	25.0 ± 4.1	14.9 ± 4.9	28.3 ± 1.9	21.4 ± 5.8
Consistency in classifying profusion‡	25	16.1 ± 3.5	11.0 ± 2.7	18.8 ± 2.4	13.5 ± 3.6
Consistency in classifying shape‡	15	12.6 ± 1.9	9.4 ± 2.7	13.7 ± 1.0	12.1 ± 1.6
Large opacity					
Accuracy in identifying large opacity†	15	13.5 ± 1.7	9.9 ± 3.5	14.3 ± 0.8	12.6 ± 2.0
Pleural plaque					
Accuracy in identifying pleural plaque†	15	10.4 ± 3.1	5.7 ± 3.1	13.0 ± 1.6	10.1 ± 2.5
Total score	100	77.6 ± 9.4	51.0 ± 7.6	88.1 ± 4.5	69.6 ± 8.4

Max score, maximum possible score. Passing score in the examination is 60 for certification and 80 for recertification. †Accuracy scores are calculated by the formula: (sensitivity + specificity) − 1. ‡Consistency scores are calculated as percentage agreement with the readings of a panel of 12 B Readers.

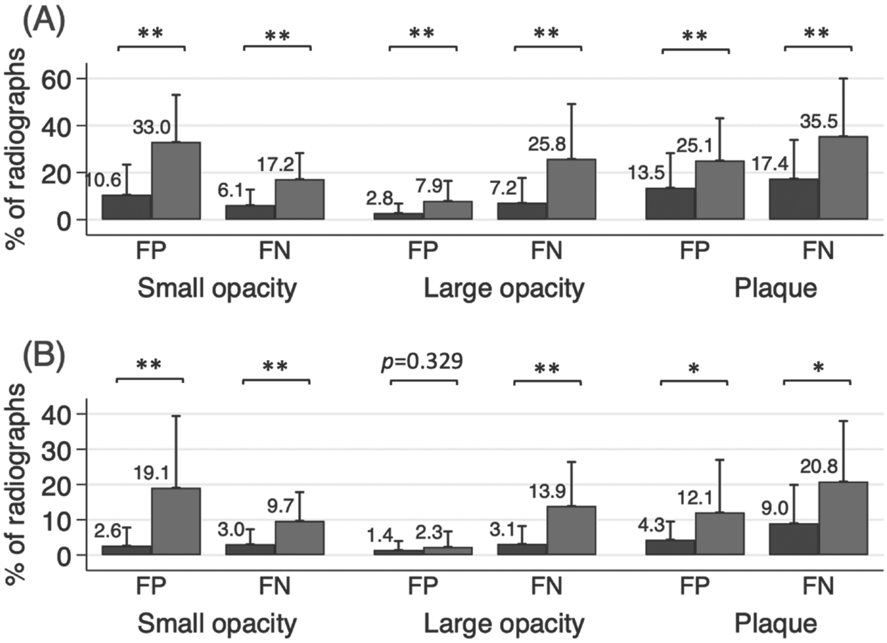

Fig. 2. False-positive (FP) and false-negative (FN) rates in classifying pneumoconiosis, stratified according to pass (black bar) or fail (gray bar) status in (A) certification examination and (B) recertification examination. Group comparisons were performed using Student's *t*-test; *$p<0.01$; **$p<0.001$. Error bars represent standard deviations. The ILO International Classification of Radiographs of Pneumoconioses defines parenchymal abnormalities as small opacities (opacities with diameters up to 1 cm) or large opacities (opacities larger than 1 cm) and pleural abnormalities as localized plaques or diffuse pleural thickening (abnormalities extending up the lateral chest wall with involvement of obliterated costophrenic angle).

Figure 2 (A) and 2 (B) display the false-positive and false-negative rates in classifying radiographs for parenchymal and pleural lesions among physicians who passed and failed the certification and recertification examinations, respectively. The figures indicate that false positives are more common than false negatives in identifying small opacities among physicians (except for physicians who passed the recertification examination), while the opposite pattern is observed for identifying large opacities and pleural plaques. Compared to physicians who passed the examination, physicians who failed had significantly higher false-positive and false-negative rates in identifying the lesions (except for the false-positive rate in identifying large opacities among physicians taking recertification examinations). Figure 3 (A) and 3 (B), respectively for the certification and recertification examinations, demonstrate an over-reading/under-reading tendency among physicians in classifying small opacity profusion. The figures indicate that physicians tend to read higher profusion, particularly those who failed the examination. Compared with true profusion classified by the expert panel, the classifications of physicians' groups were significantly different: χ^2 (9)=98.5, p<0.001 and χ^2 (9)=78.2, p<0.001 for physicians who passed and failed the certification examinations, respectively; and χ^2 (9)=106.2, p<0.001 and χ^2 (9)=83.8, p<0.001 for physicians who passed and failed the recertification examinations, respectively. Table 3 presents the recognition of small opacity shape by the physicians who passed and failed the examinations. The percentage of physicians who correctly recognized the shape of small opacities was higher among physicians who passed the examination than those who failed, and when the radiographs contained rounded opacities compared with irregular opacities.

Discussion

In the present study, we summarized the AIR Pneumo examinations conducted between 2008 and 2020 and evaluated the differences in radiograph readings between physicians who passed and those who failed the examination. During this twelve-year period, a total of 555 physicians from approximately 20 countries participated in the examination. Most physicians were from ASEAN countries and had background training in pulmonology, occupational medicine, or radiology. The increasing number of participants in the recent AIR Pneumo programs indicates

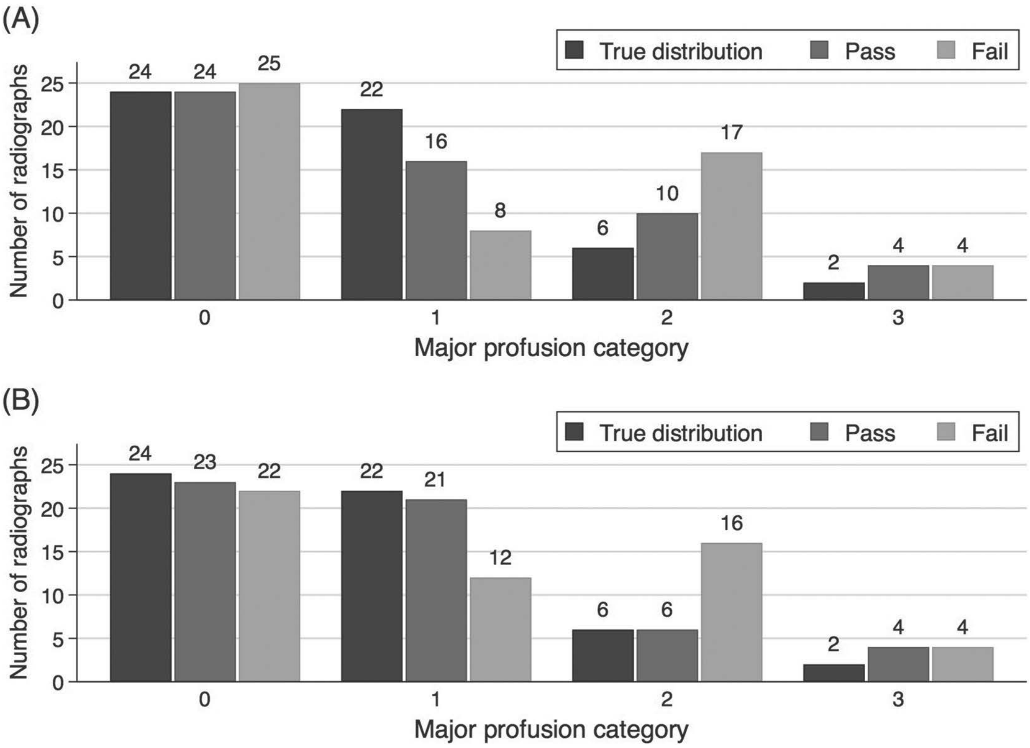

Fig. 3. Distribution of classifications for small opacity profusion of 54 test radiographs, stratified according to pass or fail status in (A) certification examination and (B) recertification examination. True distribution=classified by expert panel of 12 B Readers. To determine the profusion category for a group of physicians, we analyzed the most frequently reported profusion category by the physicians in that group. The profusion classified by physicians' groups was significantly different from the true profusion; p<0.001 for all χ^2 tests. The ILO International Classification of Radiographs of Pneumoconioses utilizes four major profusion categories, ranging from 0 to 3, indicating the increasing concentration of small opacities (opacities with diameters up to 1 cm).

Table 3. Proportion of physicians according to their classifications of the shape of small opacities

Shape of small opacity in the radiographs	Certification		Recertification	
	Pass (n=453)	Fail (n=90)	Pass (n=53)	Fail (n=16)
	% of physicians (95% Confidence interval)			
Pure irregular opacity (4 radiographs)				
Negative†	14.0 (12.4–15.6)	24.9 (20.4–29.5)	8.1 (4.4–11.8)	4.7 (0.5–9.9)
Rounded‡	15.1 (13.4–16.7)	30.4 (25.6–35.3)	9.5 (5.6–13.5)	14.1 (5.5–22.6)
Irregular§	70.9 (68.8–73.0)	44.6 (39.4–49.9)	82.4 (77.2–87.5)	81.3 (71.7–90.8)
Pure rounded opacity (20 radiographs)				
Negative†	2.1 (1.8–2.3)	8.1 (6.9–9.4)	1.8 (1.0–2.6)	2.8 (1.0–4.6)
Rounded‡	87.5 (86.8–88.2)	68.5 (66.3–70.6)	92.7 (91.1–94.3)	87.8 (84.2–91.4)
Irregular§	10.5 (9.8–11.1)	23.4 (21.4–25.4)	5.5 (4.1–6.9)	9.4 (6.2–12.6)

% of physicians for a given group was the average for radiographs containing a particular shape of small opacities (*i.e.,* 4 radiographs with pure irregular opacity and 20 with pure rounded opacity). Physicians classified the radiographs as: †having no small opacities in the radiograph; ‡the presence of rounded opacities; §the presence of irregular opacities.

a growing interest among physicians from developing countries in using the ILO classification system. However, the low rate of participation in the recertification examination suggests that physicians are primarily interested in understanding the ILO classification system or improving their knowledge of pneumoconiosis. Furthermore, the low participation from some countries highlights the importance of specific regulations regarding qualifications for reading and reporting radiographs for pneumoconiosis. To prioritize workers' health, developing countries like those in the ASEAN should establish comprehensive legal frameworks, similar to those in Japan[13] and the United States[14], to ensure the comprehensive provision of health services for workers exposed to dust.

The ability to distinguish the presence or absence of small opacities consistent with pneumoconiosis on a chest radiograph is crucial for screening, epidemiological data, and legal processes, and this skill is examined in AIR Pneumo. Physicians who failed the examination classified substantially more radiographs as the presence of pneumoconiosis than physicians who passed. Specifically, physicians who failed the certification and recertification examination incorrectly classified 33% and 19.1% of normal radiographs as positive for pneumoconiosis, respectively, while the corresponding figures for physicians who passed were 10.6% and 2.6%. In addition, physicians who failed tended to read a higher small opacity profusion than physicians who passed. Similar findings of higher false-positive rates for pneumoconiosis were reported among physicians who failed the B Reader examination[8]. Although the technical quality of the radiographs may influence the reading, this was not the case in the present study. The expert panel graded all radiographs used in the AIR Pneumo examination as ILO grade 1 (Good) or grade 2 (Acceptable, with no technical defect likely to impair the classification of the radiograph for pneumoconiosis). One possible explanation for the overreading of pneumoconiosis is the different thresholds among physicians for distinguishing between normal and abnormal chest radiographs. It was also likely that less experienced readers interpreted increased lung markings, for example, those commonly seen in the chest radiographs of heavy smokers[15], as pneumoconiosis. Lack of familiarity with the ILO standard radiographs illustrating profusion of small opacities might contribute to overreading of profusion. In cases with large opacities of progressive massive fibrosis, less experienced readers might mistakenly see the fibrotic distortion of the surrounding lung as increased profusion. Chest radiograph readings play a crucial role in health surveillance for workers exposed to mineral dust and in compensation claims[13]. Recognizing early radiographic changes is essential for preventing pneumoconiosis progression in individual workers. However, falsely identifying the disease and overdiagnosing its severity can lead to substantial economic and social costs.

In the present study, compared to physicians who passed the examination, those who failed it had a higher proportion of overlooking or not recognizing large opacities and pleural plaques in test radiographs. They also failed to notice or incorrectly classified irregular-shaped small opacities. Unfamiliarity with the appearance of large opacities of progressive massive fibrosis, pleural plaques (especially face-on plaques), and irregular-shaped small opacities on a chest radiograph might be a possible reason for these findings. Pleural plaques, characterized by discrete areas of pleural thickening, can be challenging to visualize in a posteroanterior radiograph, leading to a low detection rate in their radiographic diagnosis[16, 17]. Pleural plaques indicate past asbestos exposure, and asbestosis, which manifests as linear or reticular lesions (The ILO classification system describes as irregular opacities.), is a diffuse interstitial fibrosis associated with asbestos exposure[18]. The increasing number of asbestosis cases globally emphasizes the importance of recognizing plaques and radiographic features of asbestosis[1]. As the prognosis and management of asbestosis differ from other forms of interstitial lung diseases, such as idiopathic pulmonary fibrosis, it is crucial to identify these features. Although the association between pleural plaques and lung cancer remains inconclusive[19, 20], their presence necessitates immediate diagnostic work-up to rule out asbestos-related malignancies.

Role of AIR Pneumo and areas needing improvement

AIR Pneumo has played a crucial role in strengthening the national pneumoconiosis surveillance system in developing countries by training physicians to use the ILO classification system effectively. The acquisition of knowledge regarding the ILO classification system, particularly the standard radiographs, has shown improvements in pneumoconiosis interpretation[21]. While only a few countries[13, 22] have a similar classification system, the ILO classification system is widely accepted for reporting pneumoconiosis in surveillance programs, epidemiological studies, and compensation claims. Additionally, the screening and monitoring of pneumoconiosis among workers exposed to mineral dust, using chest radiography and reporting based on the ILO classification system, are integral components of the ILO/WHO's Global Program for the Elimination of Silicosis[23]. It is well recognized that chest radiographs alone are insufficient for clinically diagnosing parenchymal or pleural changes in pneumoconiosis, particularly in mild cases[24]. However, a recent study demonstrated that chest radiography, when compared to low-dose thin-slice computed tomography, performed adequately in classifying pneumoconiosis according to the ILO classification system, as assessed by AIR Pneumo or NIOSH-certified physicians[17]. Early identification of pneumoconiosis cases through surveillance programs is crucial for timely intervention and management. Therefore, the establishment of a national system for pneumoconiosis screening and the enhancement of diagnostic capabilities among physicians in each country are utmost importance. While certified AIR Pneumo readers currently contribute to the screening and surveillance of pneumocosis[25], further studies are required to evaluate the effectiveness of the AIR Pneumo program.

However, our data indicate the need for improvement in future training programs. First, there should be a greater emphasis on improving (1) physicians' ability to recognize and distinguish early radiographic changes of pneumoconiosis, large opacities of progressive massive fibrosis, and pleural plaques, and (2) physicians' consistency in classifying the profusion of small opacities. To achieve this, training programs can include more radiographs illustrating boundary cases (*i.e.,* ILO profusion subcategory 0/1 and 1/0) and lower profusion (for example, ILO profusion subcategory 1/1), increased training time to study the radiographic appearance of irregular opacities, large opacities of progressive massive fibrosis, and pleural plaques, and more exposure to the ILO standard radiographs illustrating profusion of small opacities. Additionally, the number of test radiographs can be increased (for example, to 80 radiographs), specifically including more radiographs containing irregular opacities, large opacities, and pleural abnormalities. Second, apart from proficiency issues, organizing a training program like AIR Pneumo involves various considerations, such as transportation of training and examination materials (*e.g.,* sets of ILO standard films, radiographs for self-practice and the test), preparation of standard view boxes, and hosting participants. Moreover, as chest radiography has transitioned to a digital environment, with the ILO extending the applicability of its classification system to digital radiographic images[26], it is important to address these developments. Additionally, the increasing participation of physicians in AIR Pneumo programs requires adapting to new technologies and overcoming previous limitations. Therefore, AIR Pneumo is developing a web-based program to facilitate training and examinations. (The training courses can be accessed via the link provided: https://kmsx.edunext.io/courses/course-v1:kmsx+AIRP101+2021_T1/about.) This web-based approach allows participants to download and study lecture videos at their convenience. Initial pilot training courses conducted in Japan using similar topics covered in on-site training have shown promising results. However, the applicability of this web-based training in other countries requires further research. Furthermore, the transition to a web-based examination presents feasibility concerns, such as ensuring participants have access to medical-grade flat-panel diagnostic monitors.

Conclusions

We conducted a study to examine the participation and performance of physicians in AIR Pneumo examinations from 2008 to 2020. The results of our study show that the number of physicians taking the initial certification test has increased in recent years. However, we also found that physicians who failed the examinations were more likely to classify radiographs as positive for pneumoconiosis and show higher small opacity profusion compared to those who passed. Furthermore, they had a tendency to overlook or not recognize pleural plaques and incorrectly classify irregular-shaped small opacities.

Despite the launch of the ILO/WHO's Global Program for the Elimination of Silicosis in 1995, which aimed to address the widespread issue of pneumoconiosis and protect workers from hazardous substances, millions of workers are still being exposed to these harmful substances, and pneumoconiosis remains prevalent in many developing countries. Since chest radiography and reporting based on the ILO classification system are the current standard in medical surveillance, research, and compensation claims related to pneumoconiosis, it is essential to make efforts to increase the number of competent physicians in developing countries who can effectively use the ILO classification system.

Authors' Contribution

All authors contributed toward data collection and reviewed and approved this manuscript. NA J-P: Writing original draft, data curation, data analysis, review & editing. NS: Writing initial draft, data curation, data analysis, review & editing. ADS: Data curation, review & editing. ES: Data curation, review & editing. MM: Data curation, review & editing. ST: Data curation, review & editing. SL: Data curation, review & editing. PS: Data curation, review & editing. SS: Data curation, review & editing. ND: Data curation, review & editing. EA: Data curation, review & editing. JEP: Data curation, review & editing. KGH: Data curation, review & editing. HK: Data curation, review & editing. TT: Data curation, review & editing. YK: Data curation, review & editing.

Disclosure

Approval of the research protocol: This study was approved by the institutional review board of Kochi Medical School (approval number: 31-68).

Informed consent: Due to the nature of this study, *i.e.,* using anonymized data from radiograph reading tests, the noninvasive nature of data collection, and no involvement of biological materials, written informed consent from the physicians taking AIR Pneumo examinations was waived.

Registry and Registration No. of the study/trial: N/A.

Animal Studies: N/A.

Conflict of interest: None declared.

Data availability: Data (in an anonymized format) are available from the corresponding author upon reasonable request.

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References

1) Shi P, Xing X, Xi S, Jing H, Yuan J, Fu Z, Zhao H (2020) Trends in global, regional and national incidence of pneumoconiosis caused by different aetiologies: an analysis from the Global Burden of Disease Study 2017. Occup Environ Med **77**, 407–14.
2) Choi Y, Lim S, Paek D (2013) Trades of dangers: a study of asbestos industry transfer cases in Asia. Am J Ind Med **56**, 335–46.
3) Le GV, Takahashi K, Karjalainen A, Delgermaa V,

Hoshuyama T, Miyamura Y, Furuya S, Higashi T, Pan G, Wagner G (2010) National use of asbestos in relation to economic development. Environ Health Perspect **118**, 116–9.

4) Pandita S (2006) Banning asbestos in Asia: campaigns and strategies by the Asian Network for the Rights of Occupational Accident Victims (ANROAV). Int J Occup Environ Health **12**, 248–53.

5) Antao VC, Pinheiro GA (2015) Surveillance for occupational respiratory diseases in developing countries. Semin Respir Crit Care Med **36**, 449–54.

6) Hosoda Y (2005) ILO International Classifications of Radiographs of Pneumoconioses—past, present and future—. In: International Classification of HRCT for Occupational and Environmental Respiratory Diseases, Kusaka Y, Hering KG, Parker JE, (Eds.), 57–70, Springer, Tokyo.

7) Felson B, Morgan WK, Bristol LJ, Pendergrass EP, Dessen EL, Linton OW, Reger RB (1973) Observations on the results of multiple readings of chest films in coal miners' pneumoconiosis. Radiology **109**, 19–23.

8) Halldin CN, Hale JM, Weissman DN, Attfield MD, Parker JE, Petsonk EL, Cohen RA, Markle T, Blackley DJ, Wolfe AL, Tallaksen RJ, Laney AS (2019) The National Institute for Occupational Safety and Health B Reader certification program—an update report (1987 to 2018) and future directions. J Occup Environ Med **61**, 1045–51.

9) Morgan RH (1979) Proficiency examination of physicians for classifying pneumoconiosis chest films. AJR Am J Roentgenol **132**, 803–8.

10) J-P NA, Suganuma N (2020) Quality assurance in reading radiographs for pneumoconiosis: AIR Pneumo program. ASEAN-JR **21**, 73–84.

11) J-P NA, Susanto AD, Samoedro E, Mansyur M, Tungsagunwattana S, Lertrojanapunya S, Subhannachart P, Siriruttanapruk S, Dumavibhat N, Algranti E, Parker JE, Hering KG, Kanayama H, Tamura T, Kusaka Y, Suganuma N (2022) Inter-observer agreement and accuracy in classifying radiographs for pneumoconiosis among Asian physicians taking AIR Pneumo certification examination. Ind Health **60**, 459–69.

12) Tamura T, Kusaka Y, Suganuma N, Suzuki K, Subhannachart P, Siriruttanapruk S, Dumavibhat N, Zhang X, Sishodiya PK, Thanh TA, Hering KG, Parker JE, Algranti E, O'Connor FS, Shida H, Akira M (2018) Assessment of physicians' proficiency in reading chest radiographs for pneumoconiosis, based on a 60-film examination set with two factors constituting eight indices. Ind Health **56**, 382–93.

13) Jp NA, Imanaka M, Suganuma N (2017) Japanese workplace health management in pneumoconiosis prevention. J Occup Health **59**, 91–103.

14) Cummings KJ, Johns DO, Mazurek JM, Hearl FJ, Weissman DN (2019) NIOSH's Respiratory Health Division: 50 years of science and service. Arch Environ Occup Health **74**, 15–29.

15) Kirchner J, Goltz JP, Lorenz F, Obermann A, Kirchner EM, Kickuth R (2012) The "dirty chest"—correlations between chest radiography, multislice CT and tobacco burden. Br J Radiol **85**, 339–45.

16) Clarke CC, Mowat FS, Kelsh MA, Roberts MA (2006) Pleural plaques: a review of diagnostic issues and possible nonasbestos factors. Arch Environ Occup Health **61**, 183–92.

17) Nogami S, J-P NA, Nogami M, Matsui T, Ngatu NR, Tamura T, Kusaka Y, Itoh H, Suganuma N (2020) Radiographic diagnosis of Pneumoconioses by AIR Pneumo-trained physicians: comparison with low-dose thin-slice computed tomography. J Occup Health **62**, e12141.

18) Norbet C, Joseph A, Rossi SS, Bhalla S, Gutierrez FR (2015) Asbestos-related lung disease: a pictorial review. Curr Probl Diagn Radiol **44**, 371–82.

19) Brims FJH, Kong K, Harris EJA, Sodhi-Berry N, Reid A, Murray CP, Franklin PJ, Musk AB, de Klerk NH (2020) Pleural plaques and the risk of lung cancer in asbestos-exposed subjects. Am J Respir Crit Care Med **201**, 57–62.

20) Pairon JC, Andujar P, Rinaldo M, Ameille J, Brochard P, Chamming's S, Clin B, Ferretti G, Gislard A, Laurent F, Luc A, Wild P, Paris C (2014) Asbestos exposure, pleural plaques, and the risk of death from lung cancer. Am J Respir Crit Care Med **190**, 1413–20.

21) Ngatu NR, Suzuki S, Kusaka Y, Shida H, Akira M, Suganuma N (2010) Effect of a two-hour training on physicians' skill in interpreting pneumoconiotic chest radiographs. J Occup Health **52**, 294–301.

22) Hodous TK, Chen RA, Kinsley KB, Liu XT, McLaughlin JK, Chen JQ, Wu ZE, Blot WJ (1991) A comparison of pneumoconiosis interpretation between Chinese and American readers and classifications. J Tongji Med Univ **11**, 225–9.

23) Fedotov I (2006) The ILO/WHO Global programme for the elimination of silicosis. Occup Health South Africa.

24) American Thoracic Society (2004) Diagnosis and initial management of nonmalignant diseases related to asbestos. Am J Respir Crit Care Med **170**, 691–715.

25) Silanun K, Chaiear N, Rechaipichitkul W (2017) Prevalence of silicosis in stone carving workers being exposed to inorganic dust at Sikhiu district Nakhonratchasima province, Thailand: preliminary results. J Med Assoc Thai **100**, 598–602.

26) ILO (2022) Guidelines for the use of the ILO International Classification of Radiographs of Pneumoconioses—revised edition 2022. International Labour Office, Geneva.

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Original Article

Inter-observer agreement and accuracy in classifying radiographs for pneumoconiosis among Asian physicians taking AIR Pneumo certification examination

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Abstract: This study examined inter-observer agreement and diagnostic accuracy in classifying radiographs for pneumoconiosis among Asian physicians taking the AIR Pneumo examination. We compared agreement and diagnostic accuracy for parenchymal and pleural lesions across

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residing countries, specialty training, and work experience using data on 93 physicians. Physicians demonstrated fair to good agreement with kappa values 0.30 (95% CI: 0.20–0.40), 0.29 (95% CI: 0.23–0.36), 0.59 (95% CI: 0.52–0.67), and 0.65 (95% CI: 0.55–0.74) in classifying pleural plaques, small opacity shapes, small opacity profusion, and large opacities, respectively. Kappa values among Asian countries ranging from 0.25 to 0.55 (pleural plaques), 0.47 to 0.73 (small opacity profusion), and 0.55 to 0.69 (large opacity size). The median Youden's J index (interquartile range) for classifying pleural plaque, small opacity, and large opacity was 61.1 (25.5), 76.8 (29.3), and 88.9 (23.3), respectively. Radiologists and recent graduates showed superior performance than other groups regarding agreement and accuracy in classifying all types of lesions. In conclusion, Asian physicians taking the AIR Pneumo examination were better at classifying parenchymal lesions than pleural plaques using the ILO classification. The degree of agreement and accuracy was different among countries and was associated with background specialty training.

Key words: AIR Pneumo, Chest radiograph, Diagnostic accuracy, Occupational health, Pneumoconiosis, Reader agreement

Introduction

Pneumoconiosis, a diffuse lung disease caused by inhaled industrial or environmental dust, presents radiographically with multiple reticular or variable-sized nodular opacities[1]. Pleural plaque, an irregular, circumscribed area of dense, firm, fibrous tissue, usually resulting from asbestos exposure, appears radiographically as discrete areas of pleural thickening[2]. Screening for lung or pleural changes in a dust-exposed worker is performed primarily by periodic reviews of chest radiographs[3]. The detection and interpretation of the two conditions in a chest radiograph is highly subjective and reader-dependent. To standardize reports and facilitate international comparison of data, the International Labour Office developed a classification system (ILO classification)[4]. This classification system is composed of guidelines and a set of standard radiographs, exemplifying the spectrum of the disease. The ILO published the first edition in 1950 and made several revisions to clarify ambiguities in earlier editions but preserved the basic structure of the system. Since its establishment, the ILO classification is increasingly being adopted internationally for use in epidemiological research, screening, and surveillance of pneumoconiosis.

Screening and surveillance programs are very effective at detecting new cases of pneumoconiosis and also provide information about trend and burden of disease in workers exposed to mineral dust[5]. To promote the efficiency of screening programs in developing countries, the Asian Intensive Reader of Pneumoconiosis (AIR Pneumo) provides training and examination programs for raising physicians who can perform the ILO classification[6]. At the end of 2019, more than five hundred physicians had received training since the program began in 2006. The participating physicians have expertise in general medicine, occupational medicine, public health, pulmonology, and radiology. They include physicians from several developing Asian countries who were practicing in hospitals or working in corporations, government institutions and ministries. Most importantly, they have been working on pneumoconiosis screening.

Despite using the ILO classification, substantial variation in the interpretation of radiographs for pneumoconiosis exists among physicians[7,8]. Thus, before sharing epidemiological information, it is worth understanding the extent of inter-observer agreement and diagnostic accuracy among physicians of Asian countries. Therefore, the objective of this study was to examine the degree of observer agreement, diagnostic accuracy, and possible causes for reader variability in classifying radiographs for pneumoconiosis using reading results of Asian physicians taking the AIR Pneumo examinations.

Subjects and Methods

AIR Pneumo's examination film set

The AIR Pneumo's examination film set is composed of 60 chest radiographs; the diagnosis of each radiograph was established by a panel of experts formed by 12 National Institute for Occupational Safety and Health of the United States (NIOSH) certified B Readers. The technical quality of the radiographs was classified by the 12 B Readers as ILO grade 1 (Good) or 2 (Acceptable, with no technical defect likely to impair classification of the radiograph for pneumoconiosis)[4]. The 60-film set includes 20 radiographs with no reticular or nodular lesions, 9 boundary cases (ILO profusion classification 0/1 or 1/0), and 31 radiographs with small opacities (ILO profusion classification 1/1 or higher). Among the radiographs with small opacities, 20 have purely rounded while 4 have purely irregular opacities. Of the 31 radiographs with small opacities, 9 also have varying sizes of large opacities (opacities with the longest diameter larger than 1 cm). Nine of the 60 examination films have pleural plaques with or without calcification. Details of the AIR Pneumo's training program, development of training materials (including chest radiographs), examination, and scoring system have been published previously[9, 10].

Physicians' information and radiograph reading data

Our study used 5,580 readings of 93 physicians from the two examinations conducted in Thailand (December 2018) and Indonesia (February 2019). They had taken the examination after completing an intensive 2-day AIR Pneumo training course. Physicians' information, including residing country, specialty training, and work experience, was collected through self-administered questionnaires. During the examinations, physicians independently read the chest radiographs on a standard view box in a comfortable reading room (controllable lighting with no direct sunlight) and reported the findings on reading sheets according to the ILO classification. They were given three hours to classify 60 radiographs. Each radiograph was graded for technical quality. Small opacities were classified according to their shape (rounded or irregular), size (size up to 1.5mm, 1.5–3mm, or 3–10mm), location (upper, middle, or lower lung zones), and profusion. Profusion was determined by side-by-side comparison with ILO standard radiographs and classified on a twelve-point scale with increasing order of concentration (codify as 0/− to 3/+ within four major profusion classifications: 0, 1, 2, and 3). Large opacities were classified as size A, B, or C, corresponding to size up to 5 cm, up to right upper lung zone, or exceeding right upper lung zone. The presence or absence of pleural plaques, their extent and width if any were recorded. We extracted data on the profusion and shape classifications of small opacities. We also obtained the size classifications of large opacities and the presence or absence of pleural plaques. Classifications on the size and location of small opacities and the technical quality of radiographs were not the purpose of this study.

Statistical analysis

We grouped physicians according to their residing country, specialty training, and experiences. Considering the number of years required to develop medical experience or to enroll in specialty training, years after graduation was grouped as "5 or fewer years", "6 to 10 years", or "11 or more years". Information on the total number of reviewed pneumoconiosis chest radiographs, the participating physicians have encountered since they became physicians, was collected as "none", "less than 10", "10 to 50", or "50 or more". For small opacity profusion, we examined inter-observer agreement on four major profusion classifications as they showed a close correlation to the clinical severity of "normal," "mild," "moderate", or "severe" conditions[11]. When computing agreement on small opacity shape, we used only the data of 40 radiographs, i.e., 9 boundary cases and 31 radiographs with small opacities. For the other analyses, we used data of all 60 radiographs. We used a Stata module 'kappaetc' to compute inter-observer agreement in physicians overall and each group formed by residing country, specialty training, or experience[12]. This command can handle any number of observers and any number of categories. It calculates the agreement coefficient by averaging the observed agreement over all pairs of observers. It also provides seven prerecorded weights, suitable for any level of measurement. We computed weighted Fleiss' kappa to quantify the degree of agreement in classifying small opacity profusion and large opacity size and unweighted Fleiss' kappa for agreement on small opacity shape and the presence or absence of pleural plaques[13]. The result was interpreted values <0.2 as poor agreement, 0.21–0.4 as fair, 0.41–0.6 as moderate, 0.61–0.8 as good, and 0.81–1.0 as almost perfect agreement. Accuracy, in this study, was the ability to discriminate between normal and abnormal radiographs, i.e., the ability to classify a radiograph for the presence or absence of small opacities, large opacities, or pleural plaque; the true condition for each chest radiograph was determined based on the reading results of expert panel. Accuracy of the physicians was assessed by using only the chest radiographs that were in complete agreement for the presence or absence of small opacities, large opacities, or pleural plaque by all expert B Readers. There were 31 radiographs with and 20 radiographs without small opacities; 9 radiographs with and 41 radiographs without large opacities; 9 radiographs with and 30 radiographs without pleural plaques. A classification of 1/0 or higher profusion and any of the size classifications for large opacity by the physicians was considered as identification of small opacities

Table 1. Information of the physicians

Total	Physicians (n=93)	Country 1 (n=6)	2 (n=54)	3 (n=10)	4 (n=23)
	Number of physicians (%)				
Gender					
Female	50 (53.8)	2 (33.3)	32 (59.3)	5 (50.0)	11 (47.8)
Male	34 (36.6)	4 (66.7)	17 (31.5)	5 (50.0)	8 (34.8)
Missing	9 (9.7)	0	5 (9.3)	0	4 (17.4)
Specialty					
Pulmonology	40 (43.0)	0	38 (70.4)	1 (10.0)	1 (4.3)
Occupational medicine	25 (26.9)	4 (66.7)	10 (18.5)	6 (60.0)	5 (21.7)
Public health	4 (4.3)	1 (16.7)	0	2 (20.0)	1 (4.3)
Radiology	15 (16.1)	0	2 (3.7)	1 (10.0)	12 (52.2)
Missing	9 (9.7)	1 (16.7)	4 (7.4)	0	4 (17.4)
Years after graduation					
Median (range)	6 (1–34)	15 (5–30)	6 (1–34)	8.5 (4–23)	3 (1–34)
≤5	37 (39.8)	1 (16.7)	21 (38.9)	1 (10.0)	14 (60.9)
6–10	27 (29.0)	2 (33.3)	16 (29.6)	6 (60.0)	3 (13.0)
≥11	15 (16.1)	3 (50.0)	7 (13.0)	3 (30.0)	2 (8.7)
Missing	14 (15.1)	0	10 (18.5)	0	4 (17.4)
Number of reviewed pneumoconiosis CXR					
None	17 (18.3)	0	12 (22.2)	3 (30.0)	2 (8.7)
<10	41 (44.1)	2 (33.3)	27 (50.0)	3 (30.0)	9 (39.1)
<50	20 (21.5)	2 (33.3)	8 (14.8)	4 (40.0)	6 (26.1)
≥50	6 (6.4)	2 (33.3)	2 (3.7)	0	2 (8.7)
Missing	9 (9.7)	0	5 (9.3)	0	4 (17.4)

and large opacities, respectively. We examined the accuracy of each physician group by plotting receiver operating characteristic (ROC) curves and computing area under the curves (AUC) against experts' diagnosis as a reference standard. An ROC curve that plots sensitivity against 1-specificity allows visual inspection of the discriminating power, while AUC quantifies the power with a value of 1.0 representing perfect discriminatory ability and 0.5 being at chance level[14]. We used Stata's 'roccomp' command to execute ROC analysis. Assuming sensitivity and specificity are equally important in identifying each type of lesion, we calculated Youden's J index (i.e., sensitivity + specificity – 1) as a global measure of accuracy for every physician[15]; multiplying the index by one hundred generated accuracy scores. For the accuracy score for small opacity shape classification, we computed percent agreement with the reading results of expert panel. There were 20 radiographs with purely rounded and 4 with purely irregular opacities. We then compared the accuracy scores between physician groups using the Kruskal-Wallis test with Bonferroni correction for multiple comparisons. All analyses were performed using Stata/MP 15.1 software (StataCorp., College Station, TX, USA). This study was approved by the institutional review board of Kochi Medical School (approval number: 31-68). Written informed consent from the participating physicians was waived, but opt-out consent was obtained via e-mails instead.

Results

Table 1 presents information about our physicians. Information on specialty training and experiences (years after graduation and the number of reviewed pneumoconiosis chest radiographs) were not reported by some participating physicians. Physicians resided in India, Indonesia, Malaysia, and Thailand. They had expertise in occupational medicine, public health, respiratory health, and radiology. Specialties' representation was uneven between countries. Working duration since medical graduation ranged from 1 to 34 years. Eighteen percent of our physicians reported they had never seen a pneumoconiosis chest radiograph, while 44% encountered less than ten in their work.

Table 2 presents the kappa values for classifying chest radiographs by physicians overall and by the groups stud-

Table 2. Inter-observer agreement in classifying radiographs for pneumoconiosis[a]

	Small opacity profusion[b]	Small opacity shape[c]	Large opacity size[b]	Presence of pleural plaque[c]
	Fleiss' kappa coefficient (95% CI)			
Physician overall	0.59 (0.52–0.67)	0.29 (0.23–0.36)	0.65 (0.55–0.74)	0.30 (0.20–0.40)
Country				
1	0.50 (0.39–0.61)	0.18 (0.05–0.32)	0.57 (0.42–0.72)	0.34 (0.19–0.49)
2	0.59 (0.51–0.67)	0.26 (0.20–0.32)	0.66 (0.57–0.75)	0.25 (0.16–0.34)
3	0.47 (0.38–0.55)	0.21 (0.13–0.30)	0.55 (0.40–0.70)	0.31 (0.20–0.42)
4	0.73 (0.66–0.80)	0.56 (0.48–0.65)	0.69 (0.59–0.79)	0.55 (0.42–0.68)
Specialty				
Pulmonology	0.62 (0.54–0.69)	0.26 (0.20–0.31)	0.69 (0.61–0.77)	0.29 (0.19–0.38)
Occupational medicine	0.53 (0.45–0.61)	0.28 (0.20–0.37)	0.56 (0.44–0.68)	0.26 (0.16–0.35)
Public health	0.51 (0.39–0.64)	0.12 (0.02–0.22)	0.56 (0.38–0.75)	0.30 (0.12–0.48)
Radiology	0.69 (0.61–0.77)	0.54 (0.45–0.64)	0.74 (0.64–0.83)	0.58 (0.44–0.71)
Years after graduation				
≤5	0.67 (0.60–0.75)	0.39 (0.32–0.46)	0.72 (0.63–0.80)	0.39 (0.27–0.51)
6–10	0.52 (0.44–0.61)	0.21 (0.16–0.27)	0.59 (0.48–0.70)	0.26 (0.17–0.35)
≥11	0.53 (0.45–0.61)	0.28 (0.20–0.36)	0.55 (0.43–0.67)	0.24 (0.14–0.34)
Number of reviewed pneumoconiosis CXR				
None	0.55 (0.48–0.62)	0.23 (0.15–0.31)	0.61 (0.52–0.70)	0.22 (0.14–0.30)
<10	0.63 (0.55–0.71)	0.32 (0.26–0.39)	0.68 (0.58–0.78)	0.33 (0.22–0.43)
<50	0.56 (0.47–0.64)	0.31 (0.24–0.38)	0.60 (0.46–0.73)	0.29 (0.17–0.41)
≥50	0.53 (0.42–0.64)	0.23 (0.11–0.36)	0.68 (0.57–0.79)	0.34 (0.19–0.49)

a= Computation included the readings of 40 radiographs (9 boundary cases and 31 radiographs with small opacities) for "small opacity shape"; included readings of all 60 radiographs for the others. b= Weighted kappa coefficient. c= Unweighted kappa coefficient.
All kappa coefficients were significant at $p<0.001$.
Interpretation of kappa coefficients: <0.2 = poor, 0.21–0.4 = fair, 0.41–0.6 = moderate, 0.61–0.8 = good, and 0.81–1.0 = almost perfect agreement.

ied. Physicians showed fair to good agreement with kappa values 0.30 (95% CI: 0.20–0.40), 0.29 (95% CI: 0.23–0.36), 0.59 (95% CI: 0.52–0.67), and 0.65 (95% CI: 0.55–0.74), respectively for classifying pleural plaques, small opacity shapes, small opacity profusion, and large opacities. The degree of agreement was different among physician groups. Physicians from Country 4, or groups formed by physicians who received radiology training, or were five or fewer years working after graduation, achieved the highest agreement in all types of lesion.

Fig. 1 depicts the ROC curves and average AUC values of the physician groups for each pneumoconiotic lesion. Table 3 compares physician groups for their accuracy scores. Accuracy in identifying small opacities, large opacities, and the pleural plaques, as determined by AUC and accuracy scores, was different among physician groups. Physicians from Country 4, or with radiology training, or who were five or fewer years working after graduation, showed the highest accuracy (Fig. 1 and Table 3). Accuracy scores for small opacity shape classification showed a similar pattern of differences (Table 3). No substantial difference in accuracy was detected between groups formed by the reported number of reviewed pneumoconiosis chest radiographs (Table 3).

Discussion

To our knowledge, this study is the first in comparing inter-observer agreement and accuracy in classifying radiographs for pneumoconiotic lesions using the ILO classification among physicians from different Asian countries. We observed that the degree of inter-observer agreement and diagnostic accuracy varied with the observer's characteristics, namely, residing country, specialty training, and time after graduation.

Physicians in this study showed better agreement in classifying parenchymal lesions than pleural plaques using the ILO classification. However, they agreed on the shape of small opacities poorly. The degree of agreement varied between countries, with kappa values ranging from 0.47 to

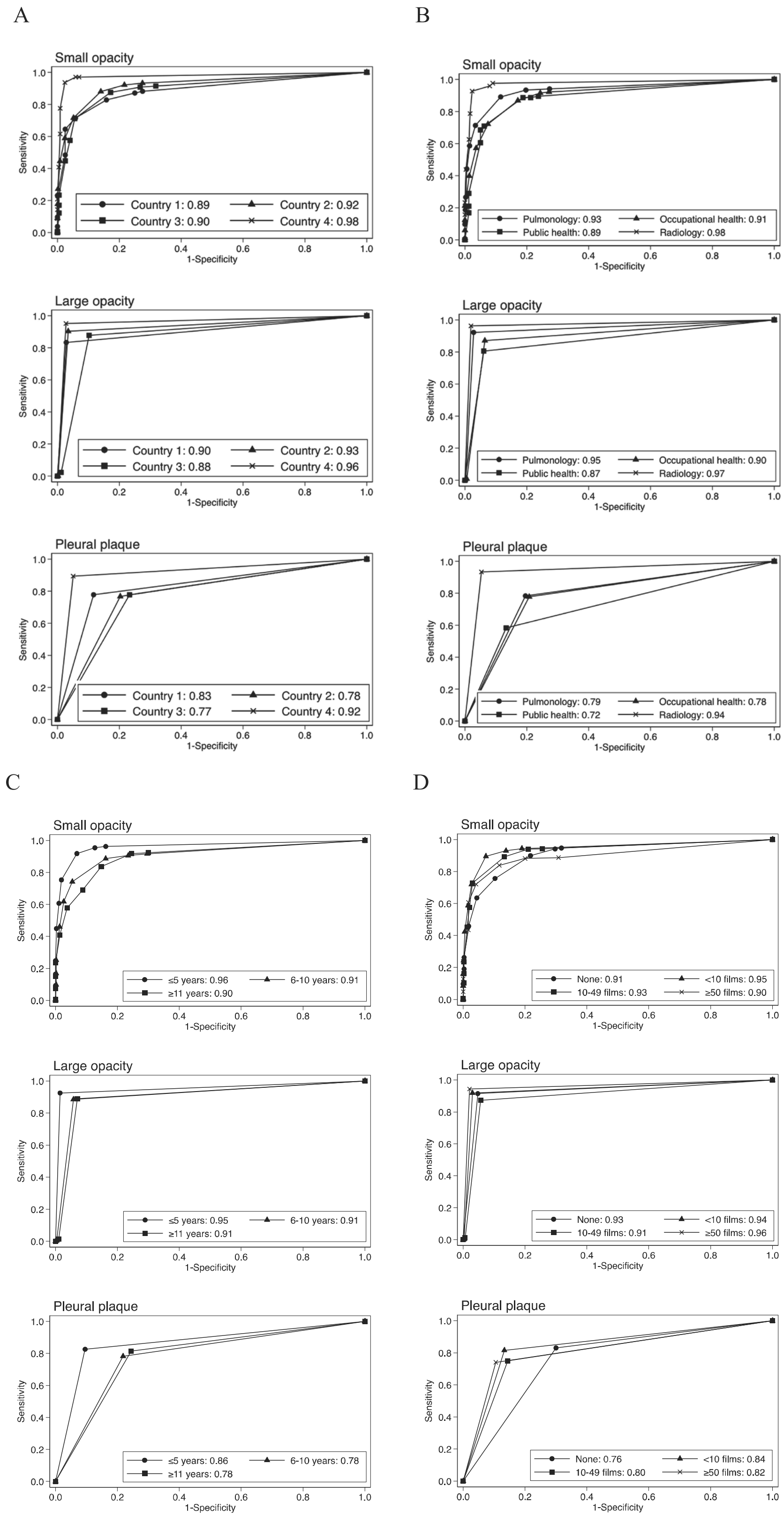

Fig. 1. Accuracy in classifying radiographs for the presence or absence of pneumoconiosis. Average AUC values of physician groups formed by (A) country, (B) specialty, (C) years after graduation, and (D) number of reviewed pneumoconiosis chest radiographs.

Table 3. Comparison between physician groups for accuracy in classifying radiographs for pneumoconiosis

	Physicians	Small opacity	Small opacity shape	Large opacity	Pleural plaque
	Number	Accuracy score[a], Median (Interquartile range)			
Physician overall	93	76.8 (29.3)	83.3 (25)	88.9 (23.3)	61.1 (25.5)
Country					
1	6	63.7 (13.5)***	79.2 (12.5)	74.1 (27.1)	68.3 (15.6)
2	54	73.9 (30.8)***	75 (20.8)***	88.9 (20.9)	56.1 (25.5)***
3	10	62.5 (16.8)***	66.7 (20.8)***	77.2 (19.5)**	55.0 (15.6)***
4 (Reference)	23	91.8 (12.9)	95.8 (12.5)	97.6 (13.5)	85.6 (18.9)
Kruskal-Wallis test		$p<0.001$	$p<0.001$	$p=0.012$	$p<0.001$
Specialty					
Radiology (Reference)	15	91.8 (25.0)	100 (16.7)	100 (13.5)	85.6 (18.9)
Pulmonology	40	77.1 (26.0)*	79.2 (22.9)**	95.1 (16.0)	58.3 (25.0)***
Occupational health	25	67.1 (35.8)**	75 (16.7)**	81.6 (30.6)**	60.0 (15.5)***
Public health	4	74.6 (32.2)	70.8 (31.2)*	72.4 (12.9)*	47.8 (13.3)***
Kruskal-Wallis test		$p=0.005$	$p=0.002$	$p=0.003$	$p<0.001$
Years after graduation					
≤5 (Reference)	37	87.1 (19.7)	87.5 (20.8)	97.6 (11.1)	75.6 (27.8)
6–10	27	70.0 (34.4)**	66.7 (29.2)***	84.0 (20.9)**	55.6 (38.9)**
≥11	15	67.1 (27.6)**	83.3 (12.5)	85.4 (16.0)*	57.8 (15.6)**
Kruskal-Wallis test		$p<0.001$	$p= 0.002$	$p=0.005$	$p=0.001$
Number of reviewed pneumoconiosis CXR					
None (Reference)	17	70 (27.1)	75 (25)	88.9 (18.4)	53.3 (25.6)
<10	41	83.9 (26.8)	83.3 (25)	95.1 (16.0)	67.8 (33.3)
<50	20	75.2 (30.9)	83.3 (22.9)	82.8 (25.3)	61.1 (28.9)
≥50	6	71.2 (26.4)	70.8 (29.2)	96.3 (8.7)	67.8 (26.7)
Kruskal-Wallis test		$p=0.10$	$p=0.206$	$p=0.113$	$p=0.139$

a= Accuracy scores are calculated as Youden's J index x 100, except for "small opacity shape". Scores for "small opacity shape" are percent agreement with experts' classification of small opacities as rounded or irregular.
Reference = reference group in Bonferroni correction for multiple comparisons.
p values of Bonferroni correction for multiple comparisons: * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

0.73 (moderate to good agreement) on the distribution of small opacity profusion, from 0.55 to 0.69 (moderate to good agreement) for large opacity size, from 0.25 to 0.55 (fair to moderate agreement) for the presence or absence of pleural plaques, and 0.18 to 0.56 (poor to moderate agreement) for small opacity shape classification. The poor agreement between observers for the shape of small opacities was not unexpected. We have noted that of the 40 radiographs with small opacities from the AIR Pneumo examination film set, the expert panel agreed on small opacity shapes in only 24 radiographs. Moreover, studies that examined the shape classification of small opacities reported substantial variation existing between observers[16, 17]. Not many studies have examined inter-observer agreement involving multiple readers using the ILO classification. One Japanese study[18], which examined inter-observer agreement between film-screen radiography and two digital systems, reported the kappa values for the distribution of small opacity profusion on a twelve-point scale ranging from 0.55 to 0.64. However, their study involved a relatively small number of subject radiographs (n=30) and readers (n=3). In an American trial where seven B Readers classified 172 coal workers' chest radiographs, the reported kappa value of 0.58 for agreement on small opacity profusion was within the range of our results[19]. In a German study, seven physicians interpreted chest radiographs of 636 asbestos-exposed workers[8]. Their reports of an overall kappa value of 0.29 for small opacity profusion was considerably lower than the American study and ours, while 0.42 for pleural lesions was within the range of our findings. Another American study[7] evaluated 79,185 matched readings by A and B Readers from a coal workers' surveillance program; moderate agreement was seen only on the size of large opacities (kappa value 0.50). (A Readers and B Readers are certified by the NIOSH of the USA. A physician can achieve A Reader status by attending a NIOSH-authorized course on the ILO classification system or submitting radiographs to the NIOSH with ILO classifications for review. To become a B Reader, a physician must pass a rigorous competency-based examination and maintaining B Reader status requires passing the recertification examination every 5 years. In the referenced study[7)], B Readers classified more pneumoconiosis chest radiographs than A Readers did.) The authors concluded that the differences between readers in terms of training in the use of ILO classification and reading experiences were the likely reasons for the observed unsatisfactory agreement in classifying pleural changes (kappa value 0.16) and small opacity profusion (kappa value 0.24)[7)]. In addition to the observers' characteristics, we suggested that the differences in study designs (including the number of radiographs and readers), the defined classifications for studied conditions, and the quality of chest radiographs being classified might have also contributed to the varying degree of inter-observer agreement found across studies.

Specialty training affects the level of diagnostic accuracy and hence the degree of agreement in classifying chest radiographs for pneumoconiosis. A past study reported the existence of differences in diagnostic capability between specialties in reviewing chest radiographs[20)]. Our observation of the radiologists' group showing the highest performance, followed by the pulmonologists' group and the other specialties, also support this (Fig. 1; Table 3). Different physicians may have different thresholds for judging a chest radiograph between normal and abnormal. They may also have differing abilities to observe and recognize radiological appearances of pneumoconiotic lesions. The training to become a radiologist or a pulmonologist differs from that of other specialties. Also, radiologists and pulmonologists may have reviewed many more chest radiographs in routine work than physicians of other specialties. In our study, we observed that radiologists made up the highest proportion of "Country 4" and pulmonologists formed the majority in "Country 2" (Table 1); this uneven representation of specialties between countries was the likely source for differences found between countries.

Physicians' working years, as determined by years after graduation, did not ensure for a better agreement or higher accuracy. We observed better performance from the recent graduates (i.e., five or fewer years working after graduation) (Tables 2 and 3; Fig. 1). Uneven distribution of radiologists and pulmonologists between groups in our study might be one possible explanation for this observation. One previous study noted that to achieve high-level expertise in radiology requires a combination of radiology-specific training and deliberate practice, rather than an absolute number of working years[21)]. Other reasons might be related to the nature of the AIR Pneumo training program. Being younger, recently graduated physicians might be able to absorb more information during the two days of intensive training than their seniors. Also, recent graduates would still be familiar with the time-limited examination environment and manage to produce better results.

Physicians' familiarity with the ILO classification and standard radiographs likely plays a significant role in the reading performance of our physicians. A past study suggested that the number of reviewed chest radiographs also contributed to the poor agreement between A Readers and B Readers[7)]. However, we observed that relatively more numbers in reviewed pneumoconiosis chest radiographs appeared to be of no assistance to better observer agreement or higher accuracy in our physicians. A possible explanation might be that our physicians are not using ILO classification or the standard radiographs in their routine work. And thus, their reading experiences could not provide superior results in a test that required the ILO classification. Although we had not tested for it, our physicians' levels of understanding of the ILO classification might vary, contributing to the variation seen among groups.

Our physicians' diagnostic accuracy for pleural plaques appeared less satisfactory compared with parenchymal lesions. This finding was very similar to that observed in the U.S. B Reader program. Studies reported that physicians generally classify pleural changes poorly compared with parenchymal lesions, and this nature was the same for physicians who passed or failed the B Reader examinations[22, 23)]. Without specific radiological expertise, the detection of pleural plaques in a chest radiograph becomes challenging. Pleural plaques are irregular, circumscribed lesions on the parietal pleura. Radiographically, they appear as discrete areas of pleural thickening and are barely visible in some cases[2)]. In posteroanterior chest radiographs, shadows of anatomical structures (e.g., subcostal fat, serratus anterior muscles) or pleural thickening secondary to medical conditions (e.g., trauma, infection) may mimic plaques, and distinguishing them required a good knowledge of local anatomy and considerable experience[2, 24, 25)]. A systematic review reported high false-negative and varying false-positive rates in diagnosing pleural plaques on a chest radiograph[24)]. In a recent chest radiograph reading trial involving four readers with different clinical and radiography interpretation experiences (one B Reader and three AIR Pneumo-certified physicians), the investigators reported a lower detection rate for pleural plaques compared with those for parenchymal lesions[26]. They also demonstrated that the detection rate varied among readers, with the most experienced one showing the highest rate. A similar trend was also seen in a study using surveillance data, where B Readers having far greater experiences in diagnosing pneumoconiosis identified more pleural plaques than A Readers did[7]. In the present study, our physicians, except the radiologists, showed a lower accuracy in identifying pleural plaques when compared with those of parenchymal lesions, indicating specific training is required to develop diagnostic accuracy and improve agreement in the diagnosis of pleural plaques.

Accurate diagnosis and reporting from physicians are vital to the success of screening programs and disease prevention. The ILO/WHO's Global Program for the Elimination of Silicosis (GPES), aiming to eliminate new cases of silicosis from all workplaces by 2030, set its strategy on early detection of diseases through surveillance along with dust exposure control[27]. Similarly, the WHO's Global campaign for the elimination of asbestos-related disease works through improving early diagnosis and establishing registries of people with past and/or current exposures along with other primary preventive measures[28]. A recent article reported the worldwide occurrence of increasing incidence of pneumoconiosis for the last three decades. Of the 60,055 incident cases in 2017, more than half occurred in Asia: 32,305 cases in China and 5,160 cases in India[29]. Moreover, as the importation and use of asbestos in developing Asian countries has been continuing, a substantial number of people may have been exposed to asbestos occupationally and non-occupationally[30]. In these circumstances, our findings have several important occupational and public health implications. First, we reported the degree of inter-observer agreement and sources for variation in classifying pneumoconiotic lesions among Asian physicians taking AIR Pneumo examination. The awareness of variability allows a careful comparison of results between different studies and knowledge of the source enables us to recommend measures to correct the variations. Second, we observed a low-level diagnostic accuracy and poor agreement in classifying radiographs for pleural plaques. Pleural plaques indicate past exposure to asbestos[31]; in most cases, they are asymptomatic and often identified as incidental chest radiographic findings[32]. Attending physician's familiarity with the radiological appearance of pleural plaques is central to their identification. The ILO standards radiographs illustrate a spectrum of radiological appearances seen in all types of pneumoconiotic lesions[4], the use of which permits physicians' familiarity with radiological appearances of pneumoconiosis, and thereby, improves diagnostic accuracy, especially for less experienced physicians[33]. Training in the use of the ILO classification, such as that provided by the AIR Pneumo, might promote physicians' reading skill further[34].

This study has several limitations. First, we used data derived from examinations. Participants might expect more radiographs showing signs of pneumoconiosis and assess them in a manner different from their routine work. However, we believed that the participants' enthusiasm and compliance with the standard assessment procedure made the data featured their actual performance in applying the ILO classification. Second, since our physicians have a common interest in pneumoconiosis, findings in this study may not necessarily represent the performance of Asian physicians in general. However, it should be noted that our physicians are grossly representing the physician population in pneumoconiosis screening in their respective countries. Third, we do not have information on the requirements of specialty training in each country. But we believe these might differ between specialties and between countries. We suggested the uneven specialty representation within each country requires careful interpretation of individual country results. Fourth, the different number of readers among the groups studied might affect the estimated kappa coefficients.

Conclusion

Reviewing chest radiographs using the ILO classification is the current international standard in screening for pneumoconiosis. Asian physicians taking the AIR Pneumo examination were better at classifying parenchymal lesions than pleural plaques using the ILO classification. The degree of inter-observer agreement differed among countries, and this difference was associated with a physician's specialty training background. Specific training on the use of the ILO classification, as provided by the AIR Pneumo, and continuing practice would improve diagnostic accuracy and lessen observer variability.

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Authors' Contribution

All authors contributed toward data collection and reviewed and approved this manuscript. NA J-P: Writing original draft, data curation, data analysis, review & editing. NS: Writing original draft, data curation, data analysis, review & editing. ADS: Data curation, review & editing. ES: Data curation, review & editing. MM: Data curation, review & editing. ST: Data curation, review & editing. SL: Data curation, review & editing. PS: Data curation, review & editing. SS: Data curation, review & editing. ND: Data curation, review & editing. EA: Data curation, review & editing. JEP: Data curation, review & editing. KGH: Data curation, review & editing. HK: Data curation, review & editing. TT: Data curation, review & editing. YK: Data curation, review & editing.

Conflict of Interest

None declared.

References

1) Chong S, Lee KS, Chung MJ, Han J, Kwon OJ, Kim TS (2006) Pneumoconiosis: comparison of imaging and pathologic findings. Radiographics **26**, 59–77.
2) Norbet C, Joseph A, Rossi SS, Bhalla S, Gutierrez FR (2015) Asbestos-related lung disease: a pictorial review. Curr Probl Diagn Radiol **44**, 371–82.
3) Wagner GR (1996) Screening and surveillance of workers exposed to mineral dust. World Health Organization, Geneva, Switzerland.
4) ILO Guidelines for the use of the ILO international classification of radiographs of pneumoconioses. Revised edition 2011. International Labour Office, Geneva, Switzerland.
5) J-P Naw Awn, Imanaka M, Suganuma N (2017) Japanese workplace health management in pneumoconiosis prevention. J Occup Health **59**, 91–103.
6) J-P Naw Awn, Suganuma N (2020) Quality assurance in reading radiographs for pneumoconiosis: AIR Pneumo program. ASEAN-JR **21**, 73–84.
7) Halldin CN, Blackley DJ, Petsonk EL, Laney AS (2017) Pneumoconioses radiographs in a large population of U.S. coal workers: variability in A Reader and B Reader classifications by using the International Labour Office classification. Radiology **284**, 870–6.
8) Ochsmann E, Carl T, Brand P, Raithel HJ, Kraus T (2010) Inter-reader variability in chest radiography and HRCT for the early detection of asbestos-related lung and pleural abnormalities in a cohort of 636 asbestos-exposed subjects. Int Arch Occup Environ Health **83**, 39–46.
9) Tamura T, Kusaka Y, Suganuma N, Suzuki K, Subhannachart P, Siriruttanapruk S, Dumavibhat N, Zhang X, Sishodiya PK, Thanh TA, Hering KG, Parker JE, Algranti E, O'Connor FS, Shida H, Akira M (2018) Assessment of physicians' proficiency in reading chest radiographs for pneumoconiosis, based on a 60-film examination set with two factors constituting eight indices. Ind Health **56**, 382–93.
10) Zhou H, Kusaka Y, Tamura T, Suganuma N, Subhannachart P, Siriruttanapruk S, Dumavibhat N, Zhang X, Sishodiya PK, Van Duy K, Hering KG, Parker JE, Algranti E, Fedotov I, Shida H, Akira M (2012) The 60-film set with 8-index for examining physicians' proficiency in reading pneumoconiosis chest X-rays. Ind Health **50**, 84–94.
11) Gamble JF, Hessel PA, Nicolich M (2004) Relationship between silicosis and lung function. Scand J Work Environ Health **30**, 5–20.
12) Klein D (2016) KAPPAETC: Stata module to evaluate interrater agreement. revised 06 Jan 2019. https://ideas.repec.org/c/boc/bocode/s458283.html. Accessed October 25, 2021.
13) Gisev N, Bell JS, Chen TF (2013) Interrater agreement and interrater reliability: key concepts, approaches, and applications. Res Social Adm Pharm **9**, 330–8.
14) Linden A (2006) Measuring diagnostic and predictive accuracy in disease management: an introduction to receiver operating characteristic (ROC) analysis. J Eval Clin Pract **12**, 132–9.
15) Youden WJ (1950) Index for rating diagnostic tests. Cancer **3**, 32–5.
16) Amandus HE, Pendergrass EP, Dennis JM, Morgan WK (1974) Pneumoconiosis: inter-reader variability in the

classification of the type of small opacities in the chest roentgenogram. Am J Roentgenol Radium Ther Nucl Med **122**, 740–3.
17) Rossiter CE (1972) Initial repeatability trials of the UICC-Cincinnati classification of the radiographic appearances of pneumoconioses. Br J Ind Med **29**, 407–19.
18) Takashima Y, Suganuma N, Sakurazawa H, Itoh H, Hirano H, Shida H, Kusaka Y (2007) A flat-panel detector digital radiography and a storage phosphor computed radiography: screening for pneumoconioses. J Occup Health **49**, 39–45.
19) Halldin CN, Petsonk EL, Laney AS (2014) Validation of the International Labour Office digitized standard images for recognition and classification of radiographs of pneumoconiosis. Acad Radiol **21**, 305–11.
20) Cascade PN, Kazerooni EA, Gross BH, Quint LE, Silver TM, Bowerman RA, Pernicano PG, Gebremariam A (2001) Evaluation of competence in the interpretation of chest radiographs. Acad Radiol **8**, 315–21.
21) Kelly BS, Rainford LA, Darcy SP, Kavanagh EC, Toomey RJ (2016) The development of expertise in radiology: in chest radiograph interpretation, “expert” search pattern may predate “expert” levels of diagnostic accuracy for pneumothorax identification. Radiology **280**, 252–60.
22) Halldin CN, Hale JM, Weissman DN, Attfield MD, Parker JE, Petsonk EL, Cohen RA, Markle T, Blackley DJ, Wolfe AL, Tallaksen RJ, Laney AS (2019) The National Institute for Occupational Safety and Health B Reader certification program - An update report (1987 to 2018) and future directions. J Occup Environ Med **61**, 1045–51.
23) Wagner GR, Attfield MD, Kennedy RD, Parker JE (1992) The NIOSH B Reader certification program. An update report. J Occup Med **34**, 879–84.
24) Clarke CC, Mowat FS, Kelsh MA, Roberts MA (2006) Pleural plaques: a review of diagnostic issues and possible nonasbestos factors. Arch Environ Occup Health **61**, 183–92.
25) Alfudhili KM, Lynch DA, Laurent F, Ferretti GR, Dunet V, Beigelman-Aubry C (2016) Focal pleural thickening mimicking pleural plaques on chest computed tomography: tips and tricks. Br J Radiol **89**, 20150792.
26) Nogami S, J-P Naw Awn, Nogami M, Matsui T, Ngatu NR, Tamura T, Kusaka Y, Itoh H, Suganuma N (2020) Radiographic diagnosis of pneumoconioses by AIR Pneumo-trained physicians: comparison with low-dose thin-slice computed tomography. J Occup Health **62**, e12141.
27) Fedotov IA, Eijkemans GJM (2007) The ILO/WHO global programme for the elimination of silicosis (GPES). GOHNET Newsletter.
28) WHO. Asbestos: elimination of asbestos-related diseases. https://www.who.int/news-room/fact-sheets/detail/asbestos-elimination-of-asbestos-related-diseases. Accessed October 25, 2021.
29) Shi P, Xing X, Xi S, Jing H, Yuan J, Fu Z, Zhao H (2020) Trends in global, regional and national incidence of pneumoconiosis caused by different aetiologies: an analysis from the Global Burden of Disease Study 2017. Occup Environ Med **77**, 407–14.
30) Leong SL, Zainudin R, Kazan-Allen L, Robinson BW (2015) Asbestos in Asia. Respirology **20**, 548–55.
31) Wolff H, Vehmas T, Oksa P, Rantanen J, Vainio H (2015) Asbestos, asbestosis, and cancer, the Helsinki criteria for diagnosis and attribution 2014: recommendations. Scand J Work Environ Health **41**, 5–15.
32) Cugell DW, Kamp DW (2004) Asbestos and the pleura: a review. Chest **125**, 1103–17.
33) Fletcher CM, Oldham PD (1951) The use of standard films in the radiological diagnosis of coalworkers’ pneumoconiosis. Br J Ind Med **8**, 138–49.
34) Ngatu NR, Suzuki S, Kusaka Y, Shida H, Akira M, Suganuma N (2010) Effect of a two-hour training on physicians’ skill in interpreting Pneumoconiotic chest radiographs. J Occup Health **52**, 294–301.