Awareness, Safety Practices and Associated Factors Among E-Waste Recycling Workers in Bangladesh

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ABSTRACT: Awareness of electronic waste (e-waste) improves safety practices among workers, thereby reducing health risks associated with pollutants. Investigating the awareness and safe practices among these workers could help identify areas for improvement, a task not yet undertaken in Bangladesh. Consequently, this study aimed to examine the awareness, safety measures, and associated factors among e-waste workers in the country. In this cross-sectional study, 236 workers from an e-waste recycling facility located near Dhaka were interviewed using a semi-structured questionnaire from August to September 2022. Eight questions captured information on socio-demographics and work factors, 24 questions on e-waste awareness, and 11 questions on safety practices. Total awareness and safety scores were calculated and categorized as "good" and "poor" based on a cut-off point of 80% of the total score. Bivariate and regression analyses were done to determine associated factors. Only 25% of workers had good e-waste awareness; major knowledge gaps were regarding minimization, health hazards, and environmental impact. Good awareness was significantly associated with female gender, higher education, income, smoking, experience ⩾5 years, and training. About 58% followed good safety practices, but the use of boots and helmets was inadequate. Good safety practices were significantly associated with higher education, income, smoking, experience, training, and overtime work. On multivariable analysis, those with higher education had 12 times (95% CI 4.83-32.81) and 6 times (95% CI 2.94-12.81) higher odds of good awareness and practices, respectively. Trained workers had 3.6 times (95% CI 1.67-7.52) higher odds of good practices. There was a significant correlation between awareness and practices ($r = .70$, $P < .001$). The study found poor awareness and inadequate safety practices related to e-waste among the workers. Urgent interventions like training, the use of protective gear, and stringent policies are warranted to increase awareness and safety behaviors.

PLAIN LANGUAGE SUMMARY: This study looked at how aware e-waste recycling workers in Bangladesh are about the hazards of e-waste and whether they take proper safety measures during their work. E-waste, which refers to discarded electronic devices and components, contains hazardous materials like heavy metals and toxic chemicals. If not handled properly, these can cause health problems for the workers as well as environmental pollution. The researchers interviewed 236 e-waste workers in Dhaka in 2022. They asked questions to assess the workers' knowledge about e-waste and its risks, as well as what safety gear and practices they used at work. The study found that only 25% of the workers had good awareness about e-waste hazards. Major gaps were around minimizing e-waste, the health risks, and environmental impact. Around 58% reported following good safety practices like using masks and gloves. However, many did not use critical protective gear like safety boots and helmets consistently. Higher education levels and professional training were linked to better awareness and safer practices. Trained workers were more likely to follow good safety practices. The study findings suggest that urgent interventions like health education and training programs are needed. This can help increase awareness and ensure workers take adequate precautions to reduce health risks from mishandling e-waste in Bangladesh.

KEYWORDS: E-waste awareness, e-waste management, e-waste related safety practices, informal recycling, Bangladesh

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Introduction

Electronic waste (e-waste), also known as Waste Electrical and Electronic Equipment (WEEE), is defined under the Basel Convention as electrical or electronic equipment that is waste, including all components, sub-assemblies, and consumables that are part of the equipment at the time the equipment becomes waste.[1] It refers to electrical and electronic equipment (EEE) and components that have been discarded by its owners. It includes six categories of equipment, including—temperature exchange equipment (eg, refrigerators), screens and monitors (eg, televisions, laptops), lamps (eg, LED retrofit lamp), large equipment (eg, washing machines), small equipment (eg, electric kettle), and small IT and telecommunication equipment (eg, mobile phones, personal computers).[2] E-waste contains hazardous materials like heavy metals (eg, lead [Pb], mercury [Hg], cadmium [Cd]), flame retardants (eg, polybrominated diphenyl ethers [PBDEs], polybrominated biphenyls [PBBs]), and combustion byproducts (eg, polychlorinated dibenzodioxins [PCDDs], polyaromatic hydrocarbons [PAHs]) that can pose risks to human health and the environment if not properly managed.[3] It has become one of the fastest-growing waste streams worldwide, with generation rising globally from an estimated 62 billion kg in 2010 to 96 billion kg in 2022, which is projected to rise up to 120 billion kg by 2030.[4]

Countries in Asia generate almost half of the e-waste produced globally[4] and a large proportion of this comes from South Asian countries. Bangladesh is the third-highest e-waste generator in South Asia,[5] with generation reaching to approximately 3 million metric tons in 2020[6] and projections for rapid increases in the coming years due to the national mission of increasing digitalization.[7,8] Moreover, low- and middle-income countries like Bangladesh are major recipients of e-waste from high-income countries.[4,6,9]

The substantial burden of electronic waste in Bangladesh necessitates its effective management to mitigate associated health and environmental hazards. The country recycles around 20% of total e-waste, which is second to India in the South Asian region.[9] The majority of e-waste recycling and disposal in this part of Asia is handled by workers in the informal sector. The formal sector is mainly active in Sri Lanka, while informal workers predominantly handle e-waste in India and Bangladesh.[9] These workers, who often operate in unhealthy conditions without proper training, protective gear, or environmental standards,[10] dismantle, sort, and extract valuable materials from discarded electronics.[6] People and the surrounding environment of informal e-waste recycling activity are at increased risk of developing different health problems.[10] Particularly, workers involved in recycling processes are directly exposed to toxic chemicals produced from the decomposition of e-waste during their work. This may lead to numerous adverse health impacts.[10,11] Awareness of e-waste and adherence to safety protocols, like wearing suitable personal protective gear and washing hands after work or before eating, can effectively lessen these health risks.[12]

However, studies have found low levels of awareness and inadequate safety practices among e-waste workers in developing countries.[13,14] The types of chemical exposures from e-waste recycling have been linked to health problems like respiratory, gastric, and dermatologic ailments among workers in countries like Brazil, China, India, Mexico, and Pakistan.[10] In Bangladesh, a high frequency of neonatal death, perinatal complications, and thyroid, skin and respiratory problems have been reported in people living near e-waste recycling sites and among recycling workers.[15] Having a better understanding of e-waste may lead e-waste workers to practice proper handling and protection measures[12] during e-waste handling, which could then reduce health hazards in this population.

Understanding the patterns and factors influencing awareness and safety practices among e-waste workers is important to improve health and safety conditions in this vulnerable population. But, there is a dearth of studies that explored these issues in Bangladesh. The available studies focused on electronic equipment sellers' intention of recycling,[8] consumers' behavior regarding e-waste disposal,[16] e-waste management scenario in the country[6,9] and physical harm associated with e-waste exposure.[17] Therefore, this study aimed to assess e-waste awareness, safety practices, and their determinants among e-waste recycling workers in Dhaka, Bangladesh. The findings can help inform targeted interventions to increase protective behaviors and reduce chemical exposures among e-waste recycling workers in similar low-resource settings.

Methods

Study setting, period, and population

The present study was conducted from August 2022 to September 2022 to assess electronic waste awareness and safety practices among e-waste recycling workers. As cross-sectional design is the best for determining prevalence and for identifying probable associations and are less time-consuming and cost-effective, this was chosen for the present study. It was conducted at an e-waste recycling company (the first of its kind) located in Delpara, Fatullah, approximately 11 km from Dhaka, Bangladesh. Workers aged 18 years and above, working in the company for at least 6 months, and willing to participate in the study were approached. Severely ill workers and pregnant women were excluded. Workers with less than 6 months of working experience were omitted, assuming that they did not gather enough experience to adapt to the working norm of the recycling center. Hence, their responses might not reflect the common awareness and safety practices in the center. Pregnant women were excluded because, during the initial piloting, we found them to be heavily stressed and reluctant to participate. Participating workers were from five sectors: collection, separation, compression, pressing, and dismantling. Using Cochran's formula with a 5% margin of error and 95% confidence interval and taking the 92% observed proportion of poor awareness from a previous study among e-waster workers,[14] the minimum required sample size was calculated to be 114. However, a total of 236 respondents were conveniently selected because of their availability and willingness to participate in the study within the specified data collection period. Additionally, proportionate participation was ensured from the 5 sectors of e-waste recycling activities.

Data collection technique and scoring

Data was collected through face-to-face interviews using a semi-structured questionnaire. At first, a pilot study was conducted among 20 recycling workers. Based on the feedback from the pilot interviews (not included in the analysis), the final questionnaire was prepared. Interviews were conducted onsite during work hours in a private setting after obtaining written informed consent. The questionnaire captured information on socio-demographic characteristics, smoking habits, work-related factors, e-waste awareness, and e-waste handling safety practices. The first section queried about age, gender, religion, educational qualification, marital status, monthly family income, job sector, and smoking habit. The work-related

factor section was comprised of the duration of work (hours/day and days/week), any professional training (present or not), years of work experience, provision of break time during work, and whether they worked overtime.

E-waste awareness-related questions and scoring. There were 24 questions related to e-waste awareness (S1 Table). Each question had 2 answers: yes and no. These were given a score of "1" and "0," respectively. A total awareness score was calculated by adding those responses with a possible range of total scores between 0 and 24. According to Bloom's cut-off point,[18] a participant with a score of ⩾20 (80%) was considered to have good awareness, and a score of <20 was considered for poor awareness.

Safety practice-related questions and scoring. A total of 11 questions were asked about the safety practices associated with e-waste (S2 Table). These questions also had the same yes/no answer with a scoring scheme similar to that of awareness-related questions. The possible range for the total score was 0 to 11. Again a score of ⩾9 (80%) was considered positive for good safety practices, and <9 was considered for defining poor safety practices using the upper value of Bloom's cut-off point as used by Feleke et al.[18]

Statistical analysis

Descriptive statistics was presented using frequency (percentage) for categorical variables and mean (standard deviation [SD]) for normally distributed continuous variables. The normality of the numerical variables was assessed using a histogram and normal curve. For bivariate analysis, the factor variables were dichotomized for simplicity of analysis and interpretation. Bivariate analyses were conducted using Pearson's chi-square test, Fisher's exact test, and independent samples *t*-tests where needed. Significant factor variables in bivariate analyses were selected for multivariable logistic regression analysis. A P-value of <.05 was considered significant for statistical tests. The statistical analysis software R Studio (version 2023.12.0+369) for Windows OS (version 11) was used for all statistical tests.

Results

Characteristics of study participants

A total of 236 e-waste collectors participated in the study. The mean age was 39.27 ± 9.36 years. Most participants were male (68.22%), completed primary education (54.24%), and were married (90.68%). The mean monthly family income was 13 173.73 ± 2488.59 Bangladeshi Taka (BDT). Nearly 40% were smokers. Most had >5 years of experience (58.90%) and received professional training (53.81%). All had break times, and most worked overtime (96.19%). The characteristics of the respondents are presented in Table 1.

Table 1. Characteristics of the respondents.

CHARACTERISTIC	N = 236[a]
Age (y)	39.27 ± 9.36
Gender	
Male	161 (68.22)
Female	75 (31.78)
Educational qualification	
Primary	128 (54.24)
Secondary	100 (42.37)
Higher secondaries	8 (3.39)
Monthly family income (BDT)	13 173.73 ± 2488.59
Monthly family income categories	
<9000	15 (6.36)
9001-12 000	66 (27.97)
12 001-15 000	113 (47.88)
>15 001	42 (17.80)
Marital status	
Married	213 (90.25)
Unmarried	12 (5.08)
Divorced	6 (2.54)
Widowed	5 (2.12)
Smoking habit	
Smoker	94 (39.83)
Non-smoker	142 (60.17)
Job sector	
Collection sector	24 (10.17)
Separation sector	99 (41.95)
Compression sector	35 (14.83)
Pressing sector	39 (16.53)
Dismantling sector	39 (16.53)
Work experience (y)	6.42 ± 2.35
Experience in years	
Less than 5 y	97 (41.10)
more than or equal to 5 y	139 (58.90)
Professional training present	127 (53.81)
Presence of break time	236 (100.00)
Do overtime duties	227 (96.19)

[a]Mean ± SD; n (%).

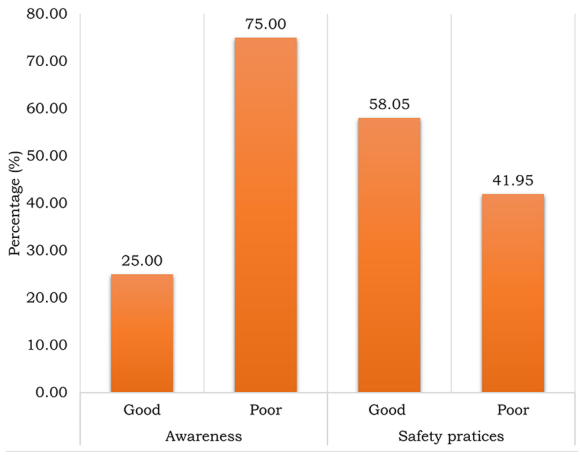

Figure 1. Level of awareness and safety practice regarding e-waste among respondents.

Awareness, safety practices, and relevant factors among participants

Out of all, 83.47% knew about the meaning of e-waste. All of the participants (100%) identified cell phones, computers, televisions, and refrigerators as the source of e-waste. Slightly more than half (54.66%) knew that e-waste is harmful to the environment, and only 37.29% knew that e-waste is associated with health problems. All participants knew about effective mechanisms of e-waste management, and that e-waste can be segregated. But, only 28.39% knew about ways of e-waste minimization, 59.32% knew how to dispose of waste, 64.41% knew about the chemicals/substances released during the dismantling of e-waste, and only 79.24% knew how e-waste products/chemicals interact with the body (See S1 Table for details).

Awareness of e-waste hazards was poor in 75% of participants and good in 25%. The proportion of awareness is shown in Figure 1. Female gender ($P < .001$), higher education ($P < .001$), higher income ($P < .001$), smoking ($P = .001$), $\geqslant 5$ years of experience ($P < .001$), and professional training ($P < .001$) were associated with good awareness. Table 2 describes the factors associated with e-waste-related awareness.

Of all, 75.42% used masks, 76.69% used safety glasses, 44.49% used safety boots, 39.41% used helmets, 63.56% used disinfectants for cleaning hands, and 76.69% used separate clothes for the job. A 100% of the participants wore personal protective equipment, used gloves, washed their hands before going home and before eating, and used soap to clean their hands (See S2 Table for details).

Safety practices were poor in 42% of participants and good in 58%. The proportion of safety practices is shown in Figure 1. Female gender ($P < .001$), higher education ($P < .001$), higher income ($P < .001$), smoking ($P = .045$), $\geqslant 5$ years of experience ($P < .001$), professional training ($P < .001$) and working overtime ($P = .005$) were associated with good safety practices. The factors associated with good safety practices are described in Table 3.

Table 2. Factors associated with e-waste-related awareness.

CHARACTERISTIC	POOR, N = 177[a]	GOOD, N = 59[a]	P-VALUE
Age (y)	39.40 ± 9.38	38.88 ± 9.36	.716[b]
Gender			<.001[c]
Male	104 (64.60)	57 (35.40)	
Female	73 (97.33)	2 (2.67)	
Education			<.001[c]
Primary	122 (95.31)	6 (4.69)	
Secondary and higher secondary	55 (50.93)	53 (49.07)	
Marital Status			.375[c]
Single[e]	19 (82.61)	4 (17.39)	
Married	158 (74.18)	55 (25.82)	
Monthly family income (BDT)			<.001[c]
⩽12000	78 (96.30)	3 (3.70)	
>12000	99 (63.87)	56 (36.13)	
Smoking habit			.001[c]
Smoker	60 (63.83)	34 (36.17)	
Non-smoker	117 (82.39)	25 (17.61)	
Experience in years			<.001[c]
<5	86 (88.66)	11 (11.34)	
⩾5	91 (65.47)	48 (34.53)	
Professional training present	81 (63.78)	46 (36.22)	<.001[c]
Presence of break time	177 (75.00)	59 (25.00)	>.999[d]
Do overtime duties	168 (74.01)	59 (25.99)	.117[d]

[a]Mean ± SD; n (%).
[b]Welch 2 sample *t*-test.
[c]Pearson's Chi-squared test.
[d]Fisher's exact test.
[e]Single includes unmarried, divorced, and widowed.

Table 4 shows the adjusted odds ratios from multivariable logistic regression analysis exploring factors associated with good awareness and good safety practices regarding e-waste. Those with secondary education and above had significantly higher odds of good awareness (Odds Ratio [OR] 11.61, 95% Confidence Interval [CI] 4.83-32.81) and good safety practices (OR 6.01, 95% CI 2.94-12.81) compared to those with primary education or less. Smokers had higher odds of good

Table 3. Factors associated with e-waste-related safety practices.

CHARACTERISTIC	POOR, N = 99[a]	GOOD, N = 137[1]	*P*-VALUE
Age (y)	40.18 ± 8.32	38.61 ± 10.01	.189[b]
Gender			<.001[c]
Male	45 (27.95)	116 (72.05)	
Female	54 (72.00)	21 (28.00)	
Religion			.485[c]
Muslim	94 (42.53)	127 (57.47)	
Hindu	5 (33.33)	10 (66.67)	
Education			<.001[c]
Primary	83 (64.84)	45 (35.16)	
Secondary and higher secondary	16 (14.81)	92 (85.19)	
Marital status			.773[c]
Single[e]	9 (39.13)	14 (60.87)	
Married	90 (42.25)	123 (57.75)	
Monthly family income (BDT)			<.001[c]
⩽12 000	58 (71.60)	23 (28.40)	
>12 000	41 (26.45)	114 (73.55)	
Smoking habit			.045[c]
Smoker	32 (34.04)	62 (65.96)	
Non-smoker	67 (47.18)	75 (52.82)	
Experience in years			<.001[c]
<5	60 (61.86)	37 (38.14)	
⩾5	39 (28.06)	100 (71.94)	
Professional training present	30 (23.62)	97 (76.38)	<.001[c]
Presence of break time	99 (41.95)	137 (58.05)	>.999[d]
Do overtime duties	91 (40.09)	136 (59.91)	.005[d]

[a]Mean ± SD; n (%).
[b]Welch 2 aample *t*-test.
[c]Pearson's Chi-squared test.
[d]Fisher's exact test.
[e]Single includes unmarried, divorced, and widowed.

safety practices compared to non-smokers (OR 3.34, 95% CI 1.44-8.78). Those who received professional training were significantly more likely to follow good safety practices (OR 3.55, 95% CI 1.67-7.52).

The graph in Figure 2 depicts a scatterplot showing the relationship between awareness and practice scores. Safety practices showed a significant linear correlation with awareness scores among participants of this study (Pearson's $r = .71$, $P < .001$). The trend (prediction) line shows a linear positive association, indicating that practice scores increased with awareness scores. The shaded area around the line covers 1 standard deviation above and below the average of the prediction.

Discussion

With increased urbanization, a free-market economy, increased purchasing power, and decreased prices of electronic products in this post-industrial world, the demand for e-products has increased enormously with the consequent generation of a large volume of e-waste.[19] However, without proper handling, e-waste may generate toxic materials harmful to the body.[20] Hence, it is essential to have awareness among e-waste handlers about the sources and toxic potential of e-waste and its toxic potential. Moreover, the lack of proper safety practices may lead to exposure to the material through different routes and cause bodily harm to those involved in the e-waste recycling process. Therefore, we aimed to explore e-waste awareness and safety practices among a group of e-waste recycling workers in Bangladesh.

Only one-quarter of the e-waste recycling workers participating in this study had good awareness about e-waste. A similar low awareness among e-waste recycling workers was observed in Ethiopia.[14] Kumari et al[13] found that nearly 70% of electronic repair workers and 79% of scrap dealers did not know the meaning of e-waste. However, unlike them, nearly four-fifths of the participants knew the meaning of e-waste in this study. In our study, the question about awareness is asking about meaning intended to identify if the term "electronic waste" or "e-waste" was familiar to the workers. Notably, we found that many of the workers knew that they were working with wastes coming from various electronic devices but were not acquainted with those terms. We restricted the options for sources of electronic waste to the most common ones (ie, cell phones, computers, television, and refrigerators) based on the responses in the pilot study with an intention to keep the questionnaire short and convenient for the workers to respond to during their duty hours. All of the respondents were able to identify these sources as generators of electronic waste.

Our participants mainly lacked knowledge about e-waste minimization processes and e-waste-associated health problems. A concordant finding was elicited in the study by Singhal et al[21] in India, indicating that e-waste recycling workers were less conscious about the health consequences of their work. In support of this point, Ohajinwa et al[12] found that e-waste workers have a significantly lower health risk awareness score compared to their counterparts in the same informal sectors. However, compared to e-waste workers in Ethiopia,[14] our

Table 4. Multivariable logistic regression exploring factors associated with e-waste-related awareness and safety practices.

CHARACTERISTIC	AWARENESS	*P*-VALUE	SAFETY PRACTICE	*P*-VALUE
	OR[a] (95% CI)[a]		OR[a] (95% CI)[a]	
Gender		.076		.078
Male	—		—	
Female	0.18 (0.02-1.19)		0.31 (0.09-1.14)	
Education		<.001		<.001
Primary	—		—	
Secondary and higher secondary	11.6 (4.83-32.8)		6.01 (2.94-12.8)	
Monthly family income (BDT)		.751		.342
⩽12000	—		—	
>12000	1.33 (0.24-9.08)		1.84 (0.52-6.76)	
Smoking habit		.937		.005
Smoker	—		—	
Non-smoker	1.03 (0.47-2.26)		3.44 (1.44-8.78)	
Experience in years		.107		.105
<5	—		—	
⩾5	2.30 (0.83-6.62)		1.94 (0.87-4.36)	
Professional training present		.397		<.001
No	—		—	
Yes	1.52 (0.58-4.05)		3.51 (1.67-7.52)	
Do overtime duties				.051
No			—	
Yes			9.69 (0.99-226.00)	

[a]CI = confidence interval; OR = odds ratio.

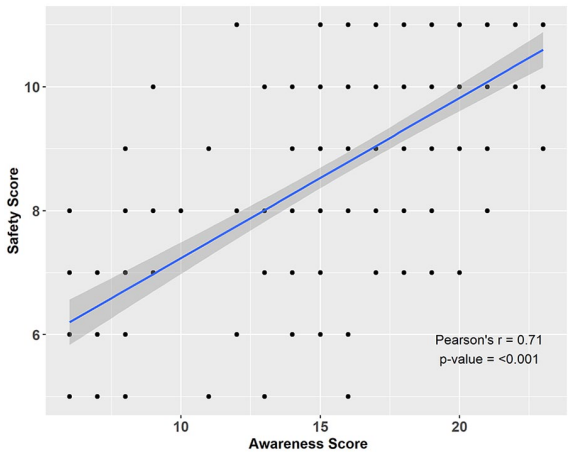

Figure 2. A scatterplot showing the association between awareness score and practice score.

respondents had a higher awareness of the health and environmental risks of e-waste. In contrast, consumers of electronic devices appeared to show a higher awareness about the hazards of e-waste,[22] which could be attributed to a higher level of education than e-waste recycling workers. However, consumers' awareness about e-waste disposal was poor compared proportionally to that of e-waste workers in our study, indicating that awareness about e-waste disposal is rather learned through doing by the workers.

We also observed that nearly half of the participants were unaware of proper e-waste disposal methods and the environmental hazards associated with e-waste. This should be a concern as environmental pollution through improper disposal may risk the health[20] of all citizens in the locality. The recruitment of relatively less educated persons and lack of proper training may explain this lower level of awareness among

e-waste workers of the company. This is supported by the fact that around half of our participants had only primary education and did not receive training.

Nearly three-fifths of the participants followed good safety practices. The major gaps in the safety practices were not using safety boots and helmets. Additionally, around one-quarter of the participants did not use masks and safety glasses. However, nearly all participants wore one or more of the personal protective equipment (PPE). In comparison, Singhal et al[21] found that only 28% of the recycling workers used PPE, and half of the participants did not use face/mouth masks. The difference could be due to increased awareness about PPE after the COVID-19 pandemic. The lack of safety practices in around one-quarter of e-waste workers in this study could be attributed to the lack of awareness and proper training of these workers during and after recruitment in the recycling center. Still, the nature of their work warrants more stringent measures to prevent bodily harm. Because, as Fischer et al[11] have shown that e-waste workers suffer work-related injuries like cuts and burns and health issues like red, itchy eyes, skin problems, and back pain significantly more often than bystanders. Promoting the use of safety boots and helmets could prevent accidental injuries to the head and foot, while masks and glasses could prevent harm to the eyes and respiratory tract. Hence, proper training should be ensured for all workers before they start their employment or immediately after they have started.

We observed that higher education was a significant determinant of good awareness and safety practices which underscore the importance of education for any occupation for that matter. Because, workers with a higher institutional education are significantly more likely to have the best safety perceptions and compliance.[23] On top of that, we found that professionally trained individuals were significantly more likely to do the safety practices than those without training. This aligns with the findings of Shoaib et al,[24] who observed that e-waste workers' knowledge, attitude, and practice regarding occupational risk mitigation can be significantly improved through training on occupational safety. Our study also found a significant correlation between e-waste workers' awareness and safety practices, which is concordant with the findings of Ohajinwa et al[12] in Nigeria.

One interesting counterintuitive observation was that smokers were significantly more likely to have good safety practices. On separate bivariate exploration, we noted that participants with longer experience and nearly all male workers were smokers. On the other hand, we found that male workers and workers with longer experience were more likely to have good safety practices. This probably explains the association between smoking and good safety practices in this study. One possible reason for the high proportion of smokers could be the perceived occupational stress experienced by e-waste workers. Occupation stress was found to affect nearly three-quarters of e-waste workers in a study in West Africa,[25] and stress is a commonly mentioned reason for smoking among people from various socio-economic strata.[26] Another reason could be low payment structures in e-waste recycling jobs in Bangladesh, with low payment being linked to smoking.[27]

We observed that slightly more than half of the participants received professional training regarding the e-waste recycling process. This could imply a large gap in the initiatives for the development of skilled workers needed in this field.

Limitations and Strengths

Our study had several limitations. Firstly, it was conducted among a small group of conveniently selected workers, which might render the findings not generalizable to all e-waste workers in the country. But, we tried to ensure the representation of e-waste recycling workers from various segments of the factory. Secondly, we had to resort to participants' responses regarding safety practices, raising the potential for information bias. However, this was one of the earliest studies to explore e-waste awareness, safety practices, and associated factors in the country. Our findings could inform relevant authorities to take necessary steps to increase awareness and safety practices, thereby reducing health risks associated with e-waste recycling processes.

Policy Implications

The study findings call for mandatory training programs on e-waste hazards and safety practices for workers, stringent occupational safety policies mandating proper use of PPE, and targeted awareness campaigns on e-waste risks and management. Furthermore, incentives should be provided for establishing formal recycling facilities that adhere to standards, incorporating e-waste topics in educational curricula, fostering multi-stakeholder collaborations, and continuous research and monitoring. Implementing these measures can significantly enhance e-waste workers' awareness, promote safer practices, mitigate health risks, and improve e-waste management in Bangladesh.

Conclusion

This study, conducted among informal e-waste recycling workers in Bangladesh, found poor awareness and inadequate safety practices related to e-waste management. Higher levels of education and provision of training were independently associated with adequate safety practices during e-waste recycling work. The companies involved in e-waste recycling should consider these factors and ensure that well-structured education and training programs should be arranged to improve awareness and safety practices among e-waste workers. The implementation of stringent occupational safety policies and monitoring of e-waste facilities is also essential to mitigate health risks by maintaining adequate safety practices among informal e-waste workers. Further studies should focus on investigating the policy and organizational level factors influencing awareness and

safety practices. Also, the environmental and health hazards that are a result of poor awareness and safety practices should be explored.

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Author Contributions

MNM conceived, designed, and conducted the study. MASK analyzed data, interpreted findings, and wrote the first draft of the manuscript. MRK, MH, and SK provided resources and reviewed the manuscript. IH designed and supervised the study and reviewed the manuscript. All authors reviewed and finalized the final draft of the manuscript.

Ethical Considerations

Ethical approval was obtained from the Institutional Review Board of the National Institute of Preventive and Social Medicine, Dhaka (Memo no: NIPSOM/IRB/2017/09). Written organizational approval and informed consent from participants were obtained. Participation was voluntary, and confidentiality was maintained. All the procedures were conducted following the updated guidelines of the Declaration of Helsinki.[28]

Declaration Regarding AI

The authors used ChatGPT (version 3.5) during the preparation of this work to enhance the language and readability of the manuscript, as the authors are not native English speakers. After utilizing the tool, the authors thoroughly reviewed and edited the content as necessary and assume full responsibility for the manuscript's content.

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Data Availability

Data is available upon reasonable request from the corresponding author.

Supplemental Material

Supplemental material for this article is available online.

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