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Impact of neck posture and insulating stick use on neck disability in Korean line workers: a cross-sectional study

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Abbreviations
CI: confidence interval; NDI: Neck Disability Index; OR: odds ratio; PHQ-2: Patient Health Questionnaire-2; QEC: Quick Exposure Check.

ABSTRACT

Background: Occupational neck disability is a prevalent issue, especially among line workers, who are often exposed to elevated levels of cervical ergonomic stress. The aim of this study was to investigate the impact of neck posture and insulating stick use on neck disability in a specific occupational group in Korea.
Methods: This cross-sectional study was conducted among 483 line workers in Gwangju and Jeonnam, Korea. Data were collected using the Neck Disability Index, Cervical Degenerative Index, and a structured questionnaire focusing on demographic and occupational factors. Logistic regression analysis was applied to determine the adjusted odds ratio (OR) and 95% confidence interval (CI) for neck posture and factors related to neck disability.
Results: Neck disability prevalence was 17.2% among the participants. Multivariate logistic regression analysis showed that factors related to neck disability included age over 60 years (adjusted OR: 3.08; 95% CI: 1.63–5.83), depression (adjusted OR: 8.33; 95% CI: 3.85–18.00), a history of cervical trauma (adjusted OR: 2.13; 95% CI: 1.04–4.40), and radiological degenerative changes in the cervical spine (adjusted OR: 2.33; 95% CI: 1.26–4.33). In particular, the adjusted OR of neck disability among live-line workers was 2.10 (95% CI: 1.12–3.92) when compared with support workers (model 1). Other analysis models showed that use of insulating sticks for more than 10 hours per week (adjusted OR: 2.46; 95% CI: 1.32–4.61) and higher neck extension (adjusted OR: 2.98; 95% CI: 1.14–3.46) were significant work-related risk factors (model 2,3).
Conclusions: Neck posture, age, depression, cervical trauma history, degenerative changes in the cervical spine, and use of insulating sticks are significant risk factors for neck disability among line workers in Korea. These findings highlight the need to improve the working environment and reduce the burden of cervical ergonomic stress among line workers.

Keywords: Neck disability; Ergonomic hazards; Musculoskeletal disorders; Line workers

BACKGROUND

Neck disability is a significant health issue affecting various populations, with implications on quality of life, functional capabilities, and psychological well-being.[1] In occupational settings, neck disability is important due to its economic impact, including direct medical

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Competing interests

The authors declare that they have no competing interests.

Author Contributions

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costs and indirect costs such as loss of productivity and compensation claims.[2] Notably individuals with professions that require repetitive movements, heavy lifting, or prolonged static postures, are at an increased risk of neck disability.[3-7]

Among them, line workers, also called linemen, powerline workers, electric utility line workers, or electric power industry workers, who are responsible for constructing and maintaining electric transmission and distribution facilities, stand out. Their occupation is notorious for its high injury and fatality rates.[8,9] These workers are exposed to unique challenges, such as working at high heights and using heavy equipment.[10] Some studies have reported high neck injury rates in this occupation due to these strenuous conditions.[11,12]

In the past, line workers handled live electricity wearing insulated gloves. This method is known for its high electric shock rate. To reduce this risk, an indirect method that involves the use of insulating sticks was proposed.[13] The stick is known by names such as high voltage hot stick, telescopic hot stick, and smart stick. Although the method has significantly led to a reduction in electric shock incidences, it has created new problems. Insulating sticks are heavy and difficult to handle, causing workers to hyperextend their cervical spine while working.

Studies on occupational risk factors of neck pain or disability have mainly been conducted among office workers[14,15] and healthcare workers.[16,17] These factors include inappropriate neck posture, long working hours, and job stress. However, research on neck pain or disability among manual workers is relatively lacking. Specifically, only a few studies have been carried out on occupations that require an upward-looking posture. Therefore, the aim of this study was to investigate the characteristics and occupational risk factors of neck disorders among Korean line workers with relatively evident cervical spine burdens. Particularly, there was a focus on the impact of using insulating sticks, reflecting recent changes in the uninterrupted technique (**Fig. 1**).

METHODS

Study design and participants

A cross-sectional design was used to investigate the association between work-related factors and neck disability among line workers in Korea. A sample of 483 line workers, representing

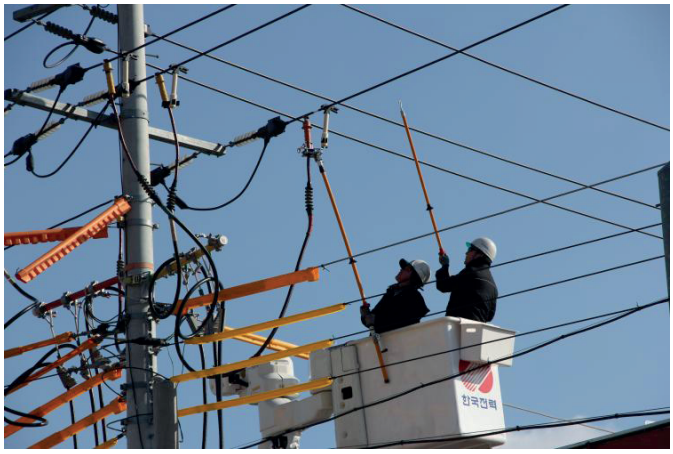

Fig. 1. Line workers (photo by Gwangju Jeonnam Construction Labor Union).

approximately 58.2% of the total membership of 830 individuals, was sourced from the Gwangju Jeonnam Construction Labor Union for this study. In addition to line workers, support workers (assistants, heavy vehicle operators, and supervisors) served as the control group for comparison. Line workers were further categorized into dead- and live-line workers to assess the impact of different work conditions on cervical ergonomic stress. Dead-line workers worked on de-energized lines, meaning electrical power is turned off during maintenance or repair activities. Conversely, live-line workers worked on energized lines, often at high heights, and used specialized equipment, such as insulating sticks or insulated aerial lifts. The dependent variable in this study was neck disability, defined as a dichotomous variable. Independent variables were divided into general factors and occupational factors. General factors included age, depression, and neck trauma history. Occupational factors included job type, insulating stick use, and neck ergonomic hazard.

Questionnaire data collection

The participants completed a questionnaire that included items related to their subjective symptoms, work history, and demographic variables (age, job type, and neck trauma history). Neck disability was quantified using the Neck Disability Index (NDI).[18] The NDI consists of 10 items measured on a 5-point Likert scale asking about neck pain and disability in daily living. The reliability and validity of the Korean version of the NDI are adequate.[19] The NDI score ranges from 0 to 50, with a score ≥ 35 indicating complete disability. In this study, neck disability was defined as scoring ≥ 15 points, which is the standard for moderate disability. Survey questions were used to evaluate intensity and frequency by applying Quick Exposure Check (QEC) list to assess ergonomic risk factors.[20] Frequency was classified as none, infrequent, frequent, and very frequent (almost continuous movement) according to the QEC D-question. Intensity was classified as not at all, mildly, moderately, and very stressful according to the QEC Q-question. Frequency and intensity of work tasks were scored on a scale of 0–3. The resultant "exposure score" was calculated by multiplying these scores, with a score ≥ 6 considered indicative of high-risk work (**Supplementary Table 1**). Depression was assessed using the Korean version of Patient Health Questionnaire-2 (PHQ-2).[21] The PHQ-2 consists of two questionnaires assessing the frequency of decreased interest and depressed mood over the past two weeks. The PHQ-2 score ranges from 0 to 6, with a score ≥ 3 indicating depression.

Physical examinations for neck disability

Physical examinations such as range of motion limitation, Spurling's test, Lhermitte's test, and tenderness of the upper trapezius, levator scapulae, and splenius capitis were performed among the participants. A positive result for range of motion limitation is indicated when asymmetry is observed in the amount of rotation, side bending, or insufficiency in the angle of flexion and extension. A positive Spurling's test result is indicated when arm symptoms are provoked with the neck in extension, lateral flexion, and axial compression.[22] A positive Lhermitte's test result is indicated when a transient electric shock-like sensation extends exclusively down the extremities due to neck flexion. Tenderness is considered positive when pressure applied with a standardized finger force of 2 kg causes pain in the affected area.[23]

Radiographic assessment

Two independent readers (A and B) evaluated the cervical radiographs of the study participants using the Picture Archiving and Communication System. The findings, as summarized in **Supplementary Table 2**, include a detailed assessment of the Cervical Degenerative Index across different cervical levels (C2-3, C3-4, C4-5, C5-6, and C6-7).[24] The

table categorizes degenerative changes as none, mild, moderate, or severe, and provides additional information on disc space narrowing, osteophyte formation, and sclerosis. In this study, a joint was considered to exhibit degenerative changes if rated as moderate or severe at any level.[25-27] The presence of one or more joints with such changes was considered indicative of degenerative change. The agreement level between the readers was evaluated using the kappa statistic (0.691) for binary classification of degenerative changes, and discrepancies were resolved through consensus.[23,24]

Statistical analysis

Data analysis was conducted using STATA version 18.0 (StataCorp, College Station, TX, USA). A χ^2 test was performed to identify the variables significantly associated with neck disability. A multiple logistic regression analysis was used to assess the association between the variables and neck disability. Three analysis results were presented according to occupational factors: job type, use of insulating sticks, neck posture factors, considering the possibility of multicollinearity between factors.

Ethics statement

This study was approved by the Institutional Review Board of Chosun University Hospital (approval No. CHOSUN 2021-07-044). This study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants, and data confidentiality was maintained throughout the study.

RESULTS

In total, 483 line workers from the Gwangju and Jeonnam Construction Labor Unions participated in this study. The participant's average age was 49.0 (standard deviation: 10.7; range: 23–72) years. The majority of the participants were live-line workers (44.9%, n = 217), followed by dead-line workers (26.1%, n = 126), assistants (13.0%, n = 63), heavy vehicle operators (9.7%, n = 47), and supervisors (6.2%, n = 30) (**Table 1**).

Regarding health history, 10.4% of the participants reported cervical trauma history, and 7.7% exhibited depressive symptoms, scoring ≥ 3 points on the PHQ-2 questionnaire. Neck ergonomic exposure revealed that 17.8% of the participants were involved in high-risk work requiring neck flexion, 52.2% in high-risk work requiring neck extension. Regarding the use of insulating sticks, 52.4% did not use them, 24.2% used them for less than 10 hours per week, and 23.4% used them for more than 10 hours per week.

Neck disability prevalence, defined by a score ≥ 15 on the NDI, was 17.2% (**Table 2**). This prevalence was highest among live-line workers (22.6%). Univariate analysis showed several factors significantly associated with neck disability, including being over 60 years of age (odds ratio [OR]: 3.05; 95% confidence interval [CI]: 1.77–5.28), having depressive symptoms (OR: 8.13; 95% CI: 4.02–16.43), and a history of cervical trauma (OR: 3.53; 95% CI: 1.88–6.63). Other significant variables included degenerative changes in the cervical spine (OR: 2.35; 95% CI: 1.36–4.07), being a live-line worker (OR: 1.56; 95% CI: 0.90–2.73), spending ≥ 10 hours per week using insulating sticks (OR: 2.12; 95% CI: 1.21–3.71), engaging in work requiring neck flexion (OR: 2.22; 95% CI: 1.28–3.83), and engaging in work requiring neck extension (OR: 2.31; 95% CI: 1.39–3.81). The multivariate analysis was organized into three models, underscoring the multifaceted nature of occupational risk factors. Model 1 revealed

Table 1. Participant characteristics by job types

Factors	Group	Support	Dead-line	Live-line	Total	*p*-value
Age	< 60	111 (79.3)	99 (78.6)	195 (89.9)	405 (83.9)	0.005
	≥ 60	29 (20.7)	27 (21.4)	22 (10.1)	78 (16.1)	
	Mean ± SD	49.3 ± 12.0	47.6 ± 12.1	49.8 ± 8.9	49.0 ± 10.7	
Career	< 10	53 (37.9)	57 (45.2)	27 (12.4)	137 (28.4)	< 0.001
	≥ 10	87 (62.1)	69 (54.8)	190 (87.6)	346 (71.6)	
	Mean ± SD	18.5 ± 13.3	18.3 ± 14.5	24.5 ± 10.2	21.1 ± 12.7	
Depression[a]	No	127 (90.7)	119 (94.4)	200 (92.2)	446 (92.3)	0.517
	Yes	13 (9.3)	7 (5.6)	17 (7.8)	37 (7.7)	
Neck trauma history	No	124 (88.6)	118 (93.7)	191 (88.0)	433 (89.6)	0.226
	Yes	16 (11.4)	8 (6.3)	26 (12.0)	50 (10.4)	
Cervical degenerative change[b]	No	115 (82.1)	105 (83.3)	180 (82.9)	400 (82.8)	0.965
	Yes	25 (17.9)	21 (16.7)	37 (17.1)	83 (17.2)	
Neck flexion[c]	Low	125 (89.3)	104 (82.5)	168 (77.4)	397 (82.2)	0.017
	High	15 (10.7)	22 (17.5)	49 (22.6)	86 (17.8)	
Neck extension[c]	Low	83 (59.3)	70 (55.6)	78 (35.9)	231 (47.8)	< 0.001
	High	57 (40.7)	56 (44.4)	139 (64.1)	252 (52.2)	
Insulating stick use/week	None	136 (97.1)	110 (87.3)	7 (3.2)	253 (52.4)	< 0.001
	< 10 hours	3 (2.1)	13 (10.3)	101 (46.5)	117 (24.2)	
	≥ 10 hours	1 (0.7)	3 (2.4)	109 (50.2)	113 (23.4)	
Neck disability[d]	No	118 (84.3)	114 (90.5)	168 (77.4)	400 (82.8)	0.007
	Yes	22 (15.7)	12 (9.5)	49 (22.6)	83 (17.2)	

Values are presented as number (%). *p*-value by χ^2 test.
SD: standard deviation.
[a]Depression: Patient Health Questionnaire-2 score 3 or higher; [b]Degenerative change: children's depression inventory score of moderate or higher in more than one cervical joint; [c]Exposure score: low—exposure score below 6, high—exposure score 6 or higher; [d]Neck disability: Neck Disability Index score moderate or higher.

Table 2. Prevalence of neck disability[a]

Factors	Group	Neck disability		*p*-value
		No	Yes	
Age	< 60	348 (85.9)	57 (14.1)	< 0.001
	≥ 60	52 (66.7)	26 (33.3)	
Career	< 10	131 (95.6)	6 (4.4)	< 0.001
	≥ 10	269 (77.8)	77 (22.2)	
Depression[b]	No	384 (86.1)	62 (13.9)	< 0.001
	Yes	16 (43.2)	21 (56.8)	
Neck trauma history	No	369 (85.2)	64 (14.8)	< 0.001
	Yes	31 (62.0)	19 (38.0)	
Cervical degenerative change[c]	No	341 (85.2)	59 (14.8)	0.002
	Yes	59 (71.1)	24 (28.9)	
Neck flexion[d]	Low	338 (85.1)	59 (14.9)	0.004
	High	62 (72.1)	24 (27.9)	
Neck extension[d]	Low	205 (88.7)	26 (11.3)	0.001
	High	195 (77.4)	57 (22.6)	
Insulating stick use/week	None	219 (86.6)	34 (13.4)	0.028
	< 10 hours	96 (82.0)	21 (18.0)	
	≥ 10 hours	85 (75.2)	28 (24.8)	

Values are presented as number (%). *p*-value by χ^2 test.
[a]Neck disability: moderate to high Neck Disability Index score; [b]Depression: Patient Health Questionnaire-2 score 3 or higher; [c]Degenerative change: children's depression inventory score of moderate or higher in more than one cervical joint; [d]Exposure score: low—exposure score below 6, high—exposure score 6 or higher.

that live-line workers had an increased risk of neck disability (adjusted OR: 2.10; 95% CI: 1.12–3.92). Model 2 showed that insulating stick use for ≥ 10 hours per week was a significant risk factor (adjusted OR: 2.46; 95% CI: 1.32–4.61). Model 3 identified high rate of work requiring neck extension as a risk factor (adjusted OR: 1.98; 95% CI: 1.14–3.46). Across these models, age ≥ 60 years (adjusted OR: 2.26; 95% CI: 1.22–4.16), depression (adjusted OR: 7.22; 95% CI: 3.36–15.51), cervical trauma history (adjusted OR: 2.37; 95% CI: 1.17–4.82), and

Table 3. Logistic regression analysis of relative factors for neck disability[a]

Factors	Group	Unadjusted OR (95% CI)	Adjusted OR (95% CI)		
			Model 1	Model 2	Model 3
Age	< 60	1	1	1	1
	≥ 60	3.05 (1.77–5.28)	**3.08 (1.63–5.83)**	**2.80 (1.49–5.26)**	**2.26 (1.22–4.16)**
Depression[b]	No	1	1	1	1
	Yes	8.13 (4.02–16.43)	**8.33 (3.85–18.00)**	**8.13 (3.80–17.40)**	**7.22 (3.36–15.51)**
Neck trauma history	No	1	1	1	1
	Yes	3.53 (1.88–6.63)	**2.13 (1.04–4.40)**	**2.34 (1.15–4.76)**	**2.37 (1.17–4.82)**
Degenerative change[c]	No	1	1	1	1
	Yes	2.35 (1.36–4.07)	**2.33 (1.26–4.33)**	**2.16 (1.17–4.01)**	**2.34 (1.27–4.33)**
Job types	Support	1	1	-	-
	Dead-line	0.57 (0.27–1.19)	0.62 (0.28–1.39)	-	-
	Live-line	1.56 (0.90–2.73)	**2.10 (1.12–3.92)**	-	-
Insulating stick use/week	None	1	-	1	-
	< 10 hours	1.41 (0.78–2.55)	-	1.73 (0.90–3.34)	-
	≥ 10 hours	2.12 (1.21–3.71)	-	**2.46 (1.32–4.61)**	-
Neck flexion work[d]	Low (< 6)	1	-	-	1
	High (≥ 6)	2.22 (1.28–3.83)	-	-	1.45 (0.77–2.72)
Neck extension work[d]	Low (< 6)	1	-	-	1
	High (≥ 6)	2.31 (1.39–3.81)	-	-	**1.98 (1.14–3.46)**

Bolds are presented as statistically significance.
OR: odds ratio; CI: confidence interval.
[a]Neck disability: moderate to high Neck Disability Index score; [b]Depression: Patient Health Questionnaire-2 score 3 or higher; [c]Degenerative change: children's depression inventory score of moderate or higher in more than one cervical joint; [d]Exposure score: low—exposure score below 6, high—exposure score 6 or higher.

degenerative changes in the cervical spine (adjusted OR: 2.34; 95% CI: 1.27–4.33) consistently showed strong correlations with neck disability (**Table 3**).

DISCUSSION

In our study, we found that neck disability prevalence was particularly high among live-line workers but lower among dead-line workers. The duration of insulating stick use showed a dose-response relationship with neck disability. Among awkward neck postures, only the extension posture showed a significant correlation. Live-line workers often use insulating sticks. As a result, both the frequency and intensity of cervical extension increased in live-line workers compared with other workers (**Supplementary Table 1**).

Several studies have been carried out regarding neck disorders among surgeons using endoscopes.[28-31] These studies serve as meaningful analogies for our research. In the past, line workers handled high voltage electric lines with insulated gloves, but recently, they have been using insulating sticks. This parallels the transition from surgeons depending on their own manual dexterity to surgeons utilizing indirect equipment. Among both line workers and surgeons, the use of indirect equipment was an independent risk factor for neck disability, even after adjusting for psychosocial stress.

Line workers have ergonomic risks similar to those of construction workers or grape growers.[3] Examples of occupations that require working with an awkward neck posture include dentistry, construction work, and farming. A study on neck disorders among dentists indicated that awkward postures and repeated movements, such as bending and twisting of the cervical spine, were related to neck disorders.[32,33] In a study on the occurrence of surgically treated cervical spondylosis in construction workers, occupational exposure to

non-neutral neck postures, working with hands above shoulders, and carrying heavy loads emerged as risk factors.[6] A study carried out to compare neck disorders among grape growers and eggplant growers suggested that neck extension movement was a risk factor.[3]

As expected, age was related to neck disability, as neck disability prevalence was higher among patients aged > 60 years than among those aged < 60 years. We hypothesized that age-related degenerative changes in the cervical spine could explain neck disability.[34,35] It is difficult to determine the severity of cervical degenerative changes in line workers compared with the general population. However, despite adjusting for degenerative changes in the cervical spine, age remained an independent factor associated with neck disability. This indicates that the effect of age cannot be explained solely by the degenerative changes in the cervical spine. Compared with the findings of Tao et al.,[34] the prevalence of moderate-to-severe degenerative changes in C5/C6 among line workers was similar to that in the general population. However, the average age of the participants in this study was 3.3 years younger than that of our study. These results suggest that cervical degenerative changes may progress more rapidly in line workers than in the general population.

In this study, depression was highly correlated with neck disabilities. This result is consistent with those of existing studies. Musculoskeletal disorders of the neck have a higher correlation with mental health than those of other parts of the body.[36-38] The strong correlation between depression and neck pain suggests an interplay between physical and psychological factors in the development of musculoskeletal disorders.[2]

When interpreting our study's findings, some caveats and limitations of this study should be considered. It is important to note that other workers sometimes use insulating sticks. This is because there are cases where dead-line and support workers replace or assist the task of live-line workers. Because cervical spine disorder rarely occurs before the age of 50 years, the number of cases was too small to compare between those younger and older than 50 years. Disability has inherent limits to objectification. Social or occupational limitations may lead to greater disability.[39] In this study, neck disability was compared with a physician's objective assessment to understand the extent to which objectivity can be achieved. As a result, when there were two or more positive findings in the physical examinations, the neck disability OR was 11.56 (95% CI: 4.65–28.74). Therefore, although the NDI is a subjective evaluation, it also showed high agreement with the objective evaluation (**Supplementary Table 3**). Time and distance constraints reduced the willingness of line workers to visit the hospital. However, since the workers visited together, it is difficult to believe that the sample disproportionately consisted of symptomatic individuals.

As this was a cross-sectional study, the ability to establish temporal relationships was limited. However, a history of neck injury, radiologically degenerative changes in the cervical spine, and recent cervical strain surgeries can be used to infer temporal sequences. The control group in our study comprised those doing support work. Support workers experience a relatively low level of cervical strain; however, the level of cervical strain may be higher than that in the general population. This indicates that the relative risk ratio in this study may have been underestimated. Additionally, the control group may have included people previously working as live-line workers. However, being healthy survivors may also have an effect.

Despite these limitations, this study is meaningful because, to our knowledge, it is the first to address the impact of insulating stick use as an occupational risk factor for neck disability among line workers.

CONCLUSIONS

This study shows that live-line workers who mainly use insulating sticks experience a high level of cervical strain and have a high neck disability prevalence. Additionally, dead-line workers, who work without insulating sticks, have a lower neck disability prevalence. Insulating sticks were introduced to reduce the risk of electric shock among workers while allowing for uninterrupted techniques. However, the use of insulating sticks can cause neck disabilities among workers. Uninterrupted techniques in electrical maintenance allow continued electricity use for citizens but can negatively impact the safety and health of line workers.

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SUPPLEMENTARY MATERIALS

Supplementary Table 1
Neck exposure score by job type

Supplementary Table 2
Cervical degenerative index

Supplementary Table 3
Logistic regression analysis of neck disability with positive physical exam count

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