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Comparison of wrist range of motion and muscle strength in assembly workers with and without lateral epicondylitis

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Abstract.
BACKGROUND: Lateral epicondylitis (LE), also called tennis elbow, is a common musculoskeletal disorder that causes pain in the elbow area and is highly prevalent in assembly workers who repeatedly move their wrists.
OBJECTIVE: The purpose of this study was to compare the wrist ROM and muscle strength of assembly workers with and without LE.
METHODS: Forty-five male assembly line workers (23 with LE) participated in the study. Participants had their wrist range of motion (flexion, extension, ulnar deviation, and radial deviation) and strength (wrist flexors, extensors, and hand grip) measured using Smart KEMA sensors.
RESULTS: Workers with LE showed significantly reduced wrist extension and radial deviation ROM compared to workers without LE, with no significant differences in wrist flexion and ulnar deviation ROM between groups. Workers with LE had significantly lower wrist extensor strength compared to workers without LE, and there was no significant difference in wrist flexor and grip strength between the two groups.
CONCLUSIONS: For workers with LE, the difference in wrist ROM and muscle strength will be useful for planning intervention and evaluating treatment outcomes for assembly workers with LE.

Keywords: Lateral epicondylitis, musculoskeletal disease, range of motion, muscle strength, occupational health

1. Introduction

Excessive use of the wrist extensor muscles leads to inflammation or irritation of the extensor tendon, causing lateral epicondylitis (LE) or tennis elbow [1]. LE is one of the most common musculoskeletal disorders of the upper extremity, occurs at similar rates in men and women, and is more common in people over 40 years of age [2]. The incidence rate of LE is estimated to be 0.7–4% in the general population [3]. Also, the incidence of LE among workers performing specific activities was found to be 6.3 to 12.2% [4–6].

Factors that can cause LE have been well established in terms of psychological, physical, and social

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aspects [5, 7]. Psychological stress was reported to have a significant relationship with LE, and the odds ratio was 4.5, indicating that psychological stress can increase the risk of developing LE by 4.5 times [8]. Furthermore, occupation-related manual tasks were associated with the risk of developing LE with an odds ratio of 3.1 [7]. The relationship between physical factors in the work environment and the incidence of LE has been clearly explained through previous studies [5, 7, 9]. Working activities that require strong force can increase the risk of developing LE [9, 10]. Also, high repetitions of specific activities and working in poor posture, especially with an awkward elbow or wrist, can further increase the risk of developing LE [7, 9, 10].

It has been reported that not only occupational factors but also individual physical characteristics may influence the onset of LE. A theoretical study indicates that weakening of the individual's muscle strength could cause the onset of LE [11]. Alizadehkhaiyat et al. reported a decrease in wrist extensor muscle strength in patients with LE and in those who recovered from LE through rehabilitation programs compared with that in the control individuals [12]. Also, it has been reported that a high level of muscle activity in the wrist extensor muscles is required to produce high grip strength [13]. When performing a strong grip using the distal finger flexor muscles, the wrist position must be maintained through the action of the extensor carpi longus and brevis muscles [14]. This weakness of the wrist extensor muscles can lead to a weakening of grip strength [14]. Dorf et al. reported that the affected side of LE had a reduced gripping force compared to the healthy side [15]. In addition, it was found that the 8% difference in grip strength between flexion and extension is 83% accurate in distinguishing between the LE side and the sound side [15]. Therefore, grip strength has generally been used to quantify the progression of LE or indicate the degree of symptom relief [15, 16].

Blanchette and Normand observed changes in the level of symptoms of LE using the patient-rated tennis elbow evaluation and visual analogue scale and changes in wrist muscle strength after taking a rest for 6 weeks without intervention in patients with LE [17]. Symptoms and pain improved after 6 weeks, and the grip strength with the wrist extension improved compared to the baseline muscle strength [17]. However, there were no significant changes in the strength of wrist extensor and flexor muscles, and no significant changes were observed even when compared to the healthy side [17]. Also, Yilmaz et al. applied the neuro-mobilization technique to subjects with LE and reported that pain was reduced but there was no change in wrist strength [18]. In addition, other than wrist strength, there are few studies comparing individual characteristics such as wrist range of motion (ROM) in flexion, extension, radial deviation, and ulnar deviation, which are likely to be related to LE. Tosti et al. reported that patients with LE generally have normal wrist ROM, but in some cases, such as intra-articular loose bodies and chondral lesions, they may have limited wrist ROM [19]. Lucado et al. compared the joint ROM of the upper extremities, including the wrist, in tennis players with and without LE and found differences in wrist flexion but no differences in extension, ulnar, or radial deviation [20].

As such, the relationship between individual physical characteristics such as wrist ROM and muscle strength and the onset or symptom relief of LE is still unclear. Additionally, no studies have simultaneously compared wrist ROM and strength in individuals with and without LE. Therefore, it would first be necessary to compare both wrist ROM and strength between subjects with and without LE. Furthermore, there have been no studies comparing differences in wrist ROM and strength according to LE in assembly workers who use their wrists more intensively compared to LE patients who are likely to have variations in the frequency of wrist use or patients with LE due to sports activities with high involvement of other joints. Therefore, the purpose of this study was to compare the wrist ROM and muscle strength of assembly workers with and without LE. Specifically, we aimed to comparatively analyze wrist ROM, including flexion, extension, radial and ulnar deviation, and wrist strength, including flexion, extension, and hand grip, in workers with and without LE. We hypothesized that workers with LE would exhibit reduced range of flexion, extension, and radial and ulnar deviation compared to workers without LE, and that workers with LE would also exhibit reduced flexor, extensor, and hand grip strength compared to workers without LE. We thus expected workers with LE to have more pronounced deficits in both wrist ROM and muscle strength than in those without LE. Although previous studies have highlighted deficits in wrist ROM and muscle strength in individuals with LE, they did not measure these deficits in workers participating in recurrent wrist activities. Therefore, this study provides important data for the development of ergonomic designs and rehabilitation programs to mitigate this risk by identifying and

quantifying wrist ROM and muscle strength deficits in workers engaged in tasks requiring recurrent wrist involvement.

2. Methods

2.1. Subjects

This cross-sectional study assessed workers from a company in the automotive supply industry that manufactures and assembles automobile parts. The sample size was calculated using G*Power 3.1 software (G*Power Software Inc., Kiel, Germany). A total of 42 subjects were calculated using an effect size of 0.41, a value of 0.05, and a power of 0.8 through the pilot study. Participants were recruited from the largest automotive parts assembly company in the community, with approximately 1,000 workers. Within the company, workers are divided into two shifts (morning-afternoon and night shifts) and perform 9 h of assembly line work per day, including 1 h of rest. A total of 45 male assembly line workers participated in this study (23 workers with LE and 22 workers without LE), with three workers added in case of dropouts from the calculated sample size. All participants were informed about the risks and benefits associated with this study and signed an informed consent form. The inclusion criteria for workers with LE were: 1) pain on the lateral epicondyle; 2) persisting pain for more than 3 months; 3) pain when performing wrist extension for resistance (Cozen's test); 4) pain during passive wrist flexion (Mill's test); and 5) pain during elbow extension with wrist flexion [21, 22]. Workers with injuries to the elbow, medial epicondylitis, radial tunnel syndrome, history of fractures, intraarticular disease, neurological symptoms, and carpal tunnel syndrome were excluded. Workers who did not meet the inclusion criteria for diagnosis of LE were assigned to the control group as workers without LE. This study was approved by the Yonsei University Mirae Institutional Review Board (approval number: 1041849-202102-BM-030-02).

2.2. Data collection procedure

Data were collected by a physical therapist with over 5 years of experience. The examiner who collected the data was blinded to the purposes and hypotheses of the study. All participants were familiarized with the testing protocol before data collection. All participants were measured for ROM, including wrist flexion, extension, radial deviation, ulnar deviation, and strength, including wrist flexor, extensor, and hand grip. The wrist ROM and strength were measured using the Smart KEMA motion and strength sensors (Smart KEMA system, KOREATECH Co., Ltd., Seoul, Korea). The instruments used in this study have been previously evaluated for reliability. In a previous study, the Smart KEMA motion sensor demonstrated high levels of intra- and inter-rater reliability, with intraclass correlation coefficients (ICCs) ranging from 0.95 to 0.99. The sensor for assessing strength also showed good reliability with ICCs ranging from 0.75 to 0.99 [23]. While one examiner performed the measurements, another recorded the data from the sensor transmitted to the tablet in real time. All wrist ROM measurement data were expressed in degrees, and the strength measurement data were expressed in kilograms. The average strength was recorded with the tablet application and normalized to the subject's body weight (strength/body weight * 100).

2.2.1. Measurement of range of motion

The ROM of the wrist was measured with the upper arm and forearm resting on a table with the shoulder flexed to 90 degrees. With forearm pronation and all fingers flexed, the metacarpals were parallel in the sagittal plane to the radial and ulnar bones to keep the wrist joint neutral. The 3rd metacarpal was parallel in the horizontal plane to the radial and ulnar bones to keep the carpal joint neutral. The sensor for measuring the angle was attached to the dorsal part of the hand. Then, the subjects performed wrist flexion, extension, radial deviation, and ulnar deviation motions, respectively, and the ROM was measured (Fig. 1). During the motion, the middle part of the forearm was fixed by the examiner to prevent movement of the forearm and upper arm while the wrist performed the motions.

2.2.2. Measurement of strength

The flexor strength measurement posture was the same as the ROM measurement posture except for the forearm supination, and the extensor strength measurement posture was the same as the ROM measurement posture. The sensor for measuring muscle strength was connected between the ground and the hand with a strap. Then, the subjects performed wrist flexion and extension, respectively, and muscle strength was measured (Fig. 2). Throughout the measurement process, the examiner immobilized the middle part of the forearm to restrict movement of



Fig. 1. Measurement of range of motion.



Fig. 2. Measurement of strength.

the forearm and upper arm while the wrist performed the measurements. Grip strength was measured in the same posture as the above postures, except that the forearm was maintained in a neutral position. Grip strength was measured using a hand-held dynamometer with a handle (Fig. 2). Moreover, throughout the measurement process, the examiner immobilized the middle part of the forearm to restrict movement of the forearm and upper arm while the wrist performed the measurements.

2.3. Statistics analysis

All measurement data were tested for normal distribution using the Shapiro–Wilk test, and assumptions for parametric testing were verified using Levene's test for equal variance. Age, body weight, height, and body mass index (BMI) were analyzed using independent *t*-tests to determine differences in the demographic characteristics of workers with and without LE. Box's M test was used to assess

Table 1
Demographic characteristics of the participants

	Total	Workers with LE ($n = 23$)	Workers without LE ($n = 22$)	p-value
Age	46.93 ± 7.38	45.35 ± 6.41	48.59 ± 8.08	0.145
Weight	72.12 ± 9.53	73.30 ± 9.76	70.89 ± 9.35	0.401
Height	170.77 ± 5.09	172.00 ± 4.73	169.48 ± 5.23	0.097
BMI	24.70 ± 2.76	24.77 ± 3.07	24.62 ± 2.46	0.858

*Significant at $\alpha = .05$. LE = Lateral epicondylitis. BMI = body mass index.

Table 2
Comparison of wrist ROM between the two groups

	Mean ± SD (°)		Effect Size (Cohen's d)	p-value
	Workers with LE ($n = 23$)	Workers without LE ($n = 22$)		
Flexion	69.29 ± 6.21	71.95 ± 5.53	0.452	0.159
Extension	57.52 ± 7.56	64.82 ± 3.30	1.241	<0.001*
Radial deviation	17.65 ± 3.58	25.59 ± 3.27	2.310	<0.001*
Ulnar deviation	30.92 ± 4.01	29.45 ± 3.21	0.403	0.182

*Significant at $\alpha = .05$. LE = Lateral epicondylitis.

Table 3
Comparison of wrist strength between the two groups

	Mean ± SD $\left(\mathrm{kg/BW^{-1}}\right)$		Effect Size (Cohen's d)	p-value
	Workers with LE ($n = 23$)	Workers without LE ($n = 22$)		
Grip	46.78 ± 12.11	52.28 ± 9.64	0.502	0.138
Flexion	17.38 ± 5.04	20.23 ± 3.41	0.660	0.055
Extension	16.11 ± 4.62	19.42 ± 4.37	0.733	0.042*

*Significant at $\alpha = .05$. LE = Lateral epicondylitis. BW = Body weight.

homogeneity of variance, as multivariate analysis of variance (MANOVA) assumes homogeneity of variance. MANOVA analysis was conducted to compare the ROM flexion, extension, and radial and ulnar deviation and flexor, extensor, and hand grip strength between both groups. After performing MANOVA, post-hoc tests were conducted using a false discovery rate of 0.05, with Benjamini–Hochberg adjustment for p-values to minimize Type I errors during multiple comparisons. All analyses were conducted using Python version 3.10.12 (Python Software Foundation) with the SciPy version 1.10.1 library and the statsmodels version 0.14.0 package.

3. Results

Table 1 displays the demographic characteristics of the participants divided into workers with and without LE. There were no significant differences in age ($p = 0.145$), weight ($p = 0.401$), height ($p = 0.097$), or BMI ($p = 0.858$) between the two groups.

The results of MANOVA revealed statistically significant differences in wrist ROM and muscle strength depending on LE, $F(7, 37) = 11.680$, $p < 0.001$, Wilk's $\Lambda = 0.312$, partial $\eta 2 = 0.214$.

The results of post-hoc tests showed that workers with LE had significantly reduced wrist extension ROM ($p < 0.001$) and significantly reduced radial deviation ROM ($p < 0.001$) compared to workers without LE (Table 2). However, there was no significant difference in wrist flexion ROM between workers with and without LE ($p = 0.159$). Additionally, there was no significant difference in wrist ulnar deviation ROM between workers with and without LE ($p = 0.182$).

Workers with LE exhibited significantly reduced wrist extensor strength ($p = 0.042$) compared to workers without LE (Table 3). However, no significant difference was observed in wrist flexor strength ($p = 0.055$) and grip strength ($p = 0.138$) between workers with and without LE.

4. Discussion

The purpose of this study was to compare wrist ROM and muscle strength between assembly line

workers who primarily perform manual tasks with and without LE. We hypothesized that workers with LE would exhibit deficits in range of wrist flexion, extension, and radial and ulnar deviation and flexor, extensor, and handgrip strength compared to workers without LE. However, our findings showed that assembly workers with LE had differences in some wrist ROM and muscle strength compared to assembly workers without LE. Assembly workers with LE showed no difference in wrist ROM in the two directions (flexion, ulnar deviation) compared to assembly workers without LE but showed a lower ROM in the other two directions (extension, radial deviation). Regarding muscle strength, assembly workers with LE had no significant difference in grip strength compared to assembly workers without LE, but wrist flexor and extensor strength were significantly lower.

The joints that make up the wrist are classified as elliptical joints, which are biaxial joints, and the movement of the wrist has two degrees of freedom [14]. Typically, wrist flexion ROM occurs about 10 to 15 degrees more than extension, and ulnar deviation occurs about 15 to 20 degrees more than radial deviation [14]. In daily life, most wrist movements combine components from each plane of movement, where flexion often accompanies ulnar deviation and extension often accompanies radial deviation [14, 24]. It is noteworthy that workers with LE had significantly lower extension and radial deviation, which are components of combined movements that typically occur at the wrist and indicate smaller ROM in each plane of wrist motion, than workers without LE. The results might have varied based on the wrist posture and movements within the assembly workers' work environments. Hagg et al. compared workstations experiencing either high or low frequencies of pain or symptoms in the hand or forearm [25]. They found that workstations with a higher frequency of pain or symptoms required longer maintenance times for ulnar deviation posture [25]. In addition, it was said that ulnar deviation limits wrist flexion and extension movements while performing tasks [25]. Klum et al. collected normative wrist-related data from subjects engaged in various occupational activities [26]. Among these, employees engaged in jobs involving high manual strain were found to have significantly lower flexion and extension ROM [26]. In our study, comparing workers with and without LE, we found limitations in wrist extension ROM, but no increased ulnar deviation was observed. The workers in this study mainly moved automobile parts or assembled parts using hands or tools. the parts handled by workers were relatively heavy and required strong force when assembled, so the muscles around the wrist would have been relatively prone to becoming stiff. These workers likely developed LE due to extensor overload while performing primarily grasping movements, along with limitations in extension movements due to stiff surrounding muscles. In addition, the assembly line task likely contributed to the observed limitations in range of wrist extension and radial deviation. For example, when a right-handed worker fastens an automobile part, the worker's right hand turns the part to the right; this is a task that primarily involves wrist flexion and ulnar deviation. Consequently, opportunities for wrist extension and radial deviation movements may have been relatively limited during these tasks. The above process may have been more intense for workers who had a relatively high load to cause LE. Moreover, as damage to the tendons of the wrist extensor muscles causes LE, it's possible that limitations arose because workers experienced difficulty performing wrist extension movements due to pain.

Pain accompanying LE, caused by irritation of the wrist extensor tendons, inevitably leads to a decrease in extensor strength [19]. Persistent and chronic pain due to LE can gradually weaken wrist extensor strength in patients with LE and restrict their ability to perform daily activities [27]. Our results showed expected significant differences in wrist extensor muscle strength between workers with and without LE. This decrease in wrist extensor muscle strength due to pain caused by LE may impede assembly work activities. However, studies on wrist flexor strength have mainly been conducted on medial epicondylitis caused by irritation of the wrist flexor tendons, so there have been relatively few studies on wrist flexor strength in LE patients [28]. Pienimäki et al. reported that in patients with LE, wrist flexion peak torque on the affected side was reduced by 13% compared to the normal side [27]. Dolibog et al. reported that patients with LE patients exhibited significantly lower wrist flexor strength (6.8 ± 3.4 kg) than normal patients (9.9 ± 3.5 kg) [29]. Reduction in grip strength is a common symptom in LE patients and has been reported to occur as a secondary problem of pain [30, 31]. Dorf et al. reported that the grip strength of LE patients in the elbow extension position was 50% lower than that of normal subjects [15]. However, unlike previous studies, in this study there was no significant difference in grip strength between workers

with and without LE. The grip strength of patients with LE is measured using pain-free grip strength and maximum grip strength [32–34]. Since both grip strength measurements showed a high level of reproducibility, both seemed to be able to be used as indicators of the condition of LE patients or progress after treatment [33]. However, it was said that there is a possibility that the maximum grip strength measurement results may vary due to bias depending on the therapist's verbal instructions [35]. Therefore, our findings may not show differences in grip strength between workers with and without LE. However, according to a recent study by Rostamzadeh et al., the average grip strength of manual workers was 52.70 kg, and that of office employees was 47.30 kg, showing a significant difference [36]. In our study, the average grip strength of normal workers was 52.28 kg and that of workers with LE was 46.78 kg, but there was no significant difference due to the relatively large standard deviation. Therefore, although there was no significant difference, the possibility that workers with LE have lower grip strength than workers without LE cannot be completely ruled out.

Our study enriches the existing literature by delineating specific deficits in range of motion (ROM) among workers with LE, particularly highlighting substantial limitations in wrist extension and radial deviation. These results confirm and extend previous research, which generally emphasizes overall ROM impairments without distinguishing their impact on specific movements. Previous studies frequently report a reduction in overall wrist ROM in individuals with LE but seldom address how specific movements, such as extension and radial deviation, which are essential for manual tasks in assembly work, are uniquely affected. By demonstrating these specific directional impairments, our findings provide more nuanced understanding of the relevant literature. They emphasize that the biomechanical demands of certain occupations, especially those requiring repetitive wrist motions, may intensify specific aspects of LE-related impairments. This insight is crucial for developing targeted rehabilitation strategies to precisely address these movement limitations and potentially improve occupational health outcomes.

This study has several limitations. First, the subjects who participated in this study were all male assembly line workers, so the results of this study cannot be generalized to other occupational groups such as office workers, and the results of this study cannot be generalized to women, children, or the elderly. Second, although this study compared the differences in wrist ROM and muscle strength between workers with and without LE with a cross-sectional research design, it cannot explain the causal relationship between the factors that showed differences and LE. Third, this study did not describe confounding variables such as individual differences in tasks, ergonomic factors, or lifestyle habits that may affect wrist ROM, muscle strength, and LE development. Fourth, although this study used validated measurement tools to assess wrist ROM and muscle strength, inherent limitations or biases may have been associated with these measurements. In future studies, participant demographics should be diversified to include various occupational groups, ages, and genders, and longitudinal studies should be conducted to explore the causal relationships. In addition, comprehensively evaluating and controlling the confounding factors such as working posture and motion and continuously verifying and improving measurement techniques for wrist ROM and muscle strength evaluation is necessary. Future studies should provide stronger evidence for preventive strategies and interventions for LE.

5. Conclusion

Assembly workers with LE had lower wrist extension and radial deviation ROM and lower wrist flexor and extensor muscle strength compared with workers without LE. However, despite the decreased wrist extensor strength in workers with LE, there was no difference in grip strength compared with workers without LE. The results of this study may help us understand the physical characteristics, such as reduced ROM and muscle strength, for certain wrist movements in assembly workers with LE. These findings could be used for LE prevention and rehabilitation interventions in occupational environments. In this study, the observed loss of wrist ROM or strength associated with LE could provide a basis for development of rehabilitation exercise programs aimed at rehabilitating workers with LE and potentially reducing the risk of developing LE or worsening of symptoms. This study's findings could also be useful for planning prevention and rehabilitation exercise programs for workers with LE, and could help evaluate specific treatments for efficacy.

Ethical approval

This study was approved by the Yonsei University Mirae institutional review board (Approval Number: 1041849-202102-BM-030-02).

Informed consent

Informed consent was obtained from all participants before being included in the study.

Conflict of interest

The authors declare that they have no conflict of interest.

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