Lateral Epicondylitis:

Pathophysiology and Risk Factors

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1.0 Introduction

Lateral epicondylitis, also referred to as tennis elbow, is a degenerative tendinopathy of the extensor tendon at the lateral epicondyle of the humerus. Typical symptoms include lateral elbow pain, pain with wrist extension, and weakened grip strength [1]. Repetitive loading on the extensor tendon is likely the cause of the condition. Lateral epicondylitis has a prevalence of 1 to 3% in the general population.

2.0 Objectives

This review explores pathophysiology and risk factors for lateral epicondylitis. In particular, it focusses on physical work factors that may contribute to this condition. As a secondary outcome, non-occupational risk factors for this condition were considered.

3.0 Anatomy and Pathophysiology of lateral epicondylitis

3.1 Muscle Groups

Lateral Epicondylitis affects the extensor tendon located in the outer elbow region. This condition involves the muscles in the forearm, the humerus, and the tendon attaching them. There are several muscles that extend along the forearm, connecting the hand and wrist to the humerus. These muscles are the extensor muscles, consisting of the extensor carpi radialis longus, extensor carpi radialis brevis, extensor digitorum communis, extensor carpi ulnaris, and the extensor digiti minimi [2]. These muscles can be seen connecting the hand and wrist to the humerus in Figure 1. The origin and insertion of each extensor muscle is identified in Table 1.

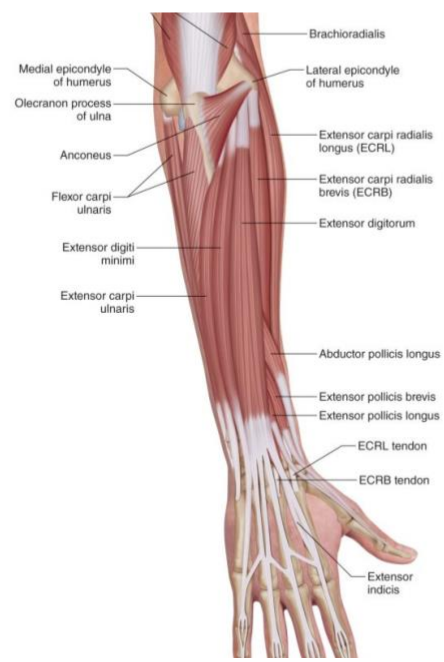

Figure 1: Anatomy of the left forearm.

Table 1: Summary of the origin and insertion points of each extensor muscle in the forearm.

Muscle	Origin	Insertion
Extensor carpi radialis longus	Lateral supracondylar ridge of humerus	Posterior base of 2^{nd} metacarpal
Extensor carpi radialis brevis	Lateral epicondyle	Posterior base of 3^{rd} metacarpal
Extensor digitorum communis	Lateral epicondyle	Extensor expansion of the 2^{nd} to 5^{th} digits
Extensor carpi ulnaris	Lateral epicondyle	Base of 5^{th} metacarpal
Extensor digiti minimi	Lateral epicondyle	Extensor expansion of 5^{th} digit

These muscles are in the superficial layer of the posterior forearm and share a general function of allowing for extension of the wrist and hand [3]. Specifically, each extensor muscle has a function, all controlled by the radial nerve. These functions are summarized in Table 2.

Table 2: A summary of the functions of each extensor muscle.

Muscle	Function
Extensor carpi radialis longus and brevis	Extend (backwards movement) and abduct (radial deviation) the wrist
Extensor digitorum communis	Extends the medial four fingers
Extensor carpi ulnaris	Extends and abducts the wrist
Extensor digiti minimi	Extends the pinky finger and plays a part in wrist extension

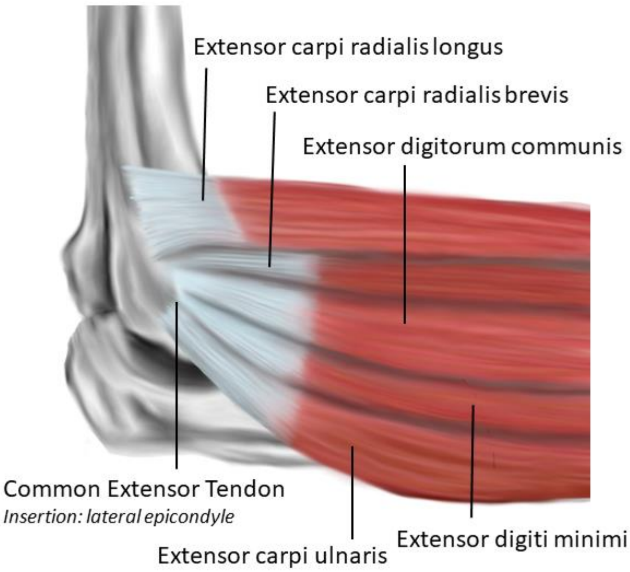

Figure 2: Anatomy of the lateral elbow. Demonstrates the extensor muscles and the extensor tendon attachment at the humerus.

These superficial muscles of the forearm are separated from the deep muscles by a layer of fascia, a thin layer of connective tissue [3]. The extensor muscles are activated by any tasks causing movement (extension or deviation) of the wrist and fingers such as lifting objects.

The extensor muscles all join to attach to the humerus via the extensor tendon. The region on the bone that is in contact with the extensor tendon is the lateral epicondyle, a prominence at the distal end of the humerus. In Figure 2, the various extensor muscles can be seen attached to the extensor tendon at the lateral epicondyle site on the humerus. The extensor tendon allows for the use of the extensor muscles as previously described. The lateral epicondyle is a small prominence that is curved forward to allow for the connection to many muscles in the forearm including the extensor muscles via the extensor tendon.

3.2 Tendons

Lateral Epicondylitis is a condition that affects the extensor tendon. Therefore, the biological structure of the tendon must be observed to understand what is physically occurring in the development degradation and tearing. Tendons are composed of tenoblasts and tenocytes located in a network of extracellular matrix [4]. As tenoblasts age, they elongate and become tenocytes. Tenocytes have a lower metabolic activity, meaning they reproduce less and do not maintain their structure or respond to environmental changes as well [4]. At the bone attachment site, 5-10% of the cellular structure of the tendon is composed of chondrocytes [4]. Tendons consume 7.5 times less oxygen than skeletal muscles and therefore have a lower metabolic rate [4]. This allows for increased tension loading capacity; however, it also result in slower healing after injury [4].

The sites of attachment between tendons and bone are called entheses [5]. They are composed of fibrous and fibrocartilaginous tissue [5].

3.2.1 Tendon Structure

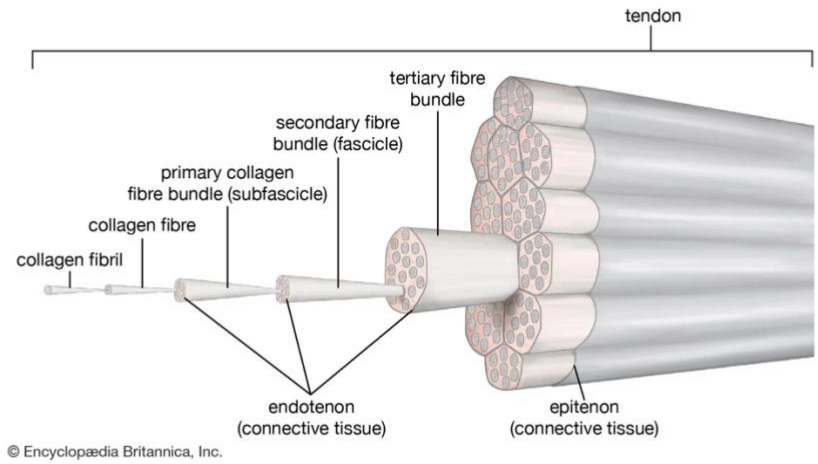

Figure 3: A breakdown of the tendon structure. [6]

Tendon structure is mainly composed of collagen, with its basic unit being collagen fibrils [6]. There are three categories of collagen fibre bundles, primary (subfascicles), secondary (fascicles), and tertiary [7]. In a healthy tendon, the collagen fibres are highly ordered [8]. This structure can be seen in **Error! Reference source not found.**.

3.3 Pathophysiology

To understand which factors cause lateral epicondylitis, the physical processes that occur to produce the syndrome must be observed. Lateral epicondylitis is a degenerative enthesopathy, meaning it involves the degeneration of the cells at the origin of the extensor tendon at the lateral epicondyle [5]. The degeneration of the tendon is observed microscopically as the disruption of collagen fibres and disorganized repair [5].

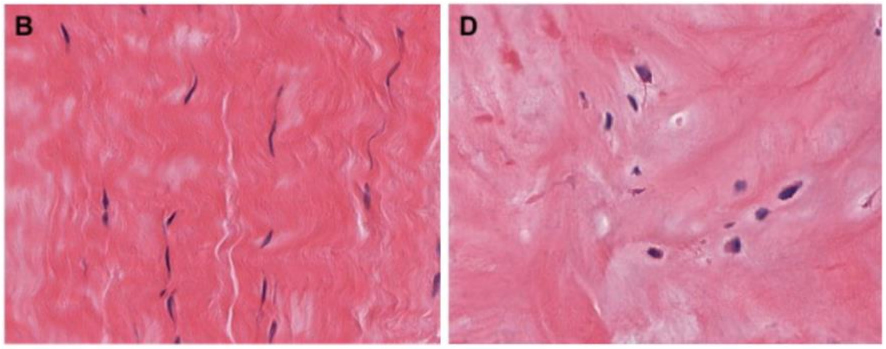

Figure 4: Samples of extensor tendon from two patients with clinical diagnoses of lateral epicondylitis. (B) Demonstrates a slightly degraded collagen structure with minimal tears in a patient with mild lateral epicondylitis. (D) Demonstrates severely degraded collagen structure with prominent tears in a patient with severe lateral epicondylitis. [9]

The disruption of the collagen fibres can be seen in Figure 4. Collagen structure in healthy tendons is ordered and parallel, whereas the structure in mild and severe lateral epicondylitis has increasing disruption and disorganization [9]. It is hypothesized that the disruption of the collagen structure is a result of increased rate of apoptosis in the extensor tendon [9]. Apoptosis refers to the orchestrated process of cell death [10]. As the tendon is repetitively loaded, the healing process is inhibited by the elevated apoptosis rate, leading to severe disruption of collagen structure [9]. It is still unknown why there is an elevated rate of apoptosis during this stage in the tendon [9].

The degeneration of the extensor tendon is called angiofibroblastic tendinosis [11]. This type of degeneration refers to the weakening of the tendon due to reduced blood flow and damage of the fibers in the tendon [12]. Due to vascular deprivation, healing may be reduced or will not occur in the tendon. Degeneration also results in the generation of angiofibroblastic tissue. This abnormal tissue disrupts the tendon fibers [13]. The difference in healthy tendon fibres and tendon fibers with angiofibroblastic tissue present can be observed in Figure 5. This process is caused by overuse of the tendon through activation of the extensor muscles in the forearm [13].

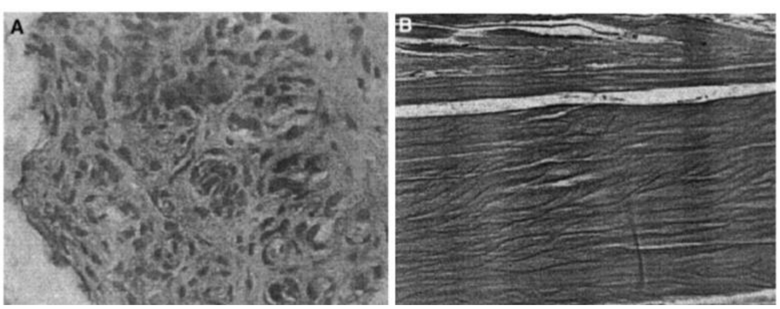

Figure 5: Tendon samples demonstrating healthy tendon fibers (Figure B) and tendon fibers disturbed by angiofibroblastic tissue (Figure A). [13]

4.0 Epidemiology

Lateral epicondylitis affects between 1% and 3% of the population with a larger prevalence in individuals aged 35 to 55 [14]. The annual incidence of lateral epicondylitis is 0.4%-0.7% [15]. No definite cause has been identified for lateral epicondylitis; however, it is likely a result of a combination of repetitive and forceful activities of the upper extremities [16].

The purpose of this paper is to investigate and identify occupational risk factors of lateral epicondylitis. Various studies will be reviewed to determine which workplace exposures are most correlated with the condition. In general, it is established that work activities involving repetitive use of the forearm extensors has been associated with the condition [14]. The effects of other possible risk factors will be reviewed as well, such as age, smoking, obesity, and other health conditions.

4.1 Methods of Literature Review

Medical databases (Pubmed, Embase, NIOSHTIC) were searched for studies examining lateral epicondylitis and occupation. The references of these studies were considered. A number of review, cohort, cross-sectional and case-control studies were identified.

An attempt was made to do a meta-analysis to explore biomechanical factors that would contribute to risk of epicondylitis. However, the broad variety of outcomes being measured by individual studies made it difficult to accumulate ample number of studies to produce meaningful summary statistics. Thus meta-analytic methods were abandoned in favour of narrative review.

4.2 Literature Review of Observational Studies

Literature review identified primary studies on lateral epicondylitis and occupation. Of these, the majority were of cohort or cross-sectional design. Of observational study methodologies, cohort analysis is generally more robust than case-control design. However, three notable case-control studies were included in this review. While case-control methodology is fraught with a number of biases, these three studies explicitly considered work-relatedness and thus were included. Note that it is likely that other case-control studies exist but were not included in this review as work-relatedness was not the focus of their design.

Barrero et al [17] conducted a cross-sectional study of 158 flower industry workers. The population included males (27.5%) and females (72.5%) from eight flower manufacturing companies in Columbia. Several work tasks were identified within the companies, such as cutting, classification, bunching, and combined activities. The study aimed to identify mechanical exposures that were associated with upper-extremity disorders and to use the results to derive preventative measures. A prevalence of 15.2% was found for medial or lateral epicondylitis. The prevalence by task was highest in those who perform cutting tasks (22.2%), followed by bunching tasks (9.5%), combined tasks (7.0%), and classification tasks (3.8%). The author concluded that the prevalence of upper-extremity disorders was high among Columbian flower industry workers which can be attributed to the high mechanical demands of the tasks performed by this group. There was no comparison group as this study provided only descriptive statistics on predictors and biomechanics of work.

Chiang et al [18] performed a cross-sectional study of 207 fish-processing workers in Taiwan. The study consisted of a questionnaire and clinical examination conducted by an occupational physician. The workers were classified by three categories. Group I, low repetitiveness and low forceful movement of upper limbs; Group II, high repetitiveness, or highly forceful movement of upper limbs; and Group III, high repetitiveness as well as high forceful movement of upper limbs. Overall, epicondylitis was diagnosed in 15.0% of the 207 workers. When comparing the prevalence of epicondylitis amongst the three classifications of workers, group I had 9.8%, group II had 15.3%, and group III had 17.9%. The author concluded that the correlation between epicondylitis and repetitive and strenuous manual work was not significant compared to other upper-extremity disorders. The author attributes this result to the nature of epicondylitis being more inhibiting than other UPDs which may result in more sick leave of affected workers.

Descatha et al [19] conducted a cohort study on 699 newly employed workers in St. Louis, USA in manufacturing, construction, biotechnology, and healthcare. The study consisted of a baseline questionnaire regarding personal information and physical work exposures. The outcome of lateral epicondylitis was observed at 36 months based on physical examination. At 36 months, 4.9% of the subjects had lateral epicondylitis. It was observed that workers who bent their wrist for greater than 4 hours per day were more likely to have developed lateral epicondylitis than those who did so for less than 1 hour per day or not at all (OR=4.4, CI=95% 1.5, 13.1). Rotation for more than 4 hours per day compared to less than 1 hour per day also had association with lateral epicondylitis (OR=2.7, 95% CI 1.2, 6.2). Workers who did a combination of bending for more than 4 hours per day and rotating for more than 2 hours per day were more likely to have the condition (OR=3.0, 95% CI 1.4, 6.1). There was no association with gripping. Body Mass Index also had an effect on the development of lateral epicondylitis, with those with a BMI greater than 30 kg/m^2 being more likely to have the condition (OR = 2.4, 95% CI 1.2, 4.8). Other factors were not found to have any significant association with developing the condition, such as gender and lack of social support. The presence of underlying medical disorders (diabetes, rheumatic arthritis, or osteoarthritis) was of significance (OR = 2.9, (95% CI = 1.0-8.9) and education level was of borderline significance. The authors concluded that work activities involving repetitive and extensive movements of the wrist and forearm were associated with lateral epicondylitis.

Dimberg et al [20] conducted a cross-sectional study of 546 workers in the manufacturing industry in Sweden. The goal of this study was to observe the prevalence of lateral epicondylitis and its relation to certain work-related factors. The study consisted of a questionnaire regarding elbow symptoms as well as demographic information. Workers who reported elbow pain were assessed by a physician. Overall, the prevalence of lateral epicondylitis was 7.4%. It was observed that 70% of the workers with lateral epicondylitis were verified to have over-exertion of the extensor muscles due to gripping and twisting. The condition was more common in white collar versus blue collar workers although this was not statistically significant. The author concluded that in 35%, the condition was caused by work-related activities, in 8% by playing tennis, in 27% by other leisure activities, and in 30% no cause was found. The author concluded that over-exertion of extensor muscles due to gripping and rotating is related to lateral epicondylitis.

Fan, Bao et al [21] performed a prospective cohort study on 607 workers in manufacturing and healthcare facilities in Washington state, USA. The workers were assessed for lateral epicondylitis after 3.5 years by physical examination and were interviewed on workplace physical exposures and personal information. There were 57 incident cases for an incidence of 10.6% over 2+ months. Increasing strain index (SI) at work was associated with increasing risk of lateral epicondylitis (HR = 2, 95% CI = 1.13-3.54). This association was true for a number of SI parameters. Regarding non-physical factors, increasing age, female gender and general poor health were correlated with lateral epicondylitis.

Fan, Silverstein et al [22] published a cross-sectional study on the same 733 workers at 12 Washington worksites. Thirty-eight (5.2%) had lateral epicondylitis. Regarding physical factors, they identified "frequency of forceful exertion (5 vs. <1 times/min (OR 5.17, 95%CI 1.78–15.02)) and forearm supination at 45° for 5% of the time with high lifting force (OR = 2.98, 95% CI 1.18–7.55) were significant physical load factors". They found significant associations with female gender, age (36 to 50 year old category) and low social support at work. Smoking was of borderline significance.

Garg et al [23] conducted a cohort study of 536 workers from 10 manufacturing facilities in Wisconsin, USA. The manufacturing facilities included poultry processing, assembly of animal laboratory testing equipment, and manufacturing of automotive parts. A baseline questionnaire and physical examination was used to collect demographic information. The outcome of lateral epicondylitis was assessed after 6 years to observe the relation to personal information such as age, gender, medical history, psychosocial factors, smoking, alcohol consumption, etc. Fifty-six workers developed lateral epicondylitis over 6 years of study. Workers with diabetes were more likely to have lateral epicondylitis (HR=2.6, 95% CI 1.05-6.61). Additionally, those who identified as often/always feeling depressed vs never were more likely to have the condition (HR=2.5, 95 CI 1.09-5.59). Those who identified as having family problems also had a higher prevalence of lateral epicondylitis (HR=2.9, 95% CI 1.16-7.18). The study used a strain index to classify the level of exertion of job activities. A greater strain index was associated with lateral epicondylitis (HR=2.6, 95% CI 1.26-5.28). Poor posture was not associated with the condition, nor was duration of work. Speed of work was of borderline significance (HR = 2.5, 95% CI = 0.77-7.88). The author concluded that increased strain index, as well as certain psychosocial factors are associated with lateral epicondylitis. Increasing age was associated with lateral epicondylitis. Female gender was slightly more affected although of non-statistical significance. There was a trend toward smoking association (OR = 1.7, 95% CI = 0.91 -3.07). Additionally, it was concluded that medical conditions such as hypertension, cholesterol, osteoarthritis and rheumatoid arthritis, and non-work-related hobbies were not associated with lateral epicondylitis. Swimming was associated with lateral epicondylitis.

Haahr et al [24] published a case-control study of 267 new cases of lateral epicondylitis and 388 control subjects in Ringkjoebing County, Denmark. A questionnaire was used to collect data including age, gender, education background, current health, as well as physical work exposure factors such as profession, duration of employment, and average working hours per week. The profession of each subject was classified as strenuous or not strenuous based on the author's occupational health experience. It was found that those with a profession classified as strenuous were associated with having lateral epicondylitis (OR=3.1, 95% CI 1.9-5.1). Among women, repetitive work tasks (OR=2.6, 95% CI 1.4-4.7), increasing time working with arms lifted in front of the body (OR=4.0, 95% CI 2.0-8.3), and working with hands bent or twisted (OR=7.4, 95% CI 2.9-18.7) were all associated with lateral epicondylitis. Among men, some association with these factors was also found although of less severity. Working with handheld vibrating tools for ¼ to ½ of time (OR=2.9, 95% CI 1.3-6.3), working with arms lifted in front of the body for ¼ to ½ of time (OR=2.7, 95% CI 1.3-5.5), and work demanding precision (OR= 5.2, 95% CI 1.5-17.9) showed association. Additionally, poor social support was a significant factor among women, however the same was not found in men. The author concluded that lateral epicondylitis is related to physical workplace factors as well as low social support at work among women. Furthermore, the author relates lateral epicondylitis to activities involving the combination of force, posture, and repetition.

Herquelot et al [25] conducted a cohort study of 1046 workers in the Loire Valley district of France. The outcome of lateral epicondylitis was observed after 5 years. Physical examinations were conducted to diagnose epicondylitis in workers who reported elbow pain. Several workplace exposures were observed such as repetition, physical exertion combined with elbow movements, and physical exertion. The annual incidence rate of lateral epicondylitis in women was 0.9 in 100 workers and 1.0 in 100 for men. Among women, workers with highly repetitive tasks (IRR=2.3, 95% CI 1.1-4.9 were more likely to have lateral epicondylitis, however this factor was not significantly associated in men. The association with age was not significant. High physical exertion combined with elbow movements was an associated risk factor (IRR=2.9, 95% CI 1.4-5.9). The author concluded that physical exertion combined with elbow movement as well as repetitive movements have an effect on lateral epicondylitis in the workplace.

Leclerc et al [26] published a cohort study of 598 workers in manufacturing, clothing and shoe industry, food industry, food packaging, and cashiering over 3 years. The goal of this study was to observe the relationship between workplace exposures and the outcome of lateral epicondylitis as well as carpal tunnel syndrome and wrist tendinitis. The exposures included biomechanical constraints, psychosocial factors, and personal factors. The biomechanical factor observed was the “turn and screw” motion. Those who performed this motion in their profession were more likely to have lateral epicondylitis (OR=2.07, 95% CI 1.16-3.70). Additionally, age was associated with the condition, with those greater than 40 years old being more likely to have lateral epicondylitis (OR=3.40, 95% CI 1.24-9.32). Other factors such as gender and depressive symptoms had no significant association with the condition. The author concluded that the “turn and screw” motion was associated with lateral epicondylitis and that this result was expected based on other studies.

Ono et al [27] conducted a cross-sectional study of 209 nursery school cooks compared to 366 control workers in Japan. The occupation of cook was classified as having forceful and highly repetitive tasks, whereas the control workers were not exposed to occasionally forceful and non-repetitive tasks. A questionnaire was used to collect data on age, sex, self-estimated workload, and duration of employment. Clinical examinations were performed to assess prevalence of lateral epicondylitis. The study aimed to investigate the relationship between workplace exposures such as forceful and repetitive tasks and lateral epicondylitis. It was found that the cooks were 4.7 times more likely to have lateral epicondylitis compared to the control workers (OR=4.7, 95% CI 2.2-9.7). Among all of the workers (cooks and controls included), there was no significant association of age or body mass index with the condition. The author concludes that the higher prevalence of lateral epicondylitis in nursery school cooks is attributed to the forceful and repetitive nature of their workplace exposures.

Park et al [28] published a cross-sectional study of 937 agricultural workers in Korea. The study aimed to determine the relationship between various demographic, physical, and social factors with lateral epicondylitis. Overall, 26.1% of the workers had lateral epicondylitis. The factors that were associated with lateral epicondylitis were the following: female sex (OR=2.36, 95% CI 1.74-3.20), dominant-side involvement (OR=3.83, 95% CI 2.72-5.41), manual labor (OR=2.78, 95% CI 1.87-4.13), ipsilateral rotator cuff tear (OR=2.97, 95% CI 2.19-4.03), and hypertriglyceridemia (OR=1.41, 95% CI 1.03-1.95). No significant association was found for factors such as age, smoking, alcohol intake, or diabetes. The author concluded that lateral epicondylitis is significantly associated with female sex, dominant-side involvement, manual labor, and ipsilateral rotator cuff tear. The author mentions that these factors are all commonly associated with lateral epicondylitis in literature, with the exception of female sex.

Pullopdissakul et al [29] conducted a cross-sectional study of 591 electronic appliance assembly factory workers in Bangkok, Thailand. A questionnaire was used to collect demographic data and workplace ergonomic factors as well as a clinical examination to assess upper-extremity disorders. Several ergonomic risk factors were considered in relation to lateral epicondylitis such as repetitive motion, high force/excessive physical effort, awkward posture (reaching, twisting, bending, working overhead, keeping fixed positions), and contact stress. In the entire group, the prevalence of lateral epicondylitis was 3.38% (95% CI 1.92-4.85). This study found no significant association with any of the physical exposures although there was a trend towards significance for contact stress. Significant non-physical factors included lower education and BMI. There was no association with gender, smoking or age.

Roto et al [30] published a cross-sectional study on 90 workers in the meat cutting industry and 77 control workers from the construction industry in Tampere, Finland. The goal of the study was to determine the prevalence of epicondylitis among meat-processing workers and determine possible workplace exposures that are associated with the condition. The controls were construction foremen and were chosen as they were not exposed to repetitive movements of the upper extremities. Among meatcutters, the occurrence of epicondylitis increased with age, with 6% of those aged 31-40 years affected, 11% of those aged 41-50 years affected, and 25% of those aged 51-65 years affected. Whereas the occurrence of epicondylitis was 0% in all age categories among controls. The author concludes that meat cutting workers are exposed to repetitive and forceful activities whereas construction foremen are not, therefore these physical factors are associated with lateral epicondylitis.

Tajika et al [31] published a cross-sectional study of 422 residents of a mountain village in Japan. A questionnaire was used to collect information on gender, weight, height, dominant hand, heaviness of labour, smoking, and drinking. This study aimed to determine risk factors for lateral epicondylitis in a mountain village. Among the entire group, the prevalence of lateral epicondylitis was 3.8% (85% CI 2.2-6.1). This study found no significant association with any of the risk factors collected in the questionnaire. Notably, there was no significant association to lateral epicondylitis of heaviness of labour, gender, age, or smoking. The author concludes that many of the findings in this study were contrary to other studies, however, it has been concluded in various studies that gender is not associated with lateral epicondylitis, which is consistent with this study's findings.

Titchener et al [32] conducted a case-control study of 4998 patients with lateral epicondylitis, and 4998 controls matched by age, sex, and general practice in the United Kingdom. The goal of this study was to determine and quantify the contributions of several risk factors to lateral epicondylitis in the general population. The authors used The Health Improvement Network database to collect demographic data on all of the subjects, including body mass index, alcohol consumption, and smoking habits. The study found that ex-smokers were more prevalent among the diseased group (OR=1.20, 95% CI 1.06-1.36). Additionally, oral steroid use (OR=1.68, 95% CI 1.47-1.92), rotator cuff pathology (OR=4.95, 95% CI 3.64-6.71), and carpel tunnel (OR=1.50, 95% CI 1.14-1.98) were all associated with lateral epicondylitis. BMI, alcohol usage, diabetes, and arthritis were not found to be associated with lateral epicondylitis. The author concluded that rotator cuff pathology, carpal tunnel syndrome, oral steroid use, and history of smoking are risk factors for lateral epicondylitis. The author speculated that the rotator cuff pathology association could be attributed to dysfunction causing eccentric movements of the hand and forearm, which could result in lateral epicondylitis.

Juntura et al [33] published a cross-sectional study on 102 meatcutters, 125 sausage makers, 150 packers, and 332 control workers not exposed to strenuous tasks. The study was conducted in a meat-processing factory in Finland. The goal of this study was to observe the association of strenuous workplace exposures in the meat industry to epicondylitis. A standardized questionnaire and clinical examinations were used to collect data from the subjects. The meatcutters, sausage makers, and packers were exposed to strenuous tasks. Meatcutters were exposed to tasks requiring precision, highly forceful movements, and high speed. Sausage makers were exposed to tasks requiring precision and repetition. Packers were exposed to highly repetitive and low-force tasks. Epicondylitis was more prevalent among those with strenuous jobs than nonstrenuous jobs. Among women, age ($P<0.001$) and duration of time in current occupation ($P<0.01$) was associated with lateral epicondylitis. The author concluded that strenuous workplace exposures were significantly associated with epicondylitis.

Walker-Bone et al [34] published a cross-sectional study on 6038 adults aged 25-64 from a variety of professions and socioeconomic backgrounds. The goal of the study was to determine prevalence of epicondylitis in relation to age, sex, and occupational risk factors. A questionnaire was used to collect demographic data, psychosocial factors, as well as mechanical workplace exposures such as repetitive movements or wrist or fingers, bending/straightening of elbow, use of vibrating tools, working with arms above shoulder height, and carrying weights on one shoulder. A prevalence of lateral epicondylitis of 0.7% was found in women and 0.8% in men.

The highest prevalence rate was found in subjects aged 45-54 in both genders. Lateral epicondylitis was found to be significantly associated with psychological distress (OR=4.5, 95% CI 2.1-9.5) and manual work (OR=3.8, 95% CI 1.8-7.9). Additionally, a significant association was found with bending/straightening of the elbow for greater than 1 hour per day (OR=2.5, 95% CI 1.2-5.5). Other workplace exposures such as keyboard use, working with arms above shoulder height, and use of vibrating tools were not significantly associated with lateral epicondylitis. Smoking status, body mass index, and diabetes were not significantly associated with lateral epicondylitis. The author concludes that repetitive motions of the elbow are related to lateral epicondylitis.

Wolf et al [35] conducted a cohort study from 1998-2006 on the U.S. Military to determine incidence rates and risk factors for lateral epicondylitis. Overall, an incidence rate of 3 per 1000 person-years was found in this study. It was found that lateral epicondylitis was significantly associated with gender, with males being the referent group (RR=1.22, 95% CI 1.19-1.26). Age was also significantly associated with the condition when comparing those greater than 40 years of age to those less than 20 years of age (RR=19.79, 95% CI 18.08-21.65). The author concluded that age and gender were associated with lateral epicondylitis. The author mentions that their finding of gender association was not consistent with other studies, whereas age was associated in other literature.

Hegmann et al [36] published a cross-sectional study of 1824 workers in manufacturing, food processing, and office jobs in the United States. This study aimed to determine cardiovascular risk factors of lateral epicondylitis. The study found a significant association with female sex and lateral epicondylitis (OR=1.72, 95% CI 1.15-2.58). The study used a scoring system called Framingham score to classify each worker based on their cardiovascular disease risk factors. The odds ratio for lateral epicondylitis increased as Framingham score increased, with a peak of OR=3.61 (95% CI 2.02-6.47). The author concluded that lateral epicondylitis may have pathophysiological bases in cardiovascular disease risk.

Aben et al [37] conducted a case-control study on 69 patients with lateral epicondylitis and 100 controls. The subjects included workers from construction, cleaning, office, warehouse, factory, nurse, and mechanic industries in Belgium. A questionnaire was used to collect information on the psychological profile of the patients, this included perfectionism, anxiety, depression, and work satisfaction. It was found that patients with lateral epicondylitis scored significantly lower on agreeableness than the controls (P=0.036). Additionally, affected patients scored higher on anxiety (P=0.047), depression (P=0.024), workload (P=0.03), repetitive work (0.031), and perfectionism (P=0.021). The author concludes that workplace environment as well as doctor-patient relationships are important as psychological factors seem to be associated with lateral epicondylitis.

Bao et al [38] conducted a cross-sectional study of 1834 workers in manufacturing, food processing, healthcare, and office industries in the United States. This study aimed to observe relationships between workplace factors and lateral epicondylitis. The workplace factors included job rotation, overtime work, having a second job, and work pacing. It was found that overtime work was associated with a lower risk of lateral epicondylitis. No significant association was found for any other workplace factors. The author concluded that the workplace factors studied were not associated with lateral epicondylitis, which is generally contrary to other studies.

Thiese et al [39] published a cross-sectional study on 1824 subjects in the United States. This study aimed to observe the relationship between psychosocial factors and lateral epicondylitis. Those who often or always felt physically exhausted after work were more likely to have lateral epicondylitis (OR=7.04, 95% CI 2.02-24.51). Further, those who felt mentally exhausted after work were also more likely to have lateral epicondylitis (OR=6.24, 95% CI 3.00-12.98). Job dissatisfaction was also associated with lateral epicondylitis (OR=2.33, 95% CI 1.31-4.14). The author concluded that certain psychosocial workplace exposures are significantly associated with lateral epicondylitis which persisted after adjustment for demographics and physical exposures.

Nordander et al [40] looked at musculoskeletal issues in those with repetitive/constrained work and compared them to those with varied/mobile work. The study considered 7320 females and

1241 males in Sweden. They found that repetitive/constrained work was related to lateral epicondylitis in females (OR = 1.9, 95% CI = 1.0-3.8) but not males (OR = 1.0, 95% CI = 0.3-2.8).

Bovenzi et al [41] published a cross-sectional study on 65 vibration-exposed forestry workers comparing them to 31 controls in Italy. They found that epicondylitis was significantly more common in the forestry workers (OR = 5.9, p< 0.012). Higher vibration scores (>7.5 m/s2 vs < 7.5m/s2) were associated with epicondylitis (p< 0.005).

Bystrom et al [42] published a cross-sectional study on 199 automotive workers in Sweden. They found no reported cases of epicondylitis.

Hansson et al [43] examined upper limb disorders in a group of 95 women with repetitive industrial work in a cross-sectional study. They found no cases of lateral epicondylitis in this group. Elbow pain was more common in the industrial group compared to non-exposed controls (OR = 1.8, 95% CI = 0.4-9.0).

In summary of this literature, it is apparent that a number of studies examined the role work may play in contributing to lateral epicondylitis. Given that this matter is largely considered by observational studies, methodological consideration necessitates important context of the results. Cohorts were rather disparate providing good generalizability to a range of occupations and societies. Specific identification of precise causal biomechanical factors would be ideal. However, there is no consensus on exposure metrics across these cohorts. Studies measured many exposure measures varying from broad, subjective characterizations such as job title (e.g. “flower cutter”) to specific, quantifiable measures such as degrees of wrist motion. This makes it difficult to accurately quantify physical factors that may contribute to risk of enthesopathy. Fortunately, outcome measures do not suffer from the same methodological vagueness. An outcome of lateral epicondylitis is likely robustly measured whether by subjective or objective means.

Recognizing these methodological limitations, general consideration of this epidemiology insinuates a consistent albeit non-quantifiable association between physical work factors and lateral epicondylitis. Table 3 of Appendix provides a general summary of the study outcomes and possible associations with lateral epicondylitis. Some common potential risk factors that were studied in the articles were repetitive tasks, forceful movement, wrist bending and rotating, gripping, arms lifted in front of body, use of vibrating tools, tasks requiring precision, strenuous tasks, manual work, and bending of the elbow. *Among these exposures, highly repetitive tasks, wrist movement, gripping and strenuous/forceful tasks were consistently associated with lateral epicondylitis.* Other factors were inconclusive, with some studies demonstrating association and others not. These factors are biomechanically consistent with the pathophysiology of the forearm musculature. The repetitive use of extensor forearm muscles in the workplace is a risk factor for lateral epicondylitis. Wrist rotation also activates the extensor muscles and therefore the findings are plausible.

Beyond physical work factors, other risk factors for lateral epicondylitis become apparent from this literature (Table 4 of Appendix). *Increasing age, female gender and increasing BMI are associated with lateral epicondylitis.* Some studies infer associations with diabetes and smoking, but this is not consistent.

Work stress measures correlate with lateral epicondylitis. While there is a vast array of quantifications of work stress, low job satisfaction and other metrics seem to be associated with this condition.

4.3 Review articles

Bretschneider et al [44] published a systematic review and meta-analysis on work-relatedness of lateral epicondylitis. Their goal was to consider physical factors in prospective cohort studies. This review considered data from 5 studies (Descatha, Fan/Bao, Fan/Silverstein, Garg, Harquelot). Meta-analysis for each outcome was limited to 2 studies each, making meta-analytic technique quite restricted. Nevertheless these authors identified that forearm rotation (OR = 1.85, 95% CI = 1.10-3.10) and strain index (OR = 1.75, 95% CI = 1.11-2.78) is associated with lateral epicondylitis. Wrist flexion/extension was associated with lateral epicondylitis but of borderline statistical significance (OR = 1.61, 95% CI = 0.47-5.52). There was no association with gripping or repetitive movements. Note that the results of this review strongly relied on the positive findings from the Descatha study.

Curti et al [45] published a systematic review on elbow tendinopathy and “occupational biomechanical overload”. They considered studies that based the diagnosis on physical examination and exposure was based on direct analysis. As a result they considered 4 studies (Fan, Garg, Barrero, Chiang). Upon narrative review, these authors concluded that “there is limited evidence of a causal relationship between occupational exposure to biomechanical risk factors and lateral elbow tendinopathy”. They advocate for further research on the matter.

Descatha et al [46] published a meta-analysis on lateral epicondylitis and physical exposures at work. They considered only prospective studies, identify 5 papers that were relevant to their inclusion criteria (Leclerc, Descatha, Herquelot, Fan, Garg). This paper used meta-analytic technique to extract one outcome measure labeled “combined biomechanic exposure involving the wrist and/or elbow and occurrence of lateral epicondylitis”. Using this vague composite, the authors produced an overall summary statistic from data from the 5 studies of meta-OR = 2.6, 95% CI = 1.9-3.5). They conclude that “biomechanic exposure involving the wrist and/or elbow at work might indeed cause lateral epicondylitis”.

Seidel et al [47] published a systematic review on physical risk factors and work. They considered 10 studies (Fan 2009, Fan 2014, Herquelot 2013a, Herquelot 2013b, Descatha, Svendsen 2012, Nordander 2009, Walker-Bone 2012, Nordander 2013 and Spahn 2016). For their outcome, they considered 5 main exposure categories (force, repetition, posture/movement, vibration and combined exposures). They seemed to consider a number of univariate evaluations of metrics under each of these 5 categories labeling them as being “significant” or “non-significant”. Much focus seemed to be on method quality and the authors suggest that their work would be useful to develop further research on the matter.

Van Rijn et al [48] looked at work factors and elbow disorders in a systematic review. For lateral epicondylitis, they considered work by Shiri, Ono, Hansson, Haahr, Descatha, Chiang and Ritz. In their narrative reporting, they describe associations with force, repetition, hand-arm vibration, posture, combined forces and psychosocial factors. The authors described limitations owing the large heterogeneity of exposure metrics. Nevertheless, they conclude, “frequent handling of loads, highly repetitive movements and forceful work were associated with the occurrence of lateral epicondylitis”.

Shiri et al [49] reviewed risk factors for lateral and medial epicondylitis. They suggest that physical load factors at work contribute to risk of lateral epicondylitis. Specifically, they found that physical job titles, forceful activities, high repetition and awkward postures related to epicondylitis. However, results were not completely consistent. These authors found that low social support at work and low job control may contribute to risk. Females seemed more affected than males.

In consideration of these review articles, it is evident that there are significant limitations in quantitative review synthesis of lateral epicondylitis data. In particular, studies use disparate exposure metrics, making generalization of biomechanical factors very problematic. These review articles considered few articles, largely limited by their focused inclusion criteria. Thus from a general perspective, these reviews provide helpful perspectives but are far from precise in providing a quantifiable (or even strongly qualifiable) estimate on the issue of work-relatedness of lateral epicondylitis. Published meta-analyses on the matter should be reviewed with caution and this topic should be restricted to systematic review and *not* meta-analysis due to methodologic limitations of the current literature.

5.0 Conclusion

Lateral epicondylitis is an enthesopathy of the extensor muscles of the forearm. It is a common condition with an estimated prevalence of up to 3% of the adult population. Given its commonality and the relative futility of treatment, it is vital to understand causative risk factors of lateral epicondylitis in order to enact preventive strategies.

Pathophysiological consideration implicates physical strain on musculotendonis structures of the condylar origin of the forearm extensors. Repetitive loading causes disruption of normal linear tendon architecture impairing tensile properties of the tendon. There also appears to be vascular dysfunction leading to possible ischemia. The combination of these physical and vascular impairments leads to angiofibroblastic tendinosis with tendon disorganization and disrepair.

Review of the literature identifies epidemiology examining lateral epicondylitis in occupational cohorts. From a methodologic perspective, there is considerable variability in this observational literature particularly with respect to exposure metrics. That is, few studies reported on the same biomechanical exposure. This makes it difficult to quantify or even qualify exact ergonomics in contributing to risk.

Recognizing the limitations of this literature, there appears to be consistent association between physical factors and lateral epicondylitis. In particular, **highly repetitive tasks, gripping, strenuous/forceful tasks, and wrist movement is related to lateral epicondylitis.** These associations by theoretical consideration of the biomechanics of the upper extremity. It is ergonomically plausible than repeated and forceful activation of extensor musculature in gripping and rotation may contribute to lateral epicondylitis.

Besides physical risk factors, increasing age, female gender and increasing BMI seem to be associated with lateral epicondylitis. As well work stress measures correlate with this condition.

The current state of the literature does not allow quantitative (i.e. numerical) resolution of the precise mechanical factors that may contribute to risk. Although meta-analyses have been conducted on the issue, the heterogeneity of the data, particularly exposure metrics, is not amenable to data pooling. Further research using refined and consistent exposure measures would help clarify ergonomic risk factors.

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Appendix

Table 3: Summary of occupational exposures and their association with lateral epicondylitis.

Study	Occupational risk factors	Significant association
Barrero et al (2013)	cutting tasks	+
	bunching tasks	+
Chiang et al (1993)	high repetitiveness and high forceful movement	-
Descatha et al (2013)	wrist bending >4 hours per day	+
	wrist rotation >4 hours per day	+
	combination of wrist rotation and bending >2 hours per day	+
	gripping	-
Dimberg et al (1987)	gripping	+
	wrist rotation	+
Fan, Bao et al (2014b)	Strain index	+
Fan, Silverstein et al (2014b)	frequency	+
	supination + lifting	+
	gripping	-
	manual handling	-
Garg et al (2014)	high strain index	+
	Poor wrist posture	-
	Speed of work	+/-
	Duration of work	-
Haahr et al (2003)	strenuous profession	+
	repetitive work tasks	+
	increased time with arms lifted in front of body	+
	working with hands bent or twisted	+
	working with handheld vibrating tools	+
	work demanding precision	+
	Work requiring force	+
Herquelot et al (2013)	highly repetitive tasks	+
	high physical exertion combined with elbow movements	+
Leclerc et al (2001)	turn and screw motion	+
Ono et al (1998)	forceful and repetitive tasks	+
Park et al (2021)	dominant-side involvement	+
	manual labour	+

Pullopdissakul et al (2013)	repetitive motion	-
	high force/excessive physical effort	-
	awkward posture (reaching, twisting, bending, working overheard, keeping fixed positions)	-
	contact stress	+/-
Roto et al (1984)	repetitive and forceful activities	+
Tajika et al (2014)	heaviness of labour	-
Juntura et al (1991)	Strenuous tasks	+
Walker-Bone et al (2012)	manual work	+
	bending/straightening of elbow >1 hour per day	+
	keyboard use	-
	working with arms above shoulder height	-
	use of vibrating tools	-
Aben et al (2018)	increased workload	+
	repetitive work	+
Bao et al (2016)	job rotation	-
	less overtime work	+
Nordander et al (2009)	Repetitive/constrained work	+
Bovenzi et al (1991)	Forestry work	+
	Vibration	+
Bystrom et al (1995)	Assembly line work	-
Hansson et al (2000)	Physical work	-

Table 4: Summary of other risk factors and exposures and their association with lateral epicondylitis.

Study	Other risk factors	Significant association
Descatha et al (2013)	BMI > 30 kg/m^2	+
	gender	-
	education level	+/-
	lack of social support	-
	Underlying medical disorder (diabetes, OA)	+
Fan, Bao et al (2014a)	Age	+
	Gender	+
	General poor health	+
	Smoking	-
	Low job satisfaction	+
	Job support	-
	Job demands	-
Fan et al (2014b)	age	+
	gender	+
	Smoker	+
	Lack of social support	-
	Job satisfaction	-
	Job demands	-
Garg et al (2014)	diabetes	+
	depression	+
	family problems	+
	smoking	+/-
	arthritis	-
	Gender	-
	Job satisfaction	+/-
Haahr et al (2003)	poor social support (among women)	+
	poor social support (among men)	-
	Gender	-
	Age	-
	Increasing BMI	+/-
	Lower education	+
Herquelot et al (2013)	age	-
	Low social support	-
Leclerc et al (2001)	age >40 years old	+
	gender	-

	depressive symptoms	+/-
Ono et al (1998)	age	-
	BMI	-
Park et al (2021)	age	-
	smoking	-
	alcohol intake	-
	diabetes	-
	female sex	+
	ipsilateral rotator cuff tear	+
	hypertriglyceridemia	+
Pullopdissakul et al (2013)	Gender	-
	Age	-
	Lower education	+
	Smoking	-
	Increasing BMI	+
Roto et al (1984)	increased age	+
Tajika et al (2014)	gender	-
	age	-
	weight	-
	height	-
	dominant hand	-
	smoking	-
	drinking	+/-
Titchener et al (2013)	smoking	+
	oral steroid use	+
	rotator cuff pathology	+
	carpal tunnel	+
	Trigger finger	+
	Carpal tunnel syndrome	+
	Increasing BMI	+
	alcohol intake	-
	diabetes	-
	arthritis	-
Juntura et al (1991)	Age	+
Walker-Bone et al (2012)	psychological distress	+
	Smoking	-
	Diabetes	-

Wolf et al (2010)	female sex	+
	age >40 years	+
Hegman et al (2017)	female sex	+
	increased Framingham score (cardiovascular disease risk)	+
Aben et al (2018)	decreased agreeableness	+
	increased anxiety	+
	depression	+
	perfectionism	+
Bao et al (2016)	having a second job	-
	work pacing	-
Thiese et al (2016)	physical exhaustion after work	+
	mental exhaustion after work	+
	job dissatisfaction	+