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Scapholunate interosseous ligament dysfunction as a source of elbow pain syndromes: Possible mechanisms and implications for hand surgeons and therapists

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ABSTRACT

Elbow pain syndromes are common upper extremity musculoskeletal disorders, and they are usually associated with repetitive occupational exposure. Ligaments are often one of the sources of musculoskeletal disorders because of their mechanical and neurological properties. The wrist ligaments are some of the ligaments most vulnerable to occupational exposure. Since most occupational tasks require wrist extension for handling tools and loading, the scapholunate interosseous ligament (SLIL) bears greater strain during loading, which results in creep deformation and hysteresis. Ligamentous creep may result in diminished ability to detect signal changes during joint movements, which impairs neuromuscular control established by ligamentomuscular reflex arcs elicited from mechanoreceptors in the ligaments. Changes in muscle activation patterns of forearm muscles due to diminished ligamentomuscular reflexes may initiate a positive feedback loop, leading to musculoskeletal pain syndromes. The relationship between elbow pain syndromes and SLIL injury will be presented through two hypotheses and relevant pain mechanisms: 1. Repetitive tasks may cause creep deformation of the SLIL, which then impairs ligamentomuscular reflexes, leading to elbow pain disorders. 2. Lateral epicondylalgia may increase the risk of SLIL injury through the compensation of the lower extensor carpi radialis muscle activity by higher extensor carpi ulnaris muscle activity, which may alter carpal kinematics, leading to SLIL degeneration over time. The differential diagnosis is usually complicated in musculoskeletal pain disorders. The failure of treatment methods is one of the issues of concern for many researchers. A key element in developing treatment strategies is to understand the source of the disorder and the nature of the injury. We proposed that the differential diagnosis include SLIL injuries when describing elbow pain syndromes, particularly, lateral epicondylalgia.

Introduction

Upper extremity musculoskeletal disorders (UEMSD) are common among working-age adults [1–6]. Elbow disorders had the third-highest incidence rate in the US [7]. Several disorders can give rise to elbow pain, but the most frequently seen musculoskeletal pain syndromes are epicondylalgia (lateral and medial). Those at high risk include musicians, athletes, dentists, and computer users [8]. The underlying mechanisms of UEMSD usually include physical workplace factors, such as repetitive and forceful wrist movements or prolonged abnormal postures, as well as working long hours [4,9–19]. The differential diagnosis is usually complicated in elbow disorders. As many cases are misdiagnosed, problems associated with the disorder persist even after many attempts at treatment. A key element in developing treatment strategies for UEMSD is to understand the source of the disorder and the nature of the injury.

Because of their unique mechanical and neurological properties, ligaments are frequently the source of musculoskeletal disorders, which has been discussed in recent studies [20–23]. Wrist ligaments are some of the ligaments most vulnerable to occupational exposure [24]. It has been reported that the position of wrist extension places greater strain on the dorsal scapholunate interosseous ligament (SLIL), consistent with the predominant injury mechanism of SLIL [25]. Repetitive occupational exposure is associated with upper extremity musculoskeletal problems [8,26,27]. Recent studies have investigated the effects of different loading patterns in which repetitive occupational exposure has been shown to impair certain mechanical properties of the ligaments [28,29]. Sustained loading of ligaments results in laxity and hysteresis

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[30]. Since most occupational tasks require wrist extension for handling tools and loading, it has been suggested that prolonged and repetitive occupational exposure may lead to creep deformation of the SLIL. Ligamentous creep (laxity of the viscoelastic tissues) not only compromises the mechanical stability of the relevant joint but also may diminish the ability of muscles to detect signal changes during joint movements [31]. Desensitization of the mechanoreceptors impairs the neuromuscular control established by ligamentomuscular reflex arcs elicited from mechanoreceptors in the ligaments [31–33].

In recent years, ligamentomuscular reflexes elicited from the dorsal SLIL have been demonstrated. This reflex arc results in early protective reflexes and, later, co-contraction reactions in forearm muscles, including the extensor carpi radialis brevis (ECRB), extensor carpi ulnaris (ECU), flexor carpi radialis (FCR), and flexor carpi ulnaris (FCU) [34,35]. SLIL injury may therefore cause altered neuromuscular responses in these forearm muscles. Chu et al. confirmed the effect of ligamentous creep on neuromuscular function, as they found spasms and increased agonist muscle activation without compensation from antagonist muscles [33]. This could make the musculoskeletal pain and spasms more obvious in forearm muscles following SLIL injury, which could lead to lateral and medial elbow pain. Based on clinical findings, we propose that neuromuscular alterations in the forearm muscles caused by micro damage of the SLIL might trigger resisted musculoskeletal pain syndromes. Injuries of the wrist and hand constitute the majority of repetitive occupational injuries of the upper extremities. Therefore, we hypothesize that prolonged and repetitive occupational exposure may lead to creep deformation of the SLIL, which may then impair the neuromuscular control of the relevant muscles, thereby being a causative factor in elbow pain syndromes.

The relationship between elbow pain syndromes and SLIL injuries will be presented through two hypotheses and neuroanatomical basis for the potent pain mechanisms will be discussed.

1. Repetitive tasks may cause creep deformation of the SLIL, which then impairs ligamentomuscular reflexes, leading to elbow pain disorders.

   Evidence for this hypothesis will be based on three considerations:

   - SLIL is a richly innervated ligament.
   - Stimulation of the SLIL causes reflexive muscle contraction via ligamentomuscular reflexes.
   - Changes in muscle activation patterns of forearm muscles due to diminished ligamentomuscular reflexes may initiate a positive feedback loop leading to musculoskeletal pain syndromes. (Prolonged or repetitive loading may result in subacute damage to the SLIL, which may trigger additional musculoskeletal problems, such as lateral and medial elbow pain–associated disorders throughout the altered ligamentomuscular reflexes.)
2. Lateral epicondylalgia may increase the risk of SLIL injury.

   Concrete steps toward testing the hypothesis will be taken.

Hypothesis 1. Repetitive tasks may cause creep deformation of the SLIL, which then impairs ligamentomuscular reflexes, leading to lateral and medial elbow pain disorders.

The SLIL is a richly innervated ligament

Mechanoreceptors play an important role in sensorimotor control of the joints. These sensory organs are the basic elements of dynamic joint stability, transforming mechanical signals into afferent proprioceptive stimuli. Mechanoreceptors in the shoulder [36,37], elbow [38], ankle [39–44], spine [45], knee [46–52], trapeziometacarpal joint [53], and, recently, the wrist [54,55] have been demonstrated.

Only in the last decade have the various mechanoreceptors been mapped in the wrist ligaments. Numerous publications revealed the distribution of mechanoreceptors and innervation patterns of wrist ligaments [54,56–58]. Several types of mechanoreceptors, including the Ruffini, Pacini, and Golgi tendon organs, are found in the wrist ligaments. The predominant mechanoreceptor in the wrist ligaments is the Ruffini endings, which is a low-threshold slowly adapting receptor. Ruffini endings react to tensile strain in the ligament, signaling constantly during extreme joint positions and rotations [59].

Mechanoreceptors mapped in the wrist ligaments exhibited different innervation patterns with regard to their distribution in the ligaments, their receptor density, and ligaments' structural composition [54,56–58,60]. Innervation patterns of the wrist ligaments suggest that they have different functional roles. The dorsal and triquetral ligaments contain more mechanoreceptors than the radiovolar ligaments, which indicates the critical role they play in the sensorimotor function of the wrist joint [54,56]. All ligaments connecting the scaphoid to the adjacent carpal bones provide proprioceptive information; however, the most richly innervated ligament is the SLIL [56]. The SLIL is innervated from terminal branches of the PIN and, through the radioscapholunate ligament, AIN. The primary sensory nerve ending found in the SLIL is the Ruffini ending [61], which signals during excessive joint positions and rotation, which is when the ligament is at risk of being torn.

Stimulation of the SLIL causes reflexive muscle contraction via ligamentomuscular reflexes

Ligamentomuscular reflexes in maintaining functional stability of their associated joints is a gradually emerging concept. Innervated ligaments are able to initiate inhibitory and excitatory muscular activity via ligamentomuscular reflexes. Payr was the first to propose a ligamentomuscular protective reflex. Many researchers have confirmed the existence of ligamentomuscular reflexes in the knee [46,62–65], ankle [66], shoulder [67–71], elbow [72], lumbar spine [45,73], TMCOA [53], and, recently, in the wrist [34]. Ligamentomuscular reflexes have been described in the functioning of the knee, shoulder, and foot for the purpose of stabilizing excessive stress in the ligaments through synergistic muscle activation relevant to the joints.

Over the years, various components of the reflex arc, including the types of mechanoreceptors, articular nerves, muscle activation patterns, and neural transmission pathways, were demonstrated. These reflexes are transmitted to the spinal cord, resulting in mono- or polysynaptic reactions. As the afferent signals are not transmitted to the sensory cortex, ligamentomuscular reflexes belong to the unconscious proprioception sense, or the neuromuscular sense. The reactivity of muscles around a joint through reflexes includes the feed-forward control of muscles, which enables the maintenance of joint stability unconsciously. Anticipatory control of muscles may both modify the load imposed on the ligament and maintain functional joint stability by inhibiting muscles that develop extremely large forces, which then destabilize the joint, or eliciting antagonist co-activation to stabilize the joint. For instance, reflexive activation of the hamstring muscles in the case of ACL rupture decrease the tension on the ACL through diminishing anterior translation of the tibia [33,63]

The existence of ligamentomuscular reflexes elicited from the dSLIL has been demonstrated, which indicates the proprioceptive role of the ligament, in addition to its biomechanical function. The SLIL could generate proprioceptive stimuli at every wrist position [34]. Recent studies have confirmed that a reflex arc originating from the dSLIL results in early protective reflexes and, later, co-contraction reactions in the forearm muscles, including the ECRB, ECU, FCR, and FCU [34,35]. Wrist motions with a relative motion of the proximal row then strains the SLIL and LTIL, transforming mechanical signals into afferent proprioceptive signals. For each wrist position, protective reflexes seen in the antagonist muscle appeared within 20 ms after stimulation. Hagert et al. found that early ligamentomuscular reaction was observed in the ECRB in flexion and in the FCR/FCU in extension, radial and ulnar