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Common grappling submissions: A descriptive, illustrative and literature review of anatomic structures at risk and pathophysiology

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Abstract

Grappling disciplines have immensely grown in popularity. These martial arts and sports, such as Judo, Brazilian Jiu Jitsu, Sambo, and Mixed Martial Arts, utilize techniques and movements to maintain control, subdue, or submit an opponent. Grappling submissions introduce risk of injury through a variety of specific moves, positions, and mechanisms. Yet grappling disciplines remain relatively niche, shrouded with confusing, non-descriptive terminology and jargon. This often results in a poor understanding of injury mechanisms, anatomic regions injured, and pathophysiologic cause of injury. The lack of basic anatomic and physiologic understanding is a potential barrier to optimal care and future research endeavors by clinicians in a burgeoning patient population. As such, this study aims to provide a concise guide to common grappling submissions, with illustrative examples and pathophysiologic mechanisms, description of anatomic structures at risk, and a literature review of injuries, with intention of improving care, and facilitating future investigative efforts by clinicians.

Abbreviations

ACL = anterior cruciate ligament
ATFL = anterior talofibular ligament
CFL = calcaneofibular ligament
IGHL = inferior glenohumeral ligament
LCL = lateral collateral ligament
MCL = medical collateral ligament
PCL = posterior cruciate ligament
POL = posterior oblique ligament

Introduction

Grappling based martial arts and sports, such as Judo, Brazilian Jiu Jitsu, Sambo, and Mixed Martial Arts, utilize techniques and movements to maintain control, position or submissions over an opponent.[1,2] Submission techniques, in particular, pose inherent risk of injury to participants, yet, this population remains understudied.[3-7] Currently, information regarding submission mechanisms and anatomic structures at risk lacks a consolidated form in the literature.[5] As such, the impetus for this study was to formulate a consolidated source of illustrative and descriptive review of common grappling submissions, anatomic structures at risk, and literature review of injury risk with intention of improving the understanding of grappling related injuries among health care professionals.

Submission types

Submissions discussed in this article will include: (1) Chokes/neck cranks, and (2) Joint locks.

The term "chokes" refers to maneuver that mechanistically achieve submission via strangulation of the neck. Strangulation leads to submission via decreasing cerebral blood flow and/or inflicting pain to the neck region. Although the term choke is a mis-representation, this is the colloquially accepted term and will be used to describe these types of submissions in this study. Joint locks apply force at a joint leading to supraphysiologic range of motion. The joint motion past normal physiologic constraints, typically confers immense pain, injury, or loss of function resulting in submission.

The following submissions will include technique descriptions, anatomic structures at risk and a review of current literature pertaining to each submission. This review will predominantly highlight the musculoskeletal structures at risk, but will include additional structures when pertinent. Illustrative and photographic examples of submissions will be shown using a combination of *gi* (the heavy fabric uniform used in traditional Sambo, Judo, or Brazilian Jiu Jitsu) and non-*gi* photographs and illustrations.

Chokes and Neck Cranks

Rear naked choke/Lapel chokes/Neck crank/ Guillotine

A rear naked choke is accomplished when an attacking player is able to mount their opponent's back, and compress both sides of the opponent's neck. This is often achieved with a *Mata Leào* grip, meaning "Lion killer" in Portuguese. This grip involves an attacking athlete placing one arm around the neck of their opponent, grasping their

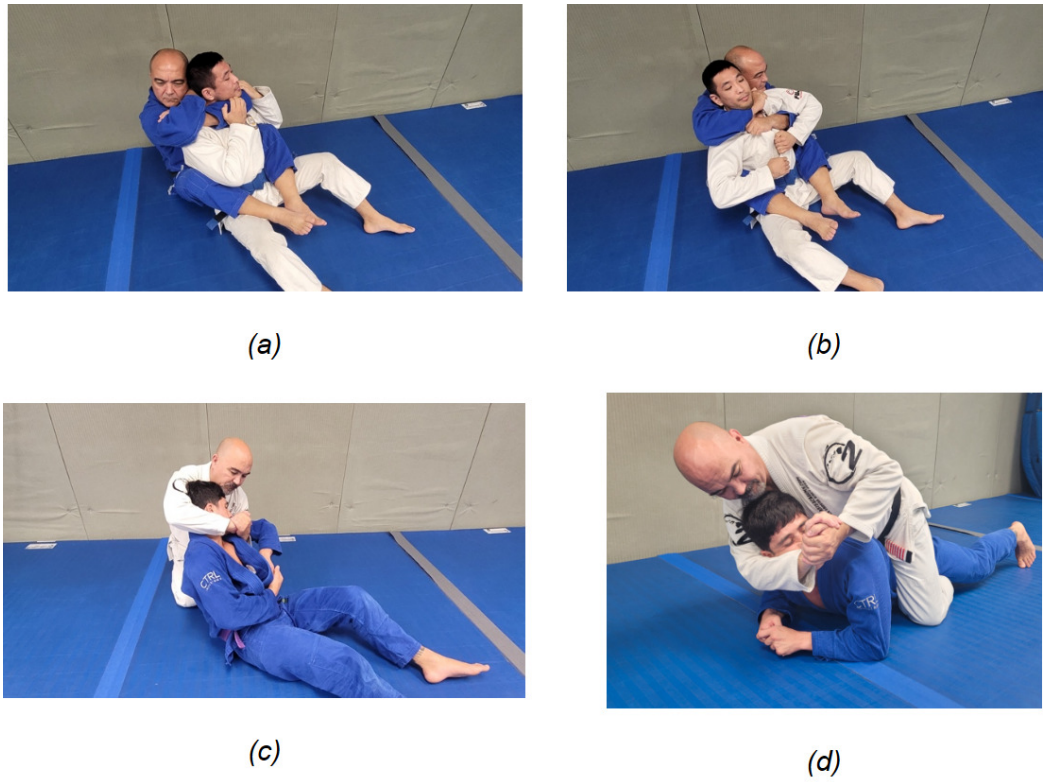

Figure 1. Variations of chokes and neck cranks a) Mata Leào grip b) Lapel choke variation c) Neck crank from back mount variation d) Neck crank from alternate back mounted position

contralateral bicep as its placed behind the opponent's head (**Figure 1a**). Similarly, lapel chokes accomplish compression through utilizing a *gi's* lapel, with a number of variations in grips, to compress an opponent's neck. An example can be seen in **Figure 1b**.

Neck cranks, as opposed to chokes, or strangles, achieve a submission due to pain. It most commonly involves applying a compressing or restricting force with their forearms or wrist against an opponent's neck (**Figure 1c and 1d**). The direction of this force is commonly oblique, creating a twisting or torsional force at the neck and jaw. This results in supraphysiologic motion, and compression, at the jaw or cervical spine eliciting immense pain.

A guillotine submission is accomplished with an attacking athlete wrapping one arm around an opponent's neck, while using the other arm to apply an inferior to superior and anterior to posterior directed compressive forces across the neck (**Figure 2a**). The position of the attacking player can differ, but the mechanisms of eliciting a submission remains the same regardless of position (**Figure 2b**).

Anatomic structures at risk and literature review

Most notably, in a choke hold or neck crack, the neck musculature is exposed to injury. In particular, the sternocleidomastoid will be at risk due to direct compression as well as eccentric or concentric contractional injury as an attacked athlete attempts to alleviate contact pressure. Other prominent muscles also at risk include the trapezius muscle, scalenes, levator scapulae, longissimus capitis, semispinalis capitis, and splenius capitis. Moreover, the trachea, thyroid cartilage, and accompanying ligaments, may be at risk. In addition, the cervical spine may be at risk of fracture, dislocations, sprains. The jaw may also be placed at risk of injury if the attacker's arm position is proximally placed over the jaw rather than the neck. This may expose the zygomatic arch, teeth and mandible, in particular the temporomandibular joint, at risk of injury.

Other structures at risk include carotid arteries, jugular veins, and various nerves. These structures are at risk for injury due to direct compression, traction injuries, or torsional forces resulting in artery dissections, vein injury, or neuropraxias. The incidence and prevalence of vascular injuries resulting from chokes is sparse in the literature, though there are case reports and case series reported.[8] Minor injuries include skin abrasions or lacerations which can occur from the forceful abrasion of the *gi* lapel utilized in the choking mechanism.

Most commonly, injuries involving rear naked chokes, lapel chokes, neck cranks, or guillotines involve muscular strains or minor cervical sprains, and loss of consciousness; however, vascular injuries, such as carotid and vertebral artery dissections, stenosis and ischemic stroke, have been reported.[8-10] Prior literature has suggested the carotid artery may be predisposed to risk from these submissions due to tethering of the vessel with free neck mobility, or a combination of direct compression and hyperextension of the neck.[9] Additionally, some biomechanical studies have suggested the force applied during these chokes may be equivalent to those experiences in a car accident, and as such, suggest participants must exercise control and cau-

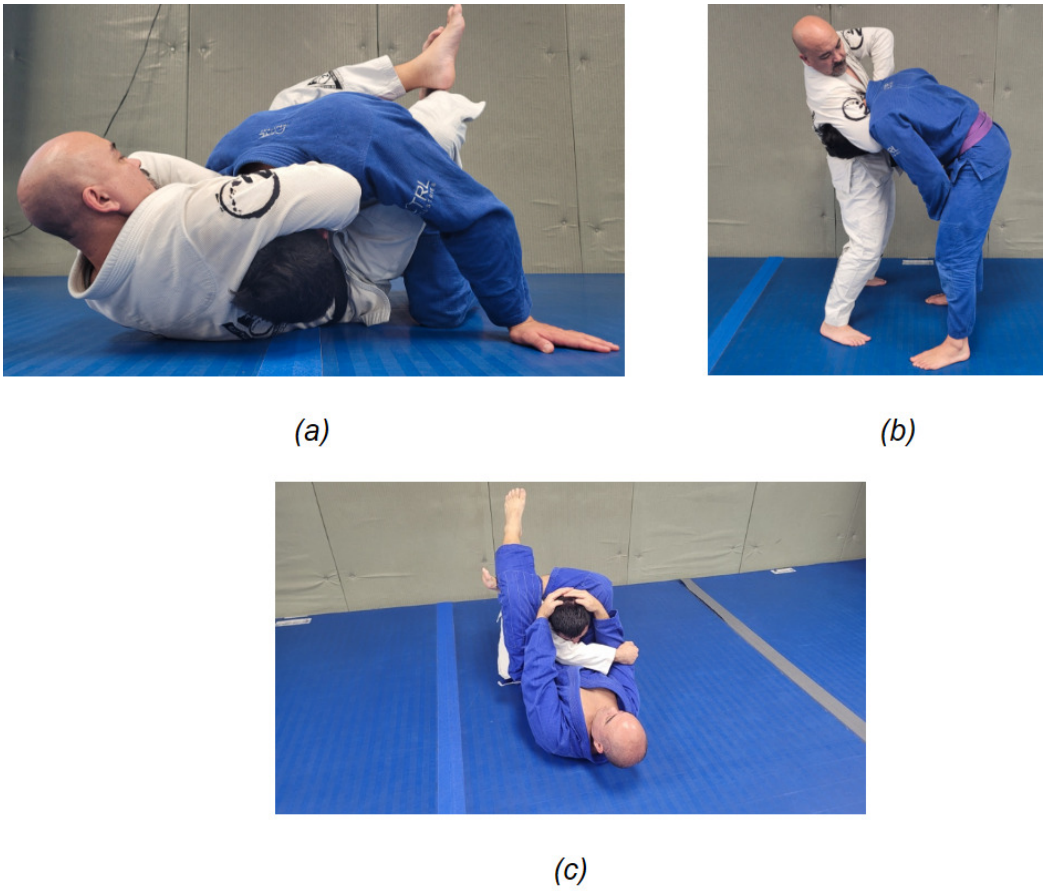

Figure 2. a) Guillotine submission from closed guard position b) Standing guillotine c) Triangle submission

tion when applying these techniques, or should submit early if caught in one.[11,12]

Triangle chokes

Triangle chokes, can be accomplished when either an attacker's legs or arms compress an attacked opponent's arm, in an adducted position, against their neck. Compression is then applied by the attacking athlete (**Figure 2c**). Again, the positions of the athletes can vary, but the mechanism of compressing vascular structures in the opponent's neck against their own arm remains the same.

Anatomic structures at risk and literature review

Much like rear naked chokes, neck cranks, or lapel chokes, the musculature of the neck is at risk of injury during triangle chokes. Additionally, because the submission involves a participant's arm, shoulder joints, tendons, ligaments, and muscles are also at risk. These may include glenohumeral and acromioclavicular joints, with accompanying ligamentous structures at those joints. The deltoid, latissimus, rotator cuff, and serratus may also be at risk of injury. Similarly to rear naked chokes, neck cranks and lapel chokes, an attacked player's neck may be rotated or in hyperextension, placing cervical vertebral articulations at risk of injury. In addition, the attacking opponent may sustain quadriceps, hamstrings, gastrocnemius, or knee ligamentous injury if using their lower extremities to accomplish the submission or the opponent attempts to escape. Neurovascular structures as mentioned in the prior choke section are also at risk of injury, as they may be subjected to similar traction, torsion or compression imparted during the triangle choke.

The triangle submission has been implicated as inciting injury in several studies. Hinz et al noted the triangle submission to be the most prevalent submission technique involving lower extremity injury to an attacking athlete.[13] Scoggin et al described one case of a cervical strain as a result of triangle choke.[5]

Joint locks

Arm bar

An arm bar is a type of joint lock that is accomplished with an attacking athlete maintaining isometric position of the shoulder and forearm with concomitant hyperextension of the elbow. Frequently, an attacker will place both legs over the shoulder, and extend their hips to hyperextend an opponent's elbow, maximizing the length of mechanical lever with distal extremity control (**Figure 3a and 3b**). Variations can occur with regards to position of attacking opponent, leg position, or foot position. However, all variations allow attacking participants to gain control of the shoulder and forearm to apply a force perpendicular to the elbow joint causing hyperextension.

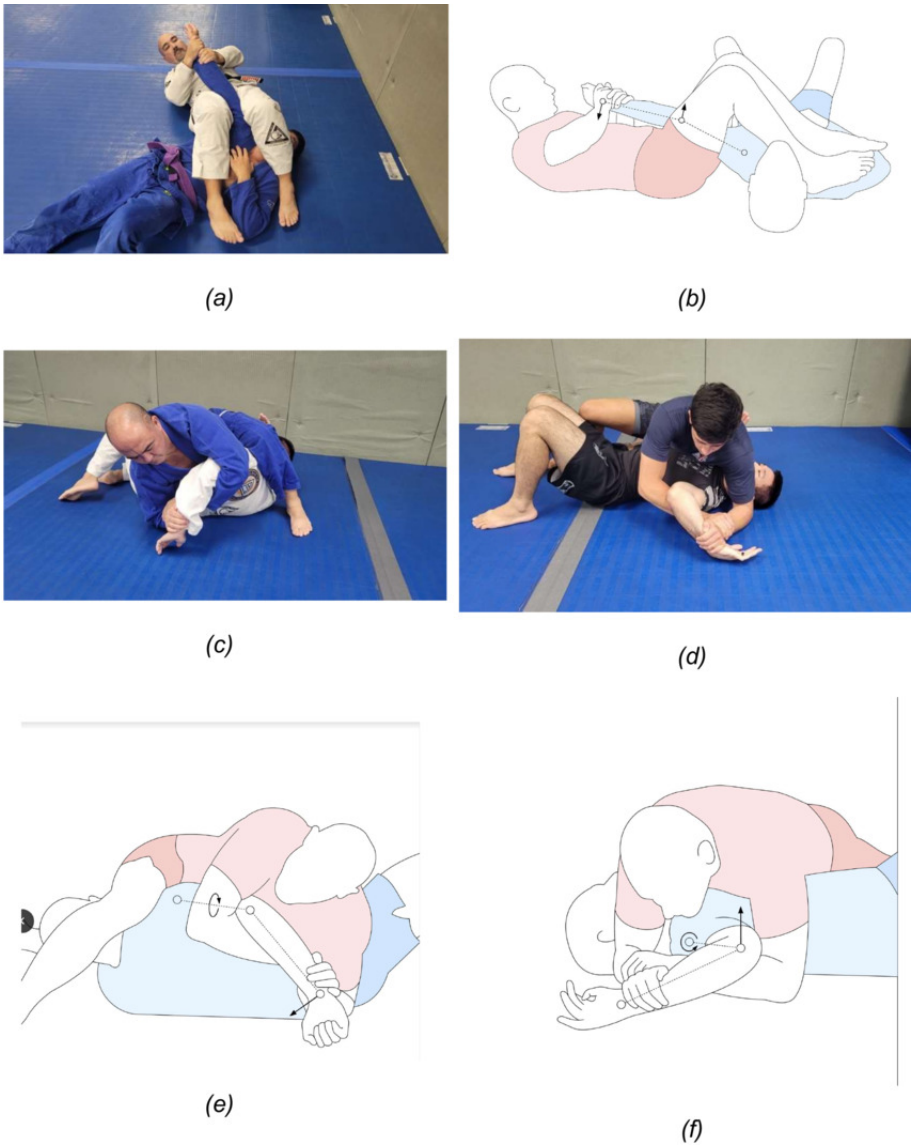

Figure 3. Upper extremity joint locks a) Arm bar submission b) Illustrative example of arm bar submission c) Americana submission d) Kimura submission e) Illustrative example of rotational forces during Americana f) Illustrative example of rotational forces during Kimura. Illustrations created with use of Inkscape. Inkscape Software, version 1.3 (Inkscape Project, Boston, MA).

Anatomic structures at risk and literature review

The elbow joint's osseous, ligamentous, tendinous structures are most at risk. In particularly, the olecranon and olecranon fossa may sustain injury due to elbow hyperextension. Medial and lateral collateral ligament complexes of the elbow are also at risk, dependent on position of the arm. If the forearm is supinated during the attack, the common flexor tendons are at risk, while if the forearm is pronated the origin of the extensor tendons are at risk of injury. The defender will often flex their biceps to combat hyperextension of the elbow, resulting in immense eccentric force at the bicep's distal insertion and possible injury. In addition, there may be anterior subluxation of the shoulder joint once maximal elbow extension is reached, stressing the anterior shoulder capsule, anterior labrum, or potentiating osseous injuries such as a bony Bankart or Hill-Sachs lesions. Also, the combined rotational force from defensive players trying to escape can lead to fracture.

Arm bars have been implicated as a common submissions causing injury.[14-16] Current literature suggests a higher risk of injury to the olecranon and medial structures of the elbow, though injury to lateral and anterior structures are possible.[5,17] Scoggin et al found the elbow was the most commonly injured joint in Brazilian Jiu Jitsu competitions, with arm bar submission being the most common mechanism. The authors also suggested external rotation of the attacked opponent's arm during an arm bar attempt, which imposes a valgus moment on the elbow, may increase risk to the ulnar collateral ligament.[5] These authors also reported distal biceps rupture and LCL injury from arm bars.[5] A study by de Almeida et al reported magnetic resonance imaging of 5 grappling athletes whom all had total or partial rupture of the common flexor tendon and total rupture of the ulnar collateral ligament after arm bar related in-

juries.[17] The current literature indicates most injuries after arm bar are sustained on the medial elbow, but that thorough workup is warranted for concomitant injuries.

Kimura/Americana

Kimuras and Americanas are arm locks involving hyper-internal rotation or hyper-external rotation, respectively, at the shoulder. A Kimura submission, named after legendary Japanese Judoka Masahiko Kimura, involves manipulating the arm in 90 degrees of shoulder abduction, and 90 degrees of elbow flexion, to force glenohumeral hyper-internal rotation (**Figure 3c**). Similarly, an Americana forces glenohumeral hyper-external rotation (**Figure 3d**). As with other submissions, the position of the attacking and attacked opponent may vary, but all require the shoulder in 90 degrees of abduction and 90 degrees of elbow flexion to facilitate either hyper-internal or hyper-external rotation at the shoulder (**Figure 3e and 3f**).

Anatomic structures at risk and literature review

The most immediate structures at risk of injury in these submissions are within the shoulder. For the Kimura, the posterior band of the inferior glenohumeral ligament (IGHL) may be stretched during internal rotation, as well as external shoulder rotators such as supraspinatus, infraspinatus, and teres minor. Additionally, the posterior shoulder capsule may be stretched with increasing internal rotation, while also increasing risk of impinging anterior structures such as the labrum. There also is a theoretical risk of anteromedial humeral head fracture, as the humeral head internally rotates. Whereas in an Americana submission, shoulder injury constellations may mimic that of traumatic anterior shoulder dislocation, as arm abducts and externally rotated. Glenoid labral articular defects due to shearing are also a possible, as are bony Bankart or Hill-Sachs lesions, especially there is a resultant anterior shoulder dislocation. Internal rotators of the humeral head, such as the subscapularis, pectoralis major, anterior portion of the deltoid, and latissimus dorsi, are at risk for injury are placed on stretch during hyper-external rotation. Distal elbow injuries may also occur for both submissions, via manipulation of the elbow. In particular, an Americana places the elbow in similar position as the late-cocking position seen in baseball pitchers, imparting strain on the ulnar collateral ligament of the elbow, and medial elbow structures. The axillary nerve and artery may be at risk with these submissions, particularly if there is a concurrent shoulder dislocation.

There have been several reports concerning injury associated with Kimura submissions. Scoggin et al reported an elbow ulnar collateral ligament injury and acromioclavicular joint injuries attributed to Kimura submissions.[5] Hinz et al found the Kimura was the second most likely submission to be associated with injury, though injuries sustained were not specified.[13] In addition, several authors involved with this study have anecdotally treated patients who sustained humeral shaft spiral fractures as a result of Kimura submissions. To the authors' knowledge, no literature has reported on injuries related to Americana submissions though this is likely due to underreporting, rather than a diminished injury risk.

Knee Bar

A knee bar is a lower extremity joint lock which places the knee in hyperextension. An attacker will extend their hips with a force vector perpendicular to the knee joint, in an anterior to posterior direction, resulting in supraphysiologic knee extension (**Figure 4a**).

Anatomic structures at risk and literature review

Hyperextension of the knee may involve supraphysiologic tension of hamstrings or gastrocnemius. Prior cadaveric studies have examined isolated knee hyperextension and found evidence of injury to the lateral collateral ligament (LCL), popliteus tendon, and popliteofibular ligament, anterior cruciate (ACL) and posterior cruciate ligaments (PCL).[18-20] Though, it is important to understand grappling submissions do not occur with passive motions as done in cadaveric studies. An *in vivo* knee bar will have additional valgus, varus, or torsional forces being applied. A varus directed force may affect lateral structures, such as LCL, lateral meniscus, anterolateral complex of the knee, posterolateral corner, and fabellofibular ligament. If a valgus moment is induced, then medial structures such as the medial collateral ligament (MCL), medial meniscus and its posterior horn, hamstring insertion, posterior oblique ligament (POL), and oblique popliteal ligament are at risk. Likewise posteromedial or posterolateral capsular attachments may also be at risk of injury with hyperextension of the knee. Lastly, there is a theoretical risk for knee dislocation if enough force is applied to the knee during the submission, but this would likely require previous knee injury or ligamentous instability given the multiple static and dynamic stabilizers to the knee. Neurovascular structures such as the popliteal artery, tibial nerve, and common peroneal nerve are at risk of injury, particularly if there is subluxation or dislocation of the knee.

For many grappling academies and grappling organizations, knee bars have been discouraged, banned, or reserved for advanced practitioners. This stems from grapplers' anecdotal understanding of possibly devastating injuries. Even so, the available literature on knee bars is lacking.[21] One case report described an intraarticular patellar dislocation after a knee bar, however the literature denotes this as an exceedingly rare injury.[22] A recent study suggested structures, in descending order of providing resistance to hyperextension, were posteromedial capsule, posterior oblique ligament, posterolateral ligament, fabellofibular ligament, and cruciate ligaments.[23.] MCL and oblique popliteal ligament provided resistance as well, with the same authors noting over 50% of resistance of hyperextension to the posterior capsular structures, whereas approximately 25% was provided by cruciate ligaments.[23] As such, these structures should be evaluated when caring for athletes after knee bar injuries. Additionally, health care professionals should understand when evaluating knee bar

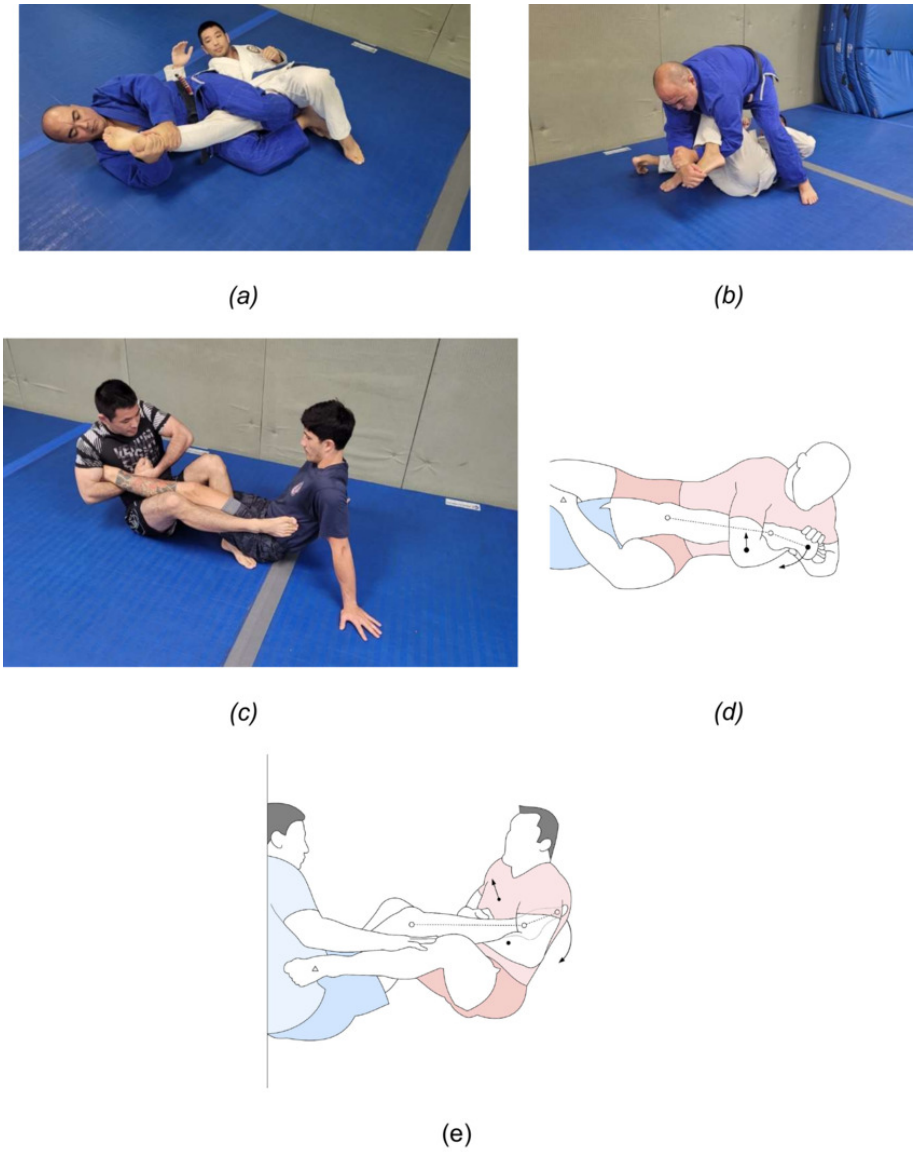

Figure 4. Lower extremity joint locks a) Knee bar submission b) Toe Hold submission c) Straight ankle lock submission d) Illustrative example of force vectors during toe hold submission e) Illustrative example of force vectors during straight ankle lock submission. Illustrations created with use of Inkscape.

related injuries, there is polyaxially motion and force being applied to the extremity. This requires a thorough examination of structures potentially effected by varus, valgus, or torsional forces at time of submission.

Toe hold/Straight ankle lock

A toe hold submission is executed when an attacking opponent is able to plantar flex the tibiotalar joint while inverting and supinating the foot (**Figure 4b**). This is accomplished by creating a fulcrum across the Achilles tendon or medial ankle (**Figure 4d**). Concurrently, a toe hold may result in maximal internal rotation at the knee after maximal arc of foot motion is achieved.

A straight ankle lock is applied when a fulcrum on the Achilles tendon is created, forcing the tibiotalar joint into maximal plantar flexion via a posterior to anteriorly directed force (**Figure 4c and 4e**).

Anatomic structures at risk and literature review

The final position of a toe hold is similar in position as to common ankle sprains. As such, the Anterior Talofibular ligament (ATFL) and Calcaneofibular ligament (CFL) may be at risk of injury, which are also at risk with straight ankle locks. Additionally, there is a theoretical injury risk to the peroneal tendons, in particular the peroneal brevis, as a result of compression of the peroneal brevis within the fibular groove.[24] Risk of osseous injury also exists, particularly with shearing or compressive force with talar motion across the tibiotalar and subtalar joints. Specific to straight ankle lock, recent literature has suggested the tibionavicular ligament and tibiospring ligament, components of the superficial deltoid, begin to tense at 10 degrees and 15 degrees of plantar flexion, increasing in tension as plantar flexion increased.[25] Likewise, the extensor digitorum longus, tibialis anterior, and extensor hallucis longus are at risk of in-

jury as they will be stretched during maximal plantar flexion. The anterior portion of the ankle joint capsule will also be placed on tension during this submission and may be an added source of injury. The Achilles tendon may also be at risk of contusion or compressive injury due to its use as the submissions' fulcrum.

Toe holds and straight ankle locks have been implicated as a major cause of ligamentous ankle injury.[13] Because the main structures at risk are the ATFL and CFL, patients sustaining repetitive lateral ankle injury due to toe holds or straight ankle locks may present with mechanical symptoms and physical examinations suggestive of lateral ankle instability, peroneal tendon instability or complaints of chronic ankle pain, similar to athletes in other sports susceptible to chronic ankle sprains. Likewise, minor injuries such as Achilles contusions have also been reported.[13,26] The dearth of literature implicating straight ankle locks and toe holds is likely due to underreporting rather than a benign risk of injury.

Heel Hook

A heel hook is accomplished by forcing maximum internal or external rotation at the knee joint. This is done by limiting motion at the hip and most commonly manipulating the calcaneal tuberosity to force maximal rotatory motion at the knee. There are 2 heel hook variations, with name designation determined by position of an attacked athlete's leg. If an attacked athlete's knee position is relatively medial to the tibia, fibula and foot-ankle complex, this allows for an "outside" heel hook (**Figure 5a**). If an attacked player's knee is relatively lateral to the tibia, fibula and foot-ankle complex traversing to a more medial position, this will facilitate an "inside" heel hook (**Figure 5b**). An "outside" heel hook will force the knee into maximum internal rotation, while an "inside" heel hook will force maximal external rotation (**Figures 5c and 5d**). The position of the foot also differs, with the final position in an "outside" heel hook a plantarflexed, inverted and supinated position, similar to a toe hold, whereas an "inside" heel hook results in a dorsiflexed and everted foot position. For both submissions, there is variable amounts of knee flexion or extension.

Anatomic structures at risk and literature review

"Outside" heel hooks stress the knee joint in maximal internal rotation. As such, the cruciate ligaments are at risk of injury, and depending on position of the knee may involve medial knee structures. The ACL is at particular risk when the knee is in an extended position at time of internal rotation, whereas the PCL becomes more prone to injury with knee flexion, particularly between 90 and 120 degrees of flexion.[27] Secondary restraints include the posterior oblique ligament, as well as the posteromedial complex, which includes both portions of the MCL, POL, popliteal ligament, and posterior horn of the medial meniscus, all of which are at risk of injury.[27] In addition, foot inversion, supination, and plantar flexion, will place lateral ankle ligaments, such as the ATFL and CFL, at risk. Patellar dislocation may occur as the knee is flexed, externally or internally rotated, and subjected to a valgus force.[28] This could potentiate injury to the patellar tendon, quadriceps tendon, medial patellofemoral ligament injury, and femoral or patellar osteochondral defects.[29]

"Inside" heel hooks will stress the knee in maximal external rotation. Primary restraints at the knee in external rotation are lateral knee structures, including popliteofibular ligament, LCL, popliteal tendon, biceps femoris tendon, fabellofibular ligament and arcuate ligament.[27,30] Secondary restraints to external rotation motion may include the MCL. Additionally, there may be meniscal injury as the medial tibial plateau moves anterolaterally in relation to the femur, resulting in a possible anterior horn medial meniscus injury, as the knee is extended.[31]

In the current literature, heel hooks have been implicated as a source of injury. Baker et al described a complete ACL rupture and MCL injury in a mixed martial artist after an "outside" heel hook submission. Hinz et al found heel hooks to the be the third most common submission to cause injury, with a high incidence of ankle ligamentous injury, though the authors did not differentiate between heel hook types.[13] Heel hook submissions carry an ominous reputation amongst grapplers, with some grappling organizations banning them from competitions.[5,6] Theoretically, there is increased injury risk with "inside" heel hooks, as it capitalizes on the decreased arc of motion in foot dorsiflexion and eversion, as compared to inversion and plantar flexion. The ability to achieve maximum foot and ankle motion arc quicker for "inside" heel hook allows an attacking player to quickly force maximal knee external rotation, leaving the opponent less reactionary time to submit. This contributes to anecdotal beliefs that an "inside" heel hook is more dangerous. Regardless, patients with injuries from heel hooks should undergo a thorough knee exam, as well as close examination of the ankle and foot for both variants of heel hooks.

Conclusion

Grappling injuries are expected to increase, as various grappling disciplines and sports continue to gain popularity. Investigative efforts into these injuries have also increased but overall remain lacking. Grappling related activities are still considered relatively niche, and are shrouded in confusing terminology and jargon, limiting improvements in patient care. While the submissions discussed in this manucript are not comprehensive, it is the authors' hope this review provides a consolidated source of reference to improve basic understanding of grappling submissions anatomic regions at risk, pathophysiology, and current literature review, in an effort to improve care for this burgeoning constellation of sport-related injuries.

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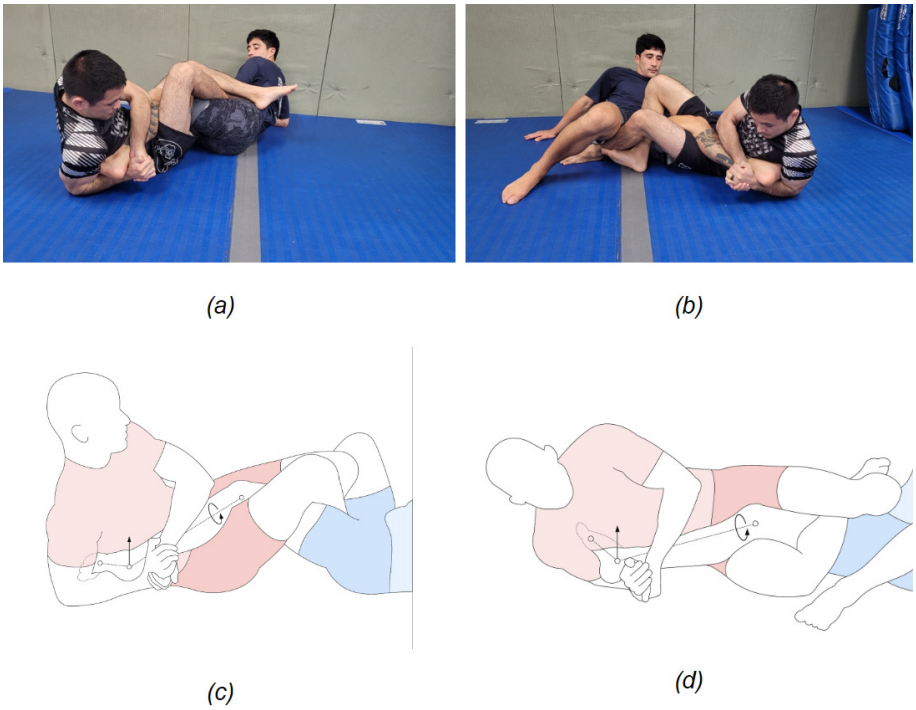

Figure 5. Heel Hooks a) Outside heel hook, notice knee position is medial relative to heel b) Inside heel hook, notice knee position is lateral relative to heel c) Illustrative example of force vectors during outside heel hook d) Illustrative example of force vectors during inside heel hook. Illustrations created with use of Inkscape.

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