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ORIGINAL ARTICLE

Video Analysis of Acute Hamstring Injury Mechanisms During Deadlifts

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ABSTRACT

Background. Existing studies on the mechanisms leading to acute hamstring injury are limited by reliance on author extrapolation and patient recall for injury details. **Objectives.** This study aims to determine potential mechanisms for acute hamstring strain injuries during deadlifts via videographic observations in vivo. **Methods.** Videos were searched on the website "YouTube.com" using each of the phrases "hamstring rupture", "hamstring tear", "hamstring injury", "hamstring strain", and "hamstring pull", combined individually with the terms "deadlift", "powerlifting", and "competition". An orthopaedic surgeon validated 16 video clips based on pre-set criteria. **Results.** 16 injury events were analyzed. Hip flexion (n=11) and knee semi-flexion (n=16) were the most common positions leading to injury. The most common injury pattern was a combination of hip flexion with knee semi-flexion and eccentric hamstring loading (n=11). Concentric hamstring loading was observed leading to injury in 3 cases. **Conclusion.** Acute hamstring injuries during deadlifts occurred by eccentric hamstring loading with a semi-flexed knee and a flexed or semi-flexed hip, or by concentric hamstring loading with a semi-flexed knee and semi-flexed hip.

KEYWORDS: ***Hamstring Muscles, Video Recording, Leg Injuries, Sports.***

INTRODUCTION

Hamstring injuries account for up to 29% of all injuries in sports, making them one of the most prevalent lower extremity injuries in athletes (1). Being a two-joint muscle group makes the hamstring muscles especially susceptible to strain, and this is frequently experienced during competitive sports (2, 3).

Clinically, hamstring injuries may be classified as Grade I to indicate mild disruption of the musculotendinous junction, Grade II to indicate a partial tear, or Grade III to indicate a complete rupture (4). While the severity and specific muscle localization of injury is important in clinical decision-making, the phrase "hamstring injury" is often used in the literature and point-of-care resources to refer to any strain or tear of any of the muscles or tendons within the hamstring group, including the biceps femoris, semitendinosus, and semimembranosus muscles (2, 4). The characteristic presentation of most acute hamstring injuries is a sudden onset of pain in the posterior aspect of the thigh during strenuous activity, often limiting continuation of the activity (2, 4).

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Askling et al. described two situations that cause acute hamstring injuries to occur; high-speed running (i.e. sprinting), and excessive elongation of the hamstrings (i.e. stretching) (5). In a 2020 systematic review, Danielsson et al. concluded from available studies that stretch-type hamstring injuries occur by extensive hip flexion with an extended knee, such as while kicking a ball or picking up a ball from the ground (6). Danielsson et al. also found that most studies of running-type injuries reported susceptibility caused by eccentric loading during the late swing phase of the running gait cycle (6). However, one stated limitation was that conclusions regarding mechanisms of hamstring injury in the included studies were often extrapolated by their authors. For example, details of all the stretch-type injuries were recalled by patients instead of being directly observed by researchers (6).

Within the past decade, various publications have emerged utilizing a novel methodology to study mechanistic details of musculoskeletal injury events by analyzing video clips of injuries posted to online video websites, such as YouTube.com (7-9). Analyzing publicly accessible clips of injury events allows researchers to verify or challenge current models of injury mechanisms derived from patient recall, with little-to-no harm added to patients. One sport containing injury events available to watch on YouTube.com is powerlifting, which involves athletes attempting to lift maximal weights during the squat, bench press, and deadlift movements. Due to the uniform nature and slowness of powerlifting movements, the mechanical body positions of a powerlifter at the precise moment of an injury event can be characterized with little difficulty. Kapicioglu et al. studied YouTube.com clips of distal bicep brachii tendon ruptures suffered during deadlift attempts, identifying an alternate mechanism of injury from what had been classically described in the literature (8). At the time of writing this paper, YouTube.com also contains several videos of individuals suffering hamstring injuries experienced during deadlift attempts. The observed loading mechanisms and positions at which individuals experience hamstring injuries during the deadlift could support or challenge current mechanisms described in the literature, such as the hip flexion with extended knee position described for the "stretch-type" mechanism, and the eccentric hamstring loading described for the "running-type mechanism" (5, 6). To the authors' understanding, there have not yet been any studies characterizing the mechanistic details of hamstring injuries in general using YouTube.com video analysis, nor any studies characterizing the specific mechanistic details of hamstring injuries incurred during deadlift attempts.

This paper investigates video clips of hamstring injuries occurring during deadlift attempts to identify mechanistic details pertaining to the injury event, with the aim of supporting currently proposed mechanisms of hamstring injuries in the literature or proposing an alternative mechanism that has not yet been identified. Improved mechanistic knowledge of activities that commonly lead to hamstring injuries may increase awareness of techniques that reduce the occurrence and/or severity of injury in both the powerlifting community and in the general population.

MATERIALS AND METHODS

This study posed no risk of harm to any of the subjects since their injuries were analyzed in retrospect. Therefore, the institution's human research committee granted an exemption upon application for ethical approval of this study. Videos were searched on the website "YouTube.com" using each of the phrases "hamstring rupture", "hamstring tear", "hamstring injury", "hamstring strain", and "hamstring pull", combined individually with each of the terms "deadlift", "powerlifting", and "competition" to produce 15 search combinations.

Under each of these, 100 search results were evaluated to determine if they provided video clips satisfying the following inclusion criteria:

1. To have a combination of the word "hamstring" along with any of the words: "rupture", "tear", "injury", "strain", or "pull" in the video title.
2. To clearly display a person attempting a deadlift.
3. To show the person ending a deadlift attempt abruptly and grabbing the posterior thigh of one leg in pain.

From 1500 video search results, the primary author selected eligible video clips for further verification of eligibility by an orthopaedic surgeon. A consensus of eligibility was obtained for 16 video clips, which were selected for inclusion (10-18). Information about each video clip, including video titles and injury details, were recorded in an Excel file, which was also used to analyze the data and create the table and graphs presented in this paper. This Excel file titled "Data Collection and Analysis" was submitted with the manuscript as a supplemental file. A compilation file displaying video clips of all the included injury events was also created and submitted as a supplemental file.

Through watching each of the video clips, parameters surrounding the injury events were recorded, including sex of the injured person, the affected side, the position of the hip (flexed, semi-flexed, or extended), and the position of the knee ("flexed", "semi-flexed", or "extended"). The hip and knee joints were classified as flexed if the degree of flexion at the joint was equal or greater than 90 degrees, semi-flexed if the degree of flexion was less than 90 degrees and extended if there was no flexion.

Finally, each hamstring injury was classified as concentric or eccentric depending on whether the hamstrings were observed to be elongating (eccentric) or shortening (concentric) at the moment of injury. One challenge of making this classification is that performing a deadlift (i.e. raising the barbell against resistance) involves two primary joint actions with opposing effects on the length of the hamstring muscles–knee extension, which elongates the hamstring muscles, and hip extension, which shortens the hamstrings. Knee extension is typically the dominant joint action at the beginning of a deadlift, but hip extension progressively contributes more as the lift progresses (Figure 1) (19, 20). The authors propose that the net change in hamstring muscle length during contraction (i.e. whether it is concentric, eccentric, or isometric) can be reasonably deduced by identifying which joint action contributes to greater change in body position directly preceding injury. In other words, the loading mechanism on the hamstring muscles was classified as eccentric if knee extension appeared to have a greater impact on the body position than hip extension preceding injury, and concentric if hip extension was the dominant action. Table 1 demonstrates the combinations of possible hip and knee actions during a deadlift (extension or no motion) that would lead to each load mechanism classification.

Statistical Analysis. All the data were recorded and analyzed in a Microsoft Excel spreadsheet (Microsoft Excel 2023, Redmond, Washington USA). The proportion of participants associated with each classification was expressed as a percentage of the total number of participants.

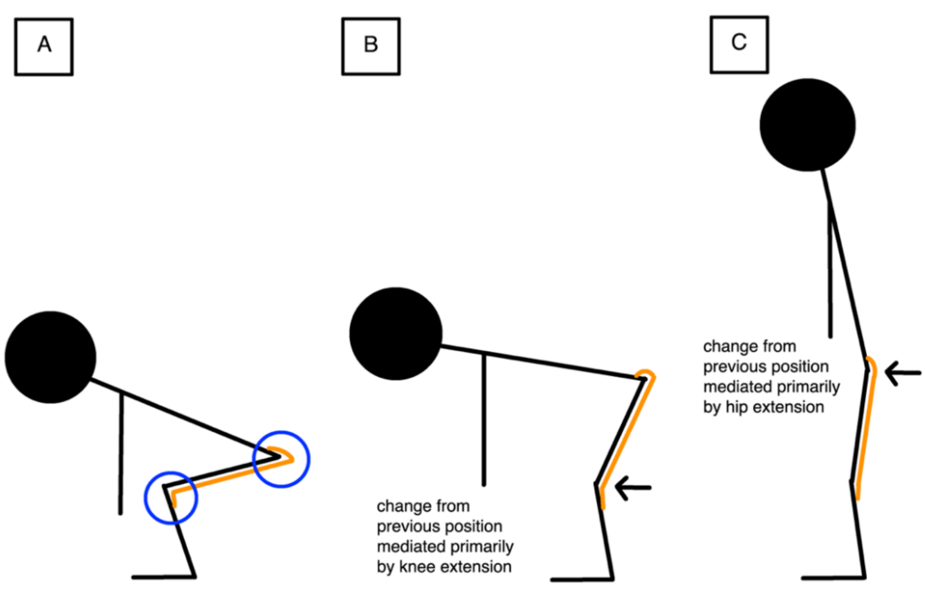

Figure 1. Schematic demonstrating the typical progression of a deadlift, including the phases of a) lift-off b) knee pass and c) lift completion. The hamstring muscles (orange) are depicted crossing both the knee and hip joints (circled in blue).

Table 1. Combinations of hip and knee actions preceding injury that warrant each loading mechanism classification

Hip Action	Knee Action	Loading mechanism
Extension	Extension	Concentric (if hip extension is greater preceding injury) or Eccentric (if knee extension is greater preceding injury)
	No motion	Concentric
No motion	Extension	Eccentric
	No motion	Isometric

RESULTS

Out of the 1500 search results produced, 16 video clips were determined to be eligible for further analysis. Video clips were excluded if they displayed an injury event that was already displayed in a different included video. Table 2 displays all raw data collected for each video clip/injury event. All participants studied were male. 69% (n=11) of injury events occurred on the left leg (Table 3).

Table 2. Compilation of raw data collected for each injury event

Case Number	Video Title	Injured Side	Hip Position	Knee Position	Hip Action	Knee Action	Dominant Action	Load Mechanism
1	*Deadlift Hamstring Tears || Compilation*	Left	Flexed	Semi-flexed	Extension	Extension	Knee extension	Eccentric
2	*Deadlift Hamstring Tears || Compilation*	Left	Flexed	Semi-flexed	Extension	Extension	Knee extension	Eccentric
3	*Deadlift Hamstring Tears || Compilation*	Left	Semi-flexed	Semi-flexed	Extension	Extension	Hip extension	Concentric
4	*Deadlift Hamstring Tears || Compilation*	Right	Flexed	Semi-flexed	Static	Extension	Knee extension	Eccentric
5	*Deadlift Hamstring Tears || Compilation*	Left	Flexed	Semi-flexed	Static	Extension	Knee extension	Eccentric
6	*Deadlift Hamstring Tears || Compilation*	Right	Flexed	Semi-flexed	Extension	Extension	Knee extension	Eccentric
7	*Deadlift Hamstring Tears || Compilation*	Left	Flexed	Semi-flexed	Static	Extension	Knee extension	Eccentric
8	*Deadlift Hamstring Tears || Compilation*	Left	Semi-flexed	Semi-flexed	Static	Extension	Knee extension	Eccentric
9	*Did I Tear My Hamstring?*	Left	Flexed	Semi-flexed	Static	Extension	Knee extension	Eccentric
10	*Deadlift Hamstring*	Right	Flexed	Semi-flexed	Extension	Extension	Knee extension	Eccentric

	Tear June 22 2020							
11	*Hamstring Injury. Lulz*	Left	Flexed	Semi-flexed	Static	Extension	Knee extension	Eccentric
12	*Did I tear my hamstring! deadlift workout video*	Right	Flexed	Semi-flexed	Extension	Extension	Knee extension	Eccentric
13	*Johnnie Jackson pulls hamstring on 3rd deadlift attempt*	Left	Semi-flexed	Semi-flexed	Extension	Static	Hip extension	Concentric
14	*700 LBS x 6! || Rehabbing a Hamstring TEAR with the RHINO || Stan Efferding Proving It DVD Update!*	Left	Semi-flexed	Semi-flexed	Extension	Static	Hip extension	Concentric
15	*4x world strongest man Brian Shaw tears hamstring*	Left	Flexed	Semi-flexed	Static	Extension	Knee extension	Eccentric
16	*Charlie Driscoll hamstring tear 2011*	Right	Semi-flexed	Semi-flexed	Extension	Extension	Knee extension	Eccentric

Table 3. Demographics and characteristics of acute hamstring injury events

Factors		**Count (%)**
Affected side	Left	11 (69)
	Right	5 (31)
Hip Position	Flexed	11 (69)
	Semi-flexed	5 (31)
	Extended	0 (0)
Knee Position	Flexed	0 (0)
	Semi-flexed	16 (100)
	Extended	0 (0)
Load Mechanism	Eccentric	13 (81)
	Concentric	3 (19)
	Isometric	0 (0)

The most common positions leading to injury were flexed hip (69%; n=11) and semi-flexed knee (100%; n=16), with the most common hamstring loading mechanism being eccentric (81%, n=13) (Table 3). Flexed hip with semi-flexed knee and eccentric hamstring loading was the most frequent pattern (69%; n=11) among three injury patterns identified (Table 4, Figure 2). Concentric hamstring loading with semi-flexed hip and semi-flexed knee was also observed (19%; n=3) (Figure 3).

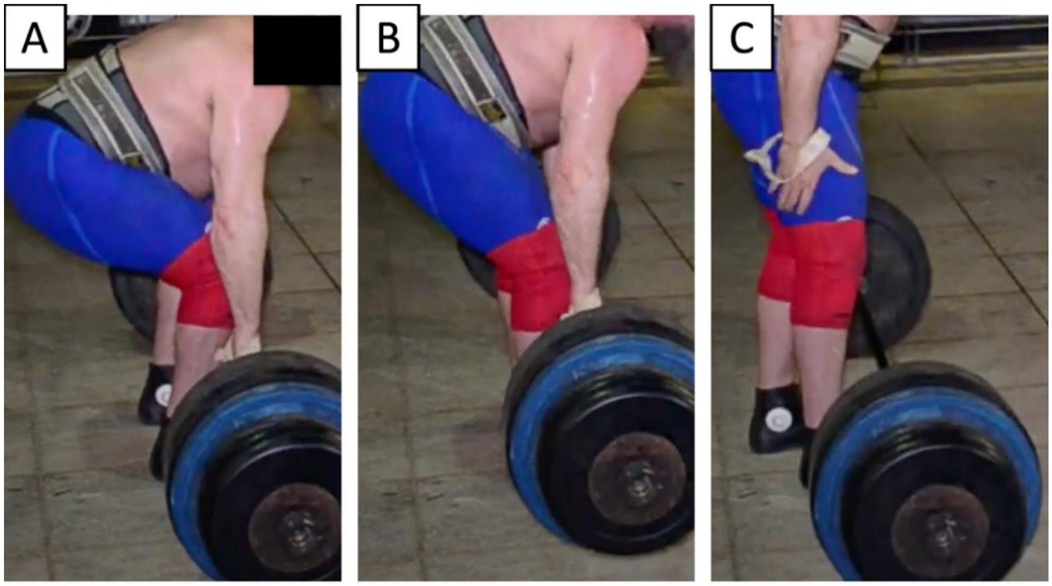

Figure 2. Flexed hip, semi-flexed knee, and eccentric contraction (pattern I) leading to injury. Displaying a) initial position, b) position at injury, and c) immediate aftermath. Sourced from: "Deadlift Hamstring Tear June 22 2020 [video]".

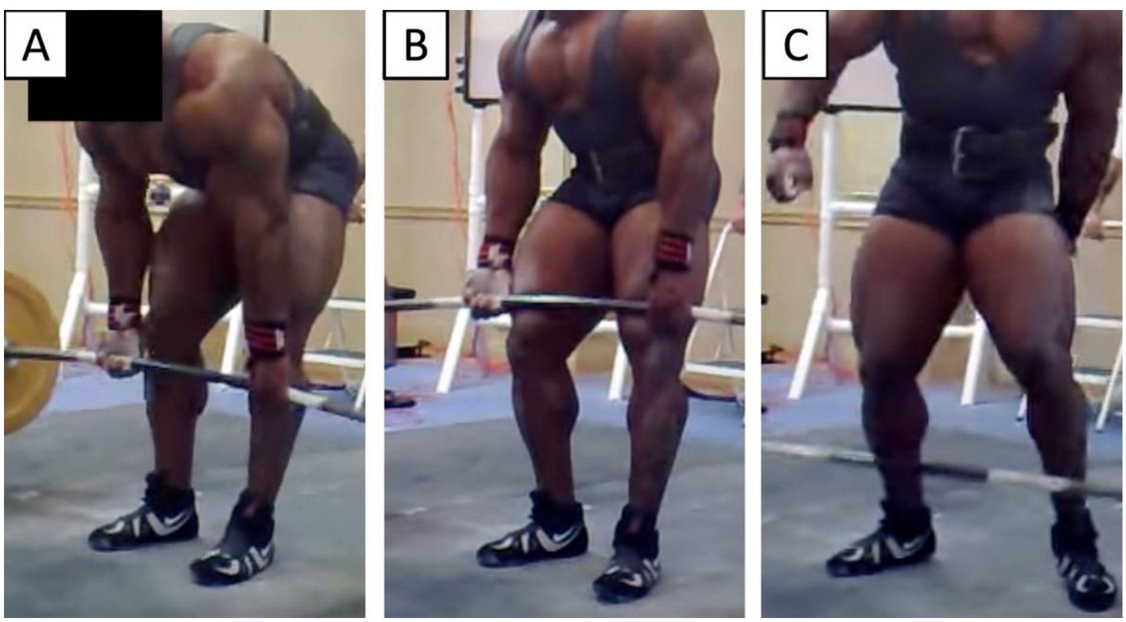

Figure 3. Semi-flexed hip, semi-flexed knee, and concentric contraction (pattern II) leading to injury. Displaying a) position before significant hip extension, b) position at injury, and c) immediate aftermath. Sourced from: "Johnnie Jackson pulls hamstring on 3rd deadlift attempt [video]".

Table 4. Observed patterns of acute hamstring strain injury mechanisms

Pattern	Hip Position	Knee Position	Load Mechanism	Count (%)
I	Flexed	Semi-flexed	Eccentric	11 (69)
II	Semi-flexed	Semi-flexed	Concentric	3 (19)
III	Semi-flexed	Semi-flexed	Eccentric	2 (13)

DISCUSSION

To the authors' knowledge, this is the first study that uses contemporaneous video analysis to identify the mechanistic factors leading up to acute hamstring injuries. The hamstring muscle group is comprised of three muscles — the semitendinosus, semimembranosus, and biceps femoris (19-21). All the hamstrings muscle originate from the ischial tuberosity and cross both the femoroacetabular and tibiofemoral joints, with the exception of the short head of the biceps femoris which originates from the middle third of the linea aspera on the femur and crosses only the knee joint (21). Due to their biarticular nature, the hamstrings play a prominent role in both hip extension and knee flexion.

Hamstring injuries occur via two main mechanisms described in the literature, namely a high-speed running-type mechanism and a stretch-type mechanism (5, 6, 21). Hamstring injuries during high-speed running are believed to occur during the terminal swing phase of the gait cycle, when the hamstrings achieve maximal length and engage in eccentric contraction to decelerate the limb in preparation for foot contact (6, 22-26). In other words, an injury occurs when an elongating or elongated hamstring muscle experiences significant eccentric loading. The biceps femoris incurs the highest degree of musculotendon stretch which could be a contributing factor to its relatively higher susceptibility to injury compared to the other two hamstring muscles (22-27). The stretch-type of hamstring injury can occur during both slow and fast movements that involve extensive hip flexion with an extended knee (6, 28). Such movements position the hamstring in an extreme stretch, frequently leading to a proximal injury of the hamstring muscles at their ischial tuberosity origin (29). This mechanism is commonly observed when an athlete gets injured while kicking a ball, picking a ball up from the ground while running, during ballet dancing, or while water skiing (6, 29).

These mechanisms may account for hamstring injuries during the deadlift. The barbell deadlift is a compound weightlifting exercise that involves lifting a barbell off the floor in a fluid motion by extending the hips and knees (19, 20). Phases of the deadlift can be identified by their temporal relation to three main events: the liftoff, knee-pass, and lift completion (Figure 1). The liftoff is the first moment that the barbell leaves the floor, during which knee extension is the dominant action (19, 20). Knee pass is the moment that the barbell vertically passes the knees, during which knee and hip extensors contribute relatively equally (19, 20). Finally, lift completion is the moment when the hips and knees are fully extended and the shoulders are thrusted back, with dominant hip extension immediately preceding this position (Figure 1) (19, 20).

Most of the injuries observed in this study (Pattern I and III) occurred while the barbell was still vertically below the level of the lifters' knees. In all of these cases (n=13), knee extension was observed to be the dominant joint action leading to injury, which was expected given that the injuries occurred before knee pass (Figure 2). Since the hamstring muscles were elongating leading to injury, this warrants an eccentric classification of the hamstring loading mechanism. This finding aligns with current understanding that hamstring injuries occur most often during sudden, forceful eccentric contraction (30). These cases also appear similar to the running-type injury mechanism, which involves significant eccentric loading to an elongating hamstring muscle (6, 22-26).

This study also had three cases (Pattern II) in which the injury occurred when the barbell was vertically at or above the level of the knees, and the primary joint action preceding injury was hip extension (warranting a concentric classification of the hamstring loading mechanism). The mechanistic parameters leading to injury in these cases clearly do not align with the running-type injury (involving concentric contraction as opposed to eccentric), and do not seem to align with the stretch-type mechanism. However, despite seeming opposite to the stretch-type mechanism in name, this injury pattern may bear some resemblance to it. For example, although none of the knees were in full extension during the injury, they were close to it after considerable extension from their starting point during the deadlift. Similarly, while the hips were actively extending from their flexed starting positions, they still remained "semi-flexed" at the moment of injury. Despite efforts to actively shorten the hamstring muscles with hip extension, maintaining "near-extended knees" with semi-flexed hips may still induce enough stretch to cause a proximal hamstring injury, especially during strenuous exertion. Stretch-type hamstring injuries have previously been identified in physical activities such as kicking a ball, picking up a ball off the ground, ballet dancing, and water skiing. To our knowledge, this is the first study analyzing hamstring injuries developed during deadlifts, which are unique in the way the hamstring muscles perform tremendous exertion while remaining in a stretched position. Differences in how stretch-type injuries manifest during deadlifts compared to during other activities may explain why this pattern differs from stretch-type injury described in the literature. Another possibility is that previous studies analyzing stretch-type injuries have relied on patient recall rather than direct observation by the researchers (6). The subtle distinction between mechanistic details (such as a fully extended knee vs a near-extended knee, or a flexed hip vs a semi-flexed hip) may be difficult for patients to discern during an episode or recall accurately, especially if the activity requires concentration on a task or causes severe pain. If this is the case, it may be possible that stretch-type hamstring injuries can occur outside of the precise mechanistic circumstances previously reported in the literature.

Using video analysis addresses an important limitation in many previous hamstring injury studies—the reliance on patient recall of injury situations or estimates of high-risk positions rather than direct observation of actual hamstring injuries (6). For example, a 2020 systematic review of hamstring injury mechanisms reported that 7 out of 10 eligible studies using kinematic analysis had to estimate the point of highest hamstring injury risk, and 2 of the 3 studies using real-time data had involved the same subject (6). In the same systematic review, all eligible studies that performed EMG-based kinematic analysis relied on estimates of when hamstring injuries would occur, rather than studying actual hamstring injuries (6). Since this study involves direct observation of the hamstring injuries as they occurred, it is not subject to this limitation.

One important limitation that does exist in this study is the small sample size, as only 16 injury events were found to be eligible for inclusion. If more data becomes available in the future, another investigation would be recommended to achieve greater power. It should be emphasized, however, that the purpose of this study was not to estimate the relative frequency of each mechanistic parameter for hamstring injuries in the population—this would not be feasible given the small sample size and unique mechanism of deadlifting that is difficult to generalize to other sports or situations. Instead, the objective was simply to determine how mechanisms of acute hamstring injury observed on video analysis compare to those proposed in the literature. Another limitation of this study is the inability to verify each patient's diagnosis through formal medication examination, diagnostic imaging, or access to medical records. Musculoskeletal ultrasound and magnetic resonance imaging would be the best modalities to verify the precise nature, severity, and localization of the injury. However, in cases where the injury mechanism and sudden onset of symptoms provide high suspicion of a hamstring injury, physical examination and diagnostic imaging are more commonly used to determine the location and severity of the injury than to actually verify its presence (4, 28). All the videos analyzed in this study included the word "tear", "injury", or "pull" to describe the impact on the hamstring in the video titles (10-18) Given this, the high-risk nature of the deadlift, and the abrupt posterior thigh pain observed on video analysis, the presence of hamstring injury in these cases can be reasonably assumed. Video analysis of injury mechanisms have provided useful conclusions in studies of other musculoskeletal injuries despite absence of radiographic correlation (7-9). Correlating video analysis with specific muscle localization and severity of injury through diagnostic imaging could be an interesting focus of future investigations.

CONCLUSION

Acute hamstring injuries during deadlifts occurred by eccentric hamstring loading with a semi-flexed knee and a flexed or semi-flexed hip, or by concentric hamstring loading with a semi-flexed knee and semi-flexed hip. The former aligns with the running-type mechanism described in the literature. The latter resembles, but differs slightly from, the stretch-type mechanism described in the literature. The reason for this difference is not clearly understood and should be explored further.

APPLICABLE REMARKS

- Improved understanding of factors leading to hamstring injury can inform practices that reduce injury occurrence.

AUTHORS' CONTRIBUTIONS

Study concept and design: Andre Dao, Flaviu Trifoi, Thomas Qu, Soroush Nedaie, Geoff MacDonald, Amr Elmaraghy. Acquisition of data: Andre Dao, Flaviu Trifoi, Thomas Qu, Soroush Nedaie, Geoff MacDonald, Amr Elmaraghy. Analysis and interpretation of data: Andre Dao, Flaviu Trifoi, Thomas Qu, Soroush Nedaie, Amr Elmaraghy. Drafting the manuscript: Andre Dao, Flaviu Trifoi, Thomas Qu, Soroush Nedaie. Critical revision of the manuscript for important intellectual content: Andre Dao, Flaviu Trifoi, Thomas Qu, Soroush Nedaie, Geoff MacDonald, Amr Elmaraghy. Statistical analysis: Andre Dao, Thomas Qu. Administrative, technical, and material support: Geoff MacDonald. Study supervision: Amr Elmaraghy.

CONFLICT OF INTEREST

The authors have no financial interests related to the material in the manuscript. The authors have no conflicts of interests to disclose.

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