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Challenging the mechanism of distal biceps tendon rupture using a video analysis study

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Aims

The conventionally described mechanism of distal biceps tendon rupture (DBTR) is of a 'considerable extension force suddenly applied to a resisting, actively flexed forearm'. This has been commonly paraphrased as an 'eccentric contracture to a flexed elbow'. Both definitions have been frequently used in the literature with little objective analysis or citation. The aim of the present study was to use video footage of real time distal biceps ruptures to revisit and objectively define the mechanism of injury.

Methods

An online search identified 61 videos reporting a DBTR. Videos were independently reviewed by three surgeons to assess forearm rotation, elbow flexion, shoulder position, and type of muscle contraction being exerted at the time of rupture. Prospective data on mechanism of injury and arm position was also collected concurrently for 22 consecutive patients diagnosed with an acute DBTR in order to corroborate the video analysis.

Results

Four videos were excluded, leaving 57 for final analysis. Mechanisms of injury included deadlift, bicep curls, calisthenics, arm wrestling, heavy lifting, and boxing. In all, 98% of ruptures occurred with the arm in supination and 89% occurred at 0° to 10° of elbow flexion. Regarding muscle activity, 88% occurred during isometric contraction, 7% during eccentric contraction, and 5% during concentric contraction. Interobserver correlation scores were calculated as 0.66 to 0.89 using the free-marginal Fleiss Kappa tool. The prospectively collected patient data was consistent with the video analysis, with 82% of injuries occurring in supination and 95% in relative elbow extension.

Conclusion

Contrary to the classically described injury mechanism, in this study the usual arm position during DBTR was forearm supination and elbow extension, and the muscle contraction was typically isometric. This was demonstrated for both video analysis and 'real' patients across a range of activities leading to rupture.

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Introduction

Distal biceps tendon rupture (DBTR) is a common injury that typically occurs in males participating in sporting, recreational or working activities. The originally described mechanism of injury by Dobbie[1] in 1941 was of a "considerable extension force suddenly applied to a resisting, actively flexed forearm". In more contemporary literature, this same description has been refined to describe an eccentric contraction that occurs during mid flexion to cause DBTR.[2-4] There has been extensive research into the anatomy, biomechanics, and surgical techniques employed to treat DBTR; however, there has been limited investigation into the exact injury mechanism or how this might affect lifting technique and rehabilitation.[5-7] Indeed, the originally proposed mechanism has become so ingrained in our understanding of DBTR

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Fig. 1
A deadlift performed with a mixed supinated (right arm) and pronated (left arm) grip.

that its source is rarely referenced, implying that it is correct beyond doubt.

One sporting discipline that is recognized as high risk for DBTR is powerlifting, specifically the deadlift exercise. This requires the participant to lift a heavy barbell from the floor, stand up straight with the bar held at hip level, and then lower it to the floor again. During this movement, the elbow remains fully extended and static throughout, which is at odds with the classically described mechanism of DBTR. Additionally, the forearm may be pronated or supinated depending upon individual grip preference (Figure 1). Personal trainers instructing on deadlift technique have cited the supinated forearm grip as being an at-risk position for DBTR, as opposed to the pronated grip.[8] This implies that elbow and forearm position may be important contributing factors to the mechanism of injury, rather than the type of muscle contraction involved.

This contradiction was also evident in our clinical practice, with the majority of patients clearly describing an extended arm position at the time of rupture and led to development of the hypothesis that the classically described injury mechanism may not apply to a substantial proportion of patients presenting with DBTR.

The availability of social media and online resources has provided new insights into injury mechanism and has been used by several authors to challenge traditional thinking about other orthopaedic injuries.[9-11] A number of videos depicting DBTR during powerlifting and other activities are available on open access media, providing the opportunity for systematic analysis.

Hence, the primary aim of this study was to use videos that depict DBTR to better understand the exact mechanism of rupture, with reference to activity being performed, arm position, and muscle force. The secondary aim was to compare the findings of the video analysis with the mechanism reported by patients presenting to our institution with an acute DBTR.

Methods

Video analysis. An online search of Google video, Yahoo video, and YouTube was performed in January 2021. The terms 'bicep/s rupture' or 'bicep/s tear' were searched for independently and then in combination with the terms 'deadlifting', 'weightlifting', 'bodybuilding', and 'bicep curls'. When a new mechanism of injury was encountered within a video search (e.g. 'arm wrestling', 'calisthenics', 'boxing'), these were also added to the search terms in order to identify more examples.

Inclusion and exclusion criteria. Only videos where there was clear visual evidence of a DBTR were included. This was defined as an obvious visible change in contour of the distal biceps during activity, with associated pain localised to the anterior elbow by the subject.

Videos citing a DBTR where visual evidence of the injury was not apparent to the assessors were excluded as were videos where there may have been an alternate tendon rupture present, such as rotator cuff, pectoralis major, or long head of biceps. Duplicate videos found across multiple websites were also excluded.

Data collection. Demographic data recorded included activity being performed during rupture, sex, and arm laterality.

The position of the shoulder and elbow at the moment of injury was recorded and categorized as forearm position (pronation/neutral/supination); elbow position (0° to 10° flexion/10° to 45° flexion/45° to 90° flexion/ > 90° flexion); and shoulder position (extended/0° to 30° forward flexion (FF)/30 to 90° FF/ > 90° FF). These categories were chosen as they were simple to gauge for the assessors. Smaller increments of position were not chosen in order to avoid compromising accuracy.

The type of biceps muscle contraction was estimated based upon direction of elbow and forearm movement at the time of injury, as described by Brukner et al[12] (flexing = concentric; static = isometric; and extending = eccentric).

Assessors. Three surgeons (CJ, MD, JP) independently reviewed all videos and recorded their findings. Two surgeons were fellowship trained shoulder and elbow surgeons and the third was a pre-fellowship senior orthopaedic resident. Any discrepancies between the reviewers were discussed as a group before coming to universal agreement. Assessors were permitted to view the videos as many times as necessary and to slow the video playback speed in order to be certain of data collection.

Interobserver correlation between the assessors was calculated using the free-marginal Fleiss kappa tool for measuring agreement of multiple observers of categorical data. Correlation scores of 0 to 0.39 were rated as poor; 0.4 to 0.6 as fair; 0.61 to 0.75 as good; and > 0.75 as excellent.

Clinical data collection. In order to understand the wider applicability of the results obtained from the video analysis, data regarding mechanism of injury, arm position, and force was also collected prospectively for 22 consecutive patients with a complete DBTR treated by the senior author (JP) between January 2021 and September 2021. Partial ruptures were not included. Care was taken to avoid influencing patients during questioning, but patients were pressed to describe the exact position of the arm and direction of movement at the moment of DBTR. Direction of motion was used as a surrogate for eccentric, concentric, and isometric force based on the definition of muscle forces cited previously.[12]

Results

Video analysis. A total of 61 videos were identified, of which four were excluded. In three videos, there was not a clear visual diagnosis of DBTR, while in the other the injured limb was obscured from view. This left 57 videos demonstrating a DBTR for inclusion in the final analysis.

Demographics and activity type. All DBTR occurred in male subjects, with 21 (37%) occurring in the right arm and 36 (63%) in the left. The most common activity being performed at the time of DBTR was deadlifting in 38 individuals (67%), followed by biceps curls in five (9%); a calisthenics ‘planching’ manoeuvre in five (9%); arm wrestling in four (7%); lifting heavy objects (e.g. atlas stones) in three (5%); and boxing in two males (3%).

Arm position. At the time of injury, the forearm was supinated in 56 cases (98%) and neutral in one case (2%). DBTR was never observed when the forearm was pronated.

The elbow position at rupture was between 0° to 10° flexion in 51 cases (89%), and 10° to 45° flexion in the remaining six cases (11%). The elbow was never observed to be flexed > 45° at the point of DBTR.

The shoulder position at rupture was observed to be in extension in one case (2%); 0° to 30° forward flexion in 37 cases (65%), and 30° to 90° forward flexion in 19 cases (33%). The shoulder was never observed to be in forward flexion greater than 90° at the point of rupture.

Muscle contraction. The type of muscle contraction at the time of injury was concentric in three cases (5%), isometric in 50 cases (88%), and eccentric in four cases (7%).

Inter-observer correlation. Interobserver correlation regarding forearm rotation, elbow flexion, shoulder position and type of muscle contraction were 0.89 (excellent), 0.66 (good), 0.86 (excellent), and 0.68 (good), respectively.

Prospective clinical data. Table I shows the data collected for the prospective series of patients.

Demographics ans activity type. All 22 patients were male. Mean age was 47 years (28 to 64). In all, 11 patients had a left-sided rupture (50%) and 11 were right-sided (50%); seven patients (32%) sustained a DBTR during sports, while the remaining 14 (68%) occurred during some form of manual non-sporting activity.

Arm position. The forearm position at the time of rupture was supinated in 18 patients (82%), pronated in one patient (4.5%), neutral in two patients (9%), and one patient (4.5%) was unsure about forearm position.

Discussion

In this study, we were able to perform an in depth analysis of DBTR mechanism using open access video footage. In addition, we were able to correlate the video findings with real clinical cases.

The most common position of rupture observed was a supinated arm with full or near-full elbow extension, and the most common force at the time of rupture was isometric. Moreover, there was not a single rupture observed in a flexed elbow or pronated forearm.

This ‘alternative’ mechanism has also been reported by two other authors using similar methodology recently. Kapicioglu et al[6] focused on deadlifting as an

Table I. Data from 22 consecutive patients treated for DBTR by the senior author.

Sex	Age, yrs	Affected arm	Activity during rupture	Forearm rotation	Degree of elbow flexion	Force
M	41	Right	Gardening	Neutral	Near extension	Flexing
M	52	Left	Lifting pool table	Supinated	Fully extended	Flexing
M	58	Right	Lifting dog into car	Supinated	Near extension	Flexing
M	42	Left	Rugby - arm forced back	Supinated	Hyperextended	Unsure
M	52	Left	Lifting fence panel	Pronated	Near extension	Flexing
M	49	Right	Lifting metal panel	Supinated	Near extension	Flexing
M	52	Left	Moving cupboard	Supinated	Near extension	Flexing
M	50	Left	Goalkeeping	Supinated	Hyperextended	Unsure
M	34	Right	Deadlifting	Supinated	Extended	Unsure
M	48	Left	Restraining assailant	Unsure	Unsure	Unsure
M	28	Left	Rugby tackle	Supinated	Hyperextended	Unsure
M	40	Left	Catching falling box	Supinated	Near extension	Unsure
M	39	Right	Picking up plaster board	Supinated	Extended	Flexing
M	64	Right	Opening sash window	Supinated	Near extension	Flexing
M	53	Right	Catching falling ladder	Supinated	Extended	Unsure
M	53	Right	Restraining assailant	Supinated	Hyperextended	Unsure
M	56	Right	Lifting wheel barrow	Neutral	Extended	Flexing
M	36	Left	Biceps curl	Supinated	Near extension	Flexing
M	53	Right	Catching falling cupboard	Supinated	Extended	Unsure
M	38	Right	Catching falling sofa	Supinated	Near extension	Unsure
M	47	Left	Chin ups	Supinated	Extended	Flexing
M	56	Left	Boxing hook	Supinated	Extended	Flexing

DBTR, distal biceps tendon rupture.

injury mechanism for DBTR. Like ours, their findings also demonstrated that DBTR occured solely in a supinated and extended arm during deadlifting. They identified fewer subjects (n = 35) for analysis than in our study because they only searched one source (YouTube) and their study focused solely on deadlifting. Furthermore, they did not look systematically at force involved at the time of rupture.

Lappen et al[5] also only searched YouTube in their video analysis study. They did, however, include other mechanisms of injury in their analysis, including arm wrestling, biceps curls, and calisthenics, although they still found that deadlifting was the most commonly recorded mechanism. Similar to our study, they attempted to define the type of force associated with rupture, although this was classified as compressive or tensile with respect to deformation of the elbow joint. While they concluded that in the majority of injuries, the elbow underwent a tensile force, this is not a commonly used terminology with respect to describing a muscle force. In our study, we defined muscle force as isometric, concentric or eccentric according to the direction of motion at the time of rupture and were able to demonstrate that the most common force was actually isometric, rather than eccentric as usually described.[3,4]

Neither study performed repeat observations of the videos,[5,6] hence inter- and intraobserver reliability of their findings was not reported as in our study.

In the present study, we analyzed a greater number of videos and included injury mechanisms not seen in the other two studies, such as boxing; however, given the closeness in time of these studies to ours, there will have been inevitable crossover in the videos analyzed. This could be interpreted as a limitation, but it also means that across the three studies, eight independent observers have all concluded that combined supination and full or near full elbow extension is the at risk position for DBTR particularly in strength training disciplines.

A further limitation of video analysis is that we were only able to comment on mechanism, which was the primary focus of our study. We were not able to comment on the pathoanatomic nature of the ruptured tendon, such as whether the tear involved the lacertus fibrosus, the musculotendinous junction, or the short head in isolation, all of which may occur.[4,13]

Interestingly, in a previous clinical study, Schamblin et al[7] reported that six patients with a musculotendinous junction tear of the distal biceps tendon all described their arm position as between 0° to 45° flexion and in full supination at the time of injury. The authors proposed that musculotendinous junction tears may occur through a different mechanism to the more common tendon avulsions.

A further limitation of this type of video analysis is that the included videos are non-standardized and not peer reviewed. Consequently, we had to be rigorous in our inclusion criteria to ensure that videos were of sufficient quality to perform accurate analysis. Indeed, in a study looking at quality of YouTube videos in relation to DBTR, Foster et al[14] concluded that the overall quality was poor, although the scope of their study was to analyze content rather than visual clarity. They also reported that videos posted by academic and non-academic sources were of similar poor standard with reference to content and information.

Previously, deadlifting has not been widely considered in the medical literature as an at risk discipline for DBTR, even in studies specifically looking at injuries that occur during lifting sports.[15] This is in contrast to the weight-lifting community where deadlifting is a well-recognized mode of DBTR.[8] While it is clear from our results that deadlifting with a supinated forearm grip is associated with DBTR, this is not the type of activity that the most patients presenting with DBTR in clinical practice describe. It is also not possible to capture video footage of most DBTR as they occur during daily lifting activities that take patients by surprise, rather than during controlled controlled lifting exercises where filming can be performed.

We therefore performed the prospective data collection of 'routine' presenting patients in order to understand whether our findings were exclusive to dead-lifting and strength sports, or more generalizable to patients representative of the general population presenting with DBTR. This is a unique feature of the present study. The majority of subjects (82%) in the clinical series described a supinated forearm position and 95% reported an extended elbow position at the time of rupture.

None of the patients described a flexed position. It was more challenging for the patients to recall the direction of elbow movement at the time of rupture given that the rupture occured suddenly and unexpectedly; however, there were none that described an extension movement of their arm (eccentric force), which was consistent with our video observations.

While it is acknowledged that unconscious bias from the clinician interviewing the patients could have influenced the patients' answers, great care was taken to avoid this, and we are confident that the findings are reflective of the true nature of DBTR in the majority of patients, not just lifting athletes.

Further confirmation of this is that even in the video cohort, the DBTRs that happened during non-lifting sports also occurred in the same mechanism, and in Schamblin et al's[7] series of six patients, none were performing a powerlifting discipline.

The findings of this study challenge the validity of the common notion that DBTR occurs due to 'an eccentric contracture in a flexed elbow'. This originally described mechanism was based on opinion, derived from a survey of clinicians unfamiliar with DBTR at a time when the foundations of our understanding of DBTR were being laid.[1] The aim of the present study was not to undermine the work of our predecessors, but to build on our knowledge by using methods only recently available. Similar studies using video analysis have challenged our thoughts regarding both knee and elbow instability for instance.[9-11]

Clinicians may feel that mechanism of injury is irrelevant once a DBTR has been diagnosed; however, we feel our findings are potentially important for both injury prevention and rehabilitation. For instance, from our results, we would strongly recommend against a supinated forearm grip during powerlifting disciplines and avoidance of trying to 'lift' the bar with the forearm but to concentrate on initiating power from the legs and back muscles, as per the correctly taught technique.[8]

Therapists can also use these results to guide rehabilitation following DBT repair by exercising caution during terminal elbow extension and forearm supination, and with pronation and flexion seeming to provide a protective role until tendon healing has consolidated. This is substantiated by electromyographic studies that demonstrate that forearm position has an influence on the intermuscular co-ordination of the biceps and brachioradialis. The biceps exhibits increased activity with the arm in supination, and inhibited activity in pronation. The opposite is true for brachioradialis, with a compensatory increase in activity with pronation, which may provide load sharing between the two muscles when the forearm is in neutral or pronation.[16,17]

Further areas of study to help understand our findings may relate to the anatomy of the radioulnar space in pronation and supination, and the force imparted on the tendon insertion at different points of extension and supination; however, these are beyond the scope of this article.

In conclusion, this is the most in-depth study to objectively analyze the mechanism of DBTR in a video analysis and clinical cohort of subjects. The findings suggest that arm position is a critical factor in DBTR with combined forearm supination and elbow extension being the at-risk position. In addition, the muscle force causing rupture in this at-risk position is likely to be concentric or isometric rather than eccentric. These findings have implications for training and rehabilitation and warrant further anatomical and biomechanical research.

Take home message

- Arm position is a critical factor in distal bicep tendon rupture with combined forearm supination and elbow extension being the at-risk position.
- In addition, the muscle force causing rupture in this at-risk position is likely to be concentric or isometric, rather than eccentric.
- These findings have implications for training and rehabilitation and warrant further anatomical and biomechanical research.

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- W. Chaundy: Conceptualization, Methodology, Writing - review & editing.
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