Original Research

The Role of Deadlifts in Distal Biceps Brachii Tendon Ruptures

An Alternative Mechanism Described With YouTube Videos

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Background: The classic injury mechanism of a distal biceps brachii tendon rupture (DBBTR) is eccentric loading to the flexed elbow when the forearm is supinated.

Purpose: To determine alternative mechanisms of a DBBTR in powerlifting sports, particularly in deadlift competitions, with the use of YouTube videos.

Study Design: Descriptive epidemiology study.

Methods: A search on YouTube was performed using the search terms "distal biceps tendon rupture" and "distal biceps tendon injury" combined with "competition," "deadlift," and "powerlifting." The videos underwent an evaluation for accuracy by 3 surgeons according to predetermined criteria. Type of sports activity, participant sex, side of the injury, and arm positions at the time of the injury were recorded.

Results: Among the videos reviewed, 35 injuries were found appropriate for an evaluation. All participants were male. The majority of the injuries (n = 25) were observed during the deadlift. Only in 1 deadlift injury were both forearms in supination. In the remaining deadlift injuries (n = 24), all elbows were in extension, with 1 forearm in supination and the other in pronation. Among the deadlift injuries in the mixed-grip position, all ruptures occurred in a supinated extremity: 25% (n = 6) of ruptures occurred on the right side, and 75% (n = 18) of ruptures occurred on the left side; this was a significant difference ($P = .014$).

Conclusion: We described an alternative mechanism for a DBBTR, namely, eccentric loading to an extended elbow when the forearm is supinated during the deadlift. As all the ruptures occurred in a supinated extremity, holding the bar with both forearms in pronation may prevent or decrease the risk of ruptures during the deadlift.

Keywords: distal biceps brachii tendon; deadlift; powerlifting; video

An avulsion of the biceps brachii tendon from its distal attachment represents 3% of all biceps tendon injuries.[14] The previously reported incidence of distal biceps brachii tendon ruptures (DBBTRs) was 1.2 per 100,000 people per year,[32] whereas a recent study demonstrated that operatively treated DBBTRs had a higher incidence of 5.35 per 100,000 patients per year.[25]

The classic mechanism of a DBBTR is a flexed elbow and supinated forearm position, which is frequently encountered in weight training and athletic competitions.[14,39] The deadlift is 1 of the 3 forms of training in powerlifting, which is a type of competitive weightlifting sport. In the deadlift, both elbows are held in a fully extended position, unlike the description of the classic DBBTR mechanism. Based on previous studies, injuries during deadlift training mainly affect the lumbar region or lower extremities.[5,37]

While watching YouTube videos (www.youtube.com) on DBBTRs, we observed that these injuries occurred outside of the classic mechanism, such as during the deadlift, and that this mechanism was not described in the literature. In the current study, we aimed to determine the mechanisms of a DBBTR in powerlifting sports, particularly in deadlift competitions, and describe an alternative mechanism to the traditional theory with the use of videos on YouTube. Our hypothesis was that a DBBTR might also occur by an alternative mechanism, namely, eccentric loading to an extended elbow when the forearm is supinated in the deadlift and that holding the bar with both forearms in pronation might decrease the risk of DBBTRs.

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METHODS

This study was deemed exempt from approval by our institutional review board, as no protected health information was accessed. A search on YouTube was performed on September 1, 2019. The search terms were "distal biceps tendon rupture" and "distal biceps tendon injury" with the combination of "competition," "deadlift," and "powerlifting."

Initially, the first 100 videos for each of the 6 search terms were evaluated by the same shoulder and elbow surgeon (M.K.). Duplicate videos, technical videos including treatment methods, videos not related to a DBBTR and sports or competitions, and videos in which the anterior elbow of the participant was not distinctly visualized and did not show all stages of deadlifting were excluded. Thereafter, the remaining videos were reviewed by 3 experienced shoulder and elbow surgeons (E.B., N.G., A.P.) at a 0.5× speed for accuracy of the evaluation. Accuracy criteria were (1) clear visualization of the elbow and detachment of the distal biceps tendon with the reverse Popeye sign during the sports activity and (2) the participant's suddenly ending his activity after the injury (Figure 1).[29] If both criteria were fulfilled and a consensus was reached among the 3 surgeons based on the video, the video was included in the study. Otherwise, the video was excluded.

After the elimination of videos, the type of competition, sex, side of the affected upper extremity, and positions of the right and left elbows and forearms were recorded for each video. The elbow position was determined as "semiflexion" if the elbow was in $<90^\circ$ of flexion. If the elbow was in $\geq 90^\circ$ of flexion, the elbow position was determined as "flexion." If the elbow was in full extension, the elbow position was determined as "extension." The position of the forearm, defined as "supination" or "pronation," was based on its position at the time of the injury. None of the video creators or participants in the videos was contacted.

A deadlift can be performed in different grip positions to maximize the lifting of weights including the double-overhand grip (both forearms are in pronation), double-underhand grip (both forearms are in supination), and mixed grip (1 forearm is in supination, and other forearm is in pronation) (Figure 2).

Statistical Analysis

Statistical analysis was performed solely for the deadlift videos to prevent bias, which could have been caused by the type of sports activity, using the SPSS statistical software package (Version 21.0; IBM Corp). Categorical variables were expressed as the frequency with percentage.

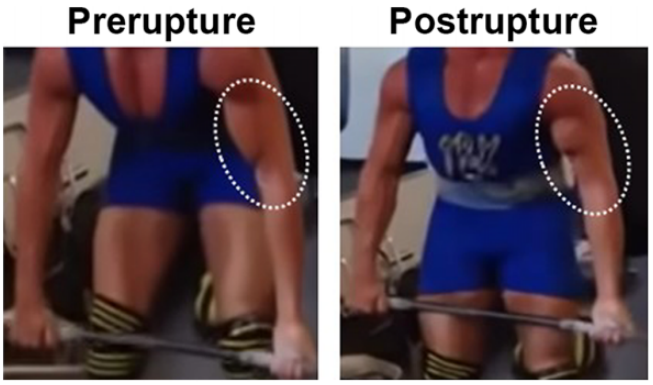

Figure 1. The elbow of a deadlifting athlete was in extension, and the forearm was in supination, during a distal biceps tendon injury. Observation of the reverse Popeye sign is typical after the injury.

Categorical comparisons were performed using the chi-square test. Results were reported as 95% CIs and related *P* values. Post hoc power analysis according to the affected side with a significance level of .05 provided a large effect size (2.11) and a power $(1 - \beta)$ of 0.96, which confirmed that the sample size was adequate. *P* values $<.05$ were considered to be statistically significant.

RESULTS

A total of 600 videos were reviewed, and among them, 35 injuries were found appropriate for an evaluation with regard to previously described inclusion and accuracy criteria. Figure 3 shows the flowchart of the video review process.

All the participants in the videos were male. The majority of the injuries were observed during the deadlift. Based on the type of sports activity, 71% (n = 25) of ruptures occurred during a deadlift, 14% (n = 5) of ruptures occurred during a biceps curl, 6% (n = 2) of ruptures occurred during truck tire lifting, 3% (n = 1) of ruptures occurred during arm wrestling, 3% (n = 1) of ruptures occurred during a stone lifting competition, and 3% (n = 1) of ruptures occurred in the Bakasana pose during yoga.

The elbow position was either flexion or semiflexion in all injuries other than those occurring during the deadlift, and these videos were excluded. In these videos (n = 10), the forearms of the participants were in supination at their injured sides. In all, 6 of 10 opposite extremities were able

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Ethical approval for this study was waived by Bezmialem Vakif University (study No. 45446446-010.99-3589).

Figure 2. The different grip positions in deadlifting: (A) double-underhand grip, (B) mixed grip, and (C) double-overhand grip.

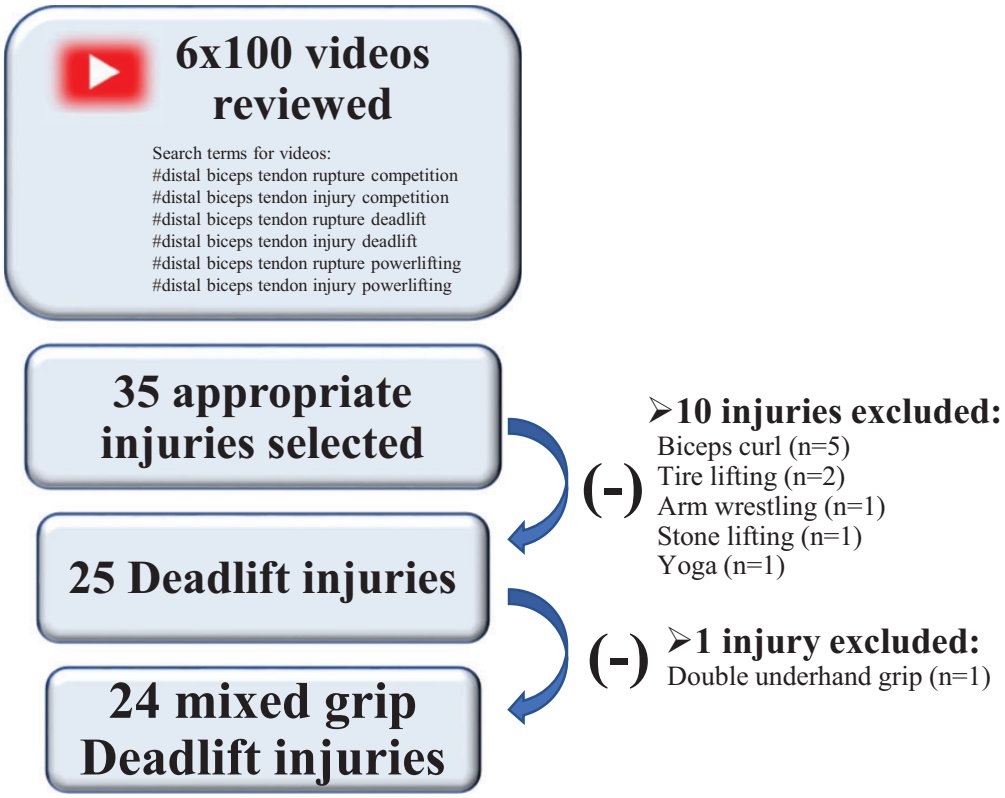

Figure 3. Flowchart of the study.

to be evaluated, and the forearms were in supination in all cases.

Only 1 of the deadlift videos was excluded because both forearms were in supination (double-underhand grip). In the remaining deadlift videos (n = 24), participants were holding the bar with their forearms in supination on 1 side and pronation on the other side (mixed grip) and with both elbows in extension, as is the standard. All the DBBTRs were observed in supinated forearms during the deadlift. No injuries were observed in pronated forearms (Appendix Table A1). Regarding the side of the injury, 25% (n = 6; 95% CI, 12%-45%) of ruptures were observed on the right, whereas 75% (n = 18; 95% CI, 55%-88%) of ruptures were observed on the left ($P = .014$). In 6 of these 24 videos, a change in elbow position, which could be a sign of eccentric contraction just before a DBBTR, was observed.

DISCUSSION

The significant finding of this study was that all DBBTRs occurred on the supinated side during the deadlift with a mixed grip, in which 1 forearm was in supination, the other forearm was in pronation, and both elbows were in full extension. No injuries were observed in pronated extremities. Moreover, all DBBTRs in the videos were observed in male athletes in whom the left side was significantly more often affected than was the right side (75% vs 25%, respectively; $P = .014$).

Patients frequently report a history of an audible pop and acute pain at the antecubital fossa after an eccentric contraction of the biceps caused by an unexpected extension force applied to a flexed elbow with the forearm in a supinated position.[31,39] However, others have reported injuries

in attempts to prevent a fall or from direct trauma just proximal to the elbow.[13,26] For some patients, it is difficult to accurately remember the position of their extremities at the time of sudden trauma, such as a DBBTR, and to clearly explain the injury mechanism to a physician. Therefore, some studies have used video-based methods to determine the mechanisms of various injury types, including ankle fractures and shoulder and elbow dislocations.[27,28,35] This research method introduced a novel approach for studying injury mechanisms.[27] Although doubt still remains on the educational role of web-based videos, this method was found to be reliable with regard to analyzing injury mechanisms during sports.[3,4,42]

The exact mechanism of a DBBTR still remains unclear; however, the 2 theories of Seiler et al[36] have been the most frequently cited. They identified a hypovascular zone 2.14 cm proximal to the distal insertion of the tendon and stated that this could make the tendon more prone to ruptures. Moreover, they demonstrated that the distance between the lateral border of the proximal ulna and radius at the level of the distal insertion of the biceps tendon was reduced by 48% when the forearm moved from supination to full pronation. They also reported that, with the forearm in full pronation, the tendon occupied 85% of the proximal radioulnar joint. Because the majority of ruptures occur at the radial tuberosity, the latter theory based on mechanical impingement was thought to be more valid.[44] In our video search of YouTube to analyze the mechanisms of a DBBTR during deadlifting, all DBBTRs (n = 24) occurred in a supinated forearm when the elbow was in extension. None of the pronated forearms were affected during the exercise. Positioning the forearm in pronation may protect against DBBTRs during deadlifting. From the perspective of DBBTRs in the position of full extension, our results may contradict 2 traditional theories on the mechanism of a rupture: (1) eccentric loading to a flexed or semiflexed elbow when the forearm is in supination and (2) impingement of the distal biceps brachii tendon during pronation of the forearm.[23,24]

Eccentric contraction is defined as the muscle lengthening while contracting when the external load is greater than the force produced by that muscle. The forces produced during maximal eccentric contractions are 80% more than those produced during other types of contractions, and injuries due to eccentric contractions in the musculotendinous unit are often the result of these exaggerated forces.[22,30,45] In sports activities such as deadlifting in which the muscles are exposed to excessive loads, lifting these loads with a mixed grip causes an increase in eccentric contraction of the biceps tendon in the supine position and thus injuries in this muscle. In our study, there were 6 of 24 (25%) cases in which the elbow position changed just before a DBBTR occurred. Therefore, DBBTRs may have been associated with eccentric contraction in these cases.

The majority of the patients with DBBTRs are male in their fourth to fifth decade of life, and 52% to 86% are affected in their dominant upper extremities.[25,32,34] Common risk factors for a DBBTR include increased body mass index, use of anabolic steroids, smoking, weightlifting, and bodybuilding.[14,25,32,43] However, Safran and Graham[32] were unable to demonstrate a correlation with steroid usage. Nevertheless, Visuri and Lindholm[43] linked bilateral DBBTRs to the use of anabolic steroids. In our study, all participants in the deadlift videos were male, and 75% of them were affected on their left sides, whereas 25% were affected on their right sides ($P = .014$). There was no predominance of dominant extremity injuries in our study. On the other hand, the fact that DBBTRs occurred on the supinated side in all participants may be a bias for the injured side. In this regard, it can only be concluded that being male carries an increased risk of a DBBTR in concordance with previous reports.

Musculoskeletal injuries in relation to powerlifting affect both the upper and lower extremities.[5,37] In a recent study, Strömbäck et al[37] investigated the localization and prevalence of injuries in powerlifting. The participants reported their injuries during the past 12 months as mostly localized to the lumbopelvic region and shoulder, followed by the hip and knee. They further revealed that based on the activity leading to the injury, 42% occurred during squat training; 27%, during the bench press; and 31%, during the deadlift. However, the injuries based on training type and specific conditions were not stated separately. In a recent review, Bengtsson et al[5] demonstrated that deadlift-specific injuries reported in the studies included lumbosacral and meniscal injuries, anterosuperior iliac spine avulsions, stress fractures of the acetabulum, pectoralis major injuries, and biceps femoris ruptures. A DBBTR was not reported among these injuries in these studies.[5,37] In another study, D'Alessandro et al[14] reported the results of anatomic double-bundle repair of 10 DBBTRs in athletes. All of the patients were men, with an average age of 40 years. Moreover, 8 of them were weightlifters and bodybuilders participating in competitive sports activities. However, most of the injuries occurred during other activities, such as lifting furniture, rodeo riding, or handball. Only 1 rupture in a bodybuilder occurred during the biceps curl exercise. Nevertheless, there were no injuries reported during powerlifting or deadlift training. Schneider et al[34] demonstrated the results of 10 patients with nonsimultaneous bilateral DBBTRs. They reported that a rupture in 7 patients occurred during sports, while 5 of the patients had a history of regular weightbearing at the time of the injury. However, they did not specifically mention the lifting activities that were responsible for the tendon ruptures. Despite the considerable injury rate of the upper extremities, studies have mainly focused on the spine and lower extremities, such as the hips, knees, or ankles, based on biomechanical analysis of the deadlift.[21,38] The positions of the upper and lower extremities as well as body posture may contribute to the mechanism of injury of the distal biceps tendon. Therefore, our results revealed the necessity of evaluating the biomechanical forces applied to the shoulders, elbows, and forearms during the deadlift. Further investigations based on both kinematics and kinetics of the upper extremities will help us better understand the mechanism of a deadlift-related DBBTR.

Our study had some limitations. Although strong accuracy criteria were used when including the videos, and all analyzed videos met the inclusion criteria, the lack of radiologic evidence may create uncertainty regarding the reliability of the findings. As none of the video creators or participants in the videos was contacted, the effects of other

predisposing factors, such as steroid or tobacco use, could not be evaluated. The amount of weight that was lifted, which can also predispose a person to ruptures, was not taken into account. In addition, the small size of the study population may have limited the power of the current study. Nevertheless, this methodology provided a considerable contribution to the present knowledge about the mechanism of a DBBTR, in particular during the deadlift. Furthermore, to our knowledge, this video analysis study is the first reported video series of DBBTRs in relation to the deadlift.

CONCLUSION

An alternative mechanism for a DBBTR was described, namely, eccentric loading to an extended elbow and supinated forearm during the deadlift, which is different from the classic mechanism of a flexed elbow and supinated forearm. Moreover, holding the bar with both forearms in pronation during the performance of a deadlift may prevent or decrease the risk of a DBBTR.

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APPENDIX

TABLE A1
YouTube Videos About DBBTRs During Mixed-Grip Deadlifting[a]

Video Title	Description
Distal biceps tendon rupture[20]	A DBBTR can be observed in the supinated left forearm of the male athlete. At the end of the video, proximal migration of the biceps is clear in slow motion.
Biceps tendon tear – deadlift[12]	During training for a university deadlift competition, a DBBTR in the supinated left forearm is observed. A "pop" can be heard in the video.
Distal bicep tendon tear while deadlifting[18]	A DBBTR occurred in the supinated left forearm of the male athlete in his final deadlift attempt with 255 kg at the 2013 Northern Ontario Powerlifting Open. A "pop" can be heard in the video.
550 lb deadlift bodyweight 181 lb ruptured bicep distal tendon[2]	A DBBTR can be seen in the supinated right forearm of the male athlete at the fitness center. The athlete could not continue deadlifting.
SCARY bicep tear! Pavlo Nakonechnyy deadlift 415 kg / giant from Ukraine[33]	A DBBTR can be observed in the supinated right forearm of the athlete in his third round with 410 kg in the deadlift competition.
Deadlifting 815 lbs after a bicep tear[17]	A DBBTR occurred in the supinated left forearm while lifting 815 lb.
Torn bicep during deadlift[40]	A DBBTR can be seen in the supinated left forearm of the male athlete during a deadlift event. The slight change in the elbow position just before the DBBTR can be a sign of eccentric contraction.
Distal biceps tendon rupture[19]	A DBBTR can be seen in the supinated right forearm of the male athlete at the fitness center. The slight change in the elbow position just before the DBBTR can be a sign of eccentric contraction.
Bicep tear while deadlifting 675[11]	A DBBTR can be observed in the supinated left forearm of the male athlete who was lifting 675 lb at the fitness center. Proximal migration of the biceps is clear in the video. The slight change in the elbow position just before the DBBTR can be a sign of eccentric contraction. The video was evaluated at a 0.5× speed.
Bicep rupture 300 kg deadlift[7]	A DBBTR occurred in the supinated left forearm of the male athlete who was lifting 300 kg at the fitness center.
Torn distal bicep tendon 4/21/2018[41]	A DBBTR can be seen in the supinated left forearm of the male athlete who was lifting 620 lb in a competition. The slight change in the elbow position just before the DBBTR can be a sign of eccentric contraction.
505 lb deadlift and distal bicep tendon tear[1]	A DBBTR can be observed in the supinated left forearm of the male athlete who was lifting 505 lb at the fitness center.
Deadlift biceps tear[15]	A DBBTR can be observed in the supinated left forearm of the male athlete at the fitness center.
Dead lift tendon tear[16]	A DBBTR occurred in the supinated left forearm of the male athlete who was lifting 302.5 kg in a competition.
Bicep tear[8]	A DBBTR can be seen in the supinated left forearm of the male athlete who was lifting 245 kg in a competition.
Bicep tear during deadlift[10]	A DBBTR can be observed in the supinated left forearm of the male athlete who was lifting 600 lb at the fitness center.
Bicep injury deadlift nasty[6]	A DBBTR occurred in the supinated left forearm of the male athlete who was lifting 766 lb in a competition.
Bicep tear compilation[9]	At 0:39-0:44 min, DBBTR can be observed in the right forearm while lifting 715 lb in a competition. The video was evaluated at a 0.5× speed. At 1:16-1:24 min, DBBTR occurred in the left forearm of a male athlete in a competition. At 2:09-2:20 min, DBBTR occurred in the left forearm of a male athlete in a competition. The video was evaluated at a 0.5× speed. At 2:52-2:56 min, DBBTR can be observed in the left forearm of a male athlete in a competiton. At 3:20-3:25 min, DBBTR can be seen in the right forearm of a male athlete. Eccentric contraction can be observed. The video was evaluated at a 0.5× speed. At 3:26-3:35 min, DBBTR occurred in the right forearm of a male athlete. The reverse Popeye sign can be seen after the DBBTR. The video was evaluated at a 0.5× speed. At 4:40-4:50 min, DBBTR can be seen in the left forearm of a male athlete. Eccentric contraction can be observed.

[a]DBBTR, distal biceps brachii tendon rupture.