Effects of restrictive and non-restrictive harnesses on shoulder extension in dogs at walk and trot

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The study aimed to compare the effect of restrictive and non-restrictive harnesses on shoulder extension of dogs at walk and trot. This was a prospective study of nine dogs. Dogs were walked and trotted on a treadmill at a comfortable walking and trotting speed, first with no harness, then with each harness type, with and without added weights. Dogs were filmed and the angle of shoulder extension was measured using non-reflective markers and a video analysis software. Significant decrease in shoulder extension was found with both types of harnesses in comparison with no harness, except for the restrictive harness with weights. Shoulder extension was 2.6° and 4.4° less in dogs wearing a non-restrictive harness than in dogs wearing a restrictive harness, at walk and trot, respectively. The addition of weights did not consistently add more restriction to shoulder extension. The results of this study indicate that harnesses do limit shoulder extension, but perhaps not in the way originally anticipated, as results show extension is significantly reduced under the non-restrictive harnesses compared with the restrictive harnesses, with and without weights.

Introduction

Harnesses are often used as an alternative to neck collars, and are regarded by many as the safer option as they do not restrict the trachea in dogs that pull. Increased pressure on the trachea from neck collars is contraindicated in dogs with laryngeal paralysis or tracheal collapse[1 2] and in dogs with neurological neck disease. Additionally, dogs in which increased intracranial or intraocular pressure could be detrimental should not be walked using these collars.[3] As an alternative, harnesses are used in many dogs—from house pets to working dogs—but their mechanical effects on gait kinematics have not been studied clinically. There are many styles of body harnesses, which can generally be classified into two main categories: non-restrictive, with a Y-shaped chest strap (figure 1), and restrictive, with a strap coming across the chest (figure 2). The categories are named as such because of the presumed limiting effect on forelimb range of motion (ROM) by the harness coming across the shoulder or not doing so.

Working and competition dogs are at an increased risk of shoulder pathologies due to repetitive stress sustained by this joint during their working activities or training/competition sessions.[4] This overuse may affect both tendons and ligaments, leading to a variety of orthopaedic conditions such as tendinopathies (with and without mineralisation), partial tears, chronic tenosynovitis, contractures and joint instability.[4 5] The tendons most commonly involved include the origin of the biceps brachii, and the insertional tendons of the supraspinatus and infraspinatus muscles,[4 5] leading to conditions such as bicipital tenosynovitis/tendinopathy, mineralised and non-mineralised supraspinatus tendinopathy, medial shoulder instability or contracture of the infraspinatus muscle.[4–18] Although historically bicipital tenosynovitis has been considered as the most common non-osteochondritis dissecans shoulder condition leading to lameness, in more recent years other soft tissue conditions in the shoulder have received more attention, as imaging techniques, such as ultrasound and MRI, have improved the diagnosis of these conditions.[19] During arthroscopic evaluation of affected shoulders, it is common to find lesions in several joint structures simultaneously.[9 20] In working and performance dogs, repetitive strain can result from quick turns, repetitive eccentric contractions and concentric contractions with the muscle in a lengthened

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Figure 1 Dog on the treadmill with a non-restrictive harness, showing a Y-shaped chest strap. Non-reflective markers were placed on the left side of the dog at the proximal aspect of the spine of the scapula, acromion, lateral humeral epicondyle and styloid process of the ulna. Leads were looped through each 2.5-kg barbell weights, one at each side of the dog, then through a ring in the metallic frame of the treadmill and clipped to the harness at the D ring where the lead attaches.

Figure 2 Dog walking on the treadmill with a restrictive harness showing a strap coming across the chest horizontally. Non-reflective markers were placed on the left side of the dog at the proximal aspect of the spine of the scapula, acromion, lateral humeral epicondyle and styloid process of the ulna.

state.[4] To the authors' knowledge, it is currently unknown if harnesses would limit shoulder extension and if so to which degree, and if this could have a role on the development of shoulder muscle injury. Although not all working and performance dogs wear a harness, some of these activities do require a harness to be worn for long periods of time (ie, police dogs, rescue dogs or sled dogs).

There is a noticeable lack of canine harness studies. A recent study on a specific type of working dog, the guide dog, looked at pressure values under specialised guide dog harnesses.[21] However, to the authors' knowledge, no study has compared the actual effects of restrictive and non-restrictive style harnesses on shoulder movement in dogs.

The shoulder is a complex joint, with over 25 muscles required for limb flexion, extension, rotation, abduction and adduction.[5] While complex movements, such as those encountered by agility dogs, make full use of the shoulders' ability for abduction, adduction and rotation, while walking and trotting, the primary motion of the shoulder is flexion and extension in the sagittal plane.[22] Passive extension of the shoulder was found to be 165° in normal labrador retrievers and 159° in normal military German shepherd dogs.[23 24] This can be measured by goniometry, which measures the angle of the joint, using the gradient of the spine of the scapula and comparing it with the line from the lateral epicondyle of the humerus to the acromion process of the scapula.[23] Normal passive ROM for the shoulder joint is through 100°–140°, with flexion ranging from 30° to 60°, and extension from 160° to 170°.[25]

Kinematic evaluation provides an objective means of measuring gait by describing joint angles. In human beings the accepted way of measuring joint angles is three-dimensional kinematics[26]; however, it has been shown in dogs that two-dimensional (2D) kinematics is an acceptable form of analysis of the pelvic limb in the sagittal plane.[27] As the motion of the shoulder joint at a walk and trot is predominantly in the sagittal plane, 2D kinematics should be suitable to objectively analyse the angles of extension of the joint.[22]

The authors hypothesise that both harnesses would decrease shoulder extension, with restrictive harnesses more significantly limiting shoulder extension and with non-restrictive harnesses limiting extension to a lesser extent. With the addition of weights, to simulate pulling or work, it was hypothesised that the angle of shoulder extension would be decreased in both harnesses, but particularly in the restrictive harness due to the presumed restrictive cross-chest design.

Materials and methods

The subjects of this study were nine adult dogs of variable age, but all older than one year of age, and of variable breed, belonging to the staff and students of this institution. Inclusion of the dogs in this study was voluntary and informed consent to participate was obtained from the owners. All dogs were required to have no known orthopaedic or neurological issues, be able to fit into the available harness sizes, and be able to walk and trot comfortably on a treadmill.

A non-restrictive harness with Y-shaped chest strap (Trixie Fusion harnesses with Neoprene padding, Trixie, Tarp, Germany) in medium and large sizes (figure 1) with a strap width of 25 mm, and a restrictive harness, with a 25 mm strap coming across the chest horizontally (Easy Walk nylon harness, PetSafe, UK) in medium and large sizes (figure 2), were used in this study. Generally, the lead is clipped to a D ring at the front of the restrictive harness; however, for the purposes of this study, it was clipped to the back so that the leads were attached to both harness types in the same way and weight was pulled from the same point. When making this change, it was observed that the distribution and location of the straps did not change. Two 2.5-kg weights were used to simulate pulling from the lead. This weight was selected because it put some tension on the harness without providing so much resistance that the dog had difficulty pulling. Leads were looped through each 2.5-kg barbell weights, then through a ring in the upper part of the metallic frame of the treadmill (higher than the dogs) and clipped to the harness at the D ring where the lead attaches to simulate pulling or work (figure 1). Non-reflective markers were placed on the left side of the dog at the proximal aspect of the spine of the scapula, acromion, lateral humeral epicondyle and styloid process of the ulna[23] (figure 1). The sites were identified by palpation and physical examination. The same two people did the fitting of the harnesses and placement of the non-reflective markers on the dogs.

A canine treadmill (Starkerhund SM01, Veneto, Italy) was used for this study to ensure constant, consistent walk and trot speeds. Dogs were habituated to the treadmill in three-minute to five-minute sessions, starting with walking and progressing to trotting, for at least one hour before analysis. The belt velocity was determined during the habituation process, and the speeds at which the dogs were comfortable walking and trotting varied between individuals, but were kept constant for that dog throughout the recording. Once the dogs were comfortable and habituated, analyses began. Each condition (no harness, non-restrictive harness, non-restrictive harness plus weights, restrictive harness and restrictive harness plus weights) was filmed for around 30 seconds to ensure at least 12 even gait cycles were recorded, in the same order: no harness, non-restrictive harness, weights clipped to the non-restrictive harness, then restrictive harness, and restrictive harness with added weights. A comfortable walking and trot pace was determined for each individual dog when consistent walking and trotting patterns were observed. A digital camera with a 30–110 mm lens (Nikon 1 J1, Nikon, UK) was used to capture video footage. It was placed on a tripod aimed at the lateral aspect of the left forelimb and at 90° to the treadmill to record the dogs' forelimb movement in the sagittal plane. Once the videos were obtained, a processing software (ImageJ, https://imagej.nih.gov/ij/index.html) was used to view 2D video footage and measure the angle of the shoulder at its greatest extension before the paw hit the ground, using the white label markers as measurement landmarks. Figure 3 demonstrates the angle created by drawing through the centre of

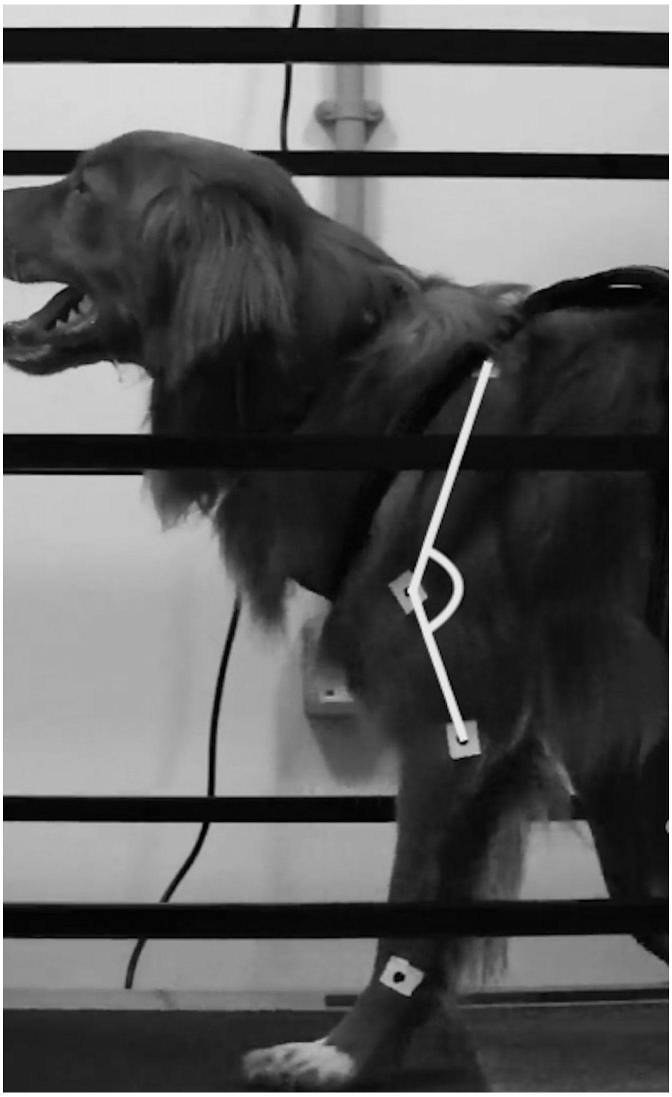

Figure 3 Photogram of the video taken during walk from the left side of the dog. Measurement of the angle of shoulder extension, as the caudal angle between a line connecting non-reflective markers at the proximal aspect of the spine of the scapula and acromion, and a line connecting non-reflecting markers at the acromion and the lateral humeral epicondyle.

Table 1 Post-hoc pairwise comparisons by means of Tukey's multiple comparisons test are illustrated for values at walk

(I) Harness (mean±sd)	(J) Harness (mean±sd)	Mean difference (I–J)	P values
Control (C) (135±9.90)	NR (130±9.04)	4.729	<0.001
	NRW (127±11)	7.7796	<0.001
	R (133±6.58)	2.156	<0.001
	RW (134±6.82)	1.024	0.369
Non-restrictive harness (NR) (130±9.04)	C (135±9.90)	−4.729	<0.001
	NRW (127±11)	3.067	<0.001
	R (133±6.58)	−2.573	<0.001
	RW (134±6.82)	−3.706	<0.001
Non-restrictive harness with weights (NRW) (127±11)	C (135±9.90)	−7.7796	<0.001
	NR (130±9.04)	−3.067	<0.001
	R (133±6.58)	−5.640	<0.001
	RW (134±6.82)	−6.772	<0.001
Restrictive harness (R) (133±6.58)	C (135±9.90)	−2.156	<0.001
	NR (130±9.04)	2.573	<0.001
	NRW (127±11)	5.640	<0.001
	RW (134±6.82)	−1.133	0. 193
Restrictive harness with weights (RW) (134±6.82)	C (135±9.90)	−1.024	0.369
	NR (130±9.04)	3.706	<0.001
	NRW (127±11)	6.772	<0.001
	R (133±6.58)	1.133	0.193

The P value shows whether the difference in means of each pair comparison is significantly different, with a P value <0.05 considered significant.

each marker, shown as white lines. This represents the caudal angle of the shoulder. For each dog, 12 angle measurements were taken for each harness condition and averaged, to reduce chance for inaccuracy or error.

Data were compiled into a spreadsheet (Microsoft Excel, Microsoft, UK) and coded, then transferred to a statistical software (SPSS, IBM, UK) for analysis. The data were tested for normal distribution and a one-way repeated-measures analysis of variance was conducted to compare the angles of shoulder extension at walk and at trot under the five conditions: no harness, non-restrictive harness, non-restrictive harness plus weights, restrictive harness and restrictive harness plus weights. The Tukey's multiple comparisons test was also used to compare the multiple conditions.

Results

Nine dogs were included in this study, with eight male dogs and one female dog. Breeds included one dog of each of the following breeds: Swiss mountain dog mix, Staffordshire bull terrier, labrador retriever, Nova Scotia duck tolling retriever, border collie, border collie mix, rottweiler mix, longhaired weimaraner and English springer spaniel.

Walk

The mean shoulder extension while walking with no harness ranged from 128° to 150° (table 1). Statistical analysis of data obtained revealed there were significant differences between groups. The highest group mean angle of shoulder extension occurred in the no harness condition at 135°, while the lowest group mean angle of shoulder extension occurred in the non-restrictive harness plus weights condition, at 127°. The angle of shoulder extension was significantly reduced in dogs while wearing the non-restrictive harnesses, both with and without weights (means=127° and 130°, respectively), compared with no harness and restrictive harness conditions. Shoulder extension was significantly less in the non-restrictive harness plus weights group compared with the non-restrictive harness alone group (P<0.001). While wearing a restrictive harness, dogs had significantly reduced angle of shoulder extension compared with when they wore no harness (mean=132° v 135°), but shoulder extension was not significantly different when a restrictive harness with added weights was worn (mean=132° v 134°). Significance and P values are shown in table 1.

Trot

The mean shoulder extension while trotting with no harness ranged from 132° to 154°. The analysis showed a significant difference between not wearing a harness and both harnesses in shoulder extension. Every harness condition was significantly more restrictive than the control trot (P<0.005 for all groups). The non-restrictive harness was significantly more restrictive than the restrictive harness with and without weights, but not from the non-restrictive harness with weights (P=0.112). Similarly the restrictive harness with weights was not significantly more restrictive than the restrictive harness without weights (P=1.00). These results are summarised in table 2.

Table 2 Post-hoc pairwise comparisons by means of Tukey's multiple comparisons test are illustrated for values at trot

(I) Harness (mean±sd)	(J) Harness (mean±sd)	Mean difference (I–J)	P values
Control (C) (144±8.38)	NR (134±11.69)	9.312	<0.001
	NRW (133±13.49)	11.072	<0.001
	R (139±9.71)	4.921	<0.001
	RW (140±10.30)	4.214	<0.001
Non-restrictive harness (NR) (134±11.69)	C (144±8.38)	−9.312	<0.001
	NRW (133±13.49)	1.760	0.112
	R(139±9.71)	−4.392	0.001
	RW (140±10.30)	−5.098	<0.001
Non-restrictive harness with weights (NRW) (133±13.49)	C (144±8.38)	−11.072	<0.001
	NR (134±11.69)	−1.760	0.112
	R (139±9.71)	−6.152	<0.001
	RW (140±10.30)	−6.858	<0.001
Restrictive harness (R) (139±9.71)	C (144±8.38)	−4.921	<0.001
	NR (134±11.69)	4.392	0.001
	NRW (133±13.49)	6.152	<0.001
	RW (140±10.30)	−0.706	1.000
Restrictive harness with weights (RW) (140±10.30)	C (144±8.38)	−4.214	<0.001
	NR (134±11.69)	5.098	<0.001
	NRW (133±13.49)	6.858	<0.001
	R (139±9.71)	0.706	1.000

The P value shows whether the difference in means of each pair comparison is significantly different, with a P value <0.05 considered significant.

Discussion

The results of the study presented here showed that the angle of shoulder extension differed significantly between when dogs were not wearing a harness and when they were wearing a harness, showing greater shoulder extension when they were not wearing a harness. Both restrictive and non-restrictive harnesses showed significantly decreased extension of the shoulder. This confirmed the authors' hypothesis that wearing a harness restricts shoulder extension to some degree. Interestingly, it was found that the non-restrictive harness actually restricted shoulder extension more than the restrictive harness used in the current study. The non-restrictive harness restricted shoulder extension by 4.73° during walk and by 9.31° during trot, while the restrictive harness only restricted extension by 2.16° at walk and by 4.92° at trot. This result was unexpected and provides evidence that this topic needs to be further investigated. Unfortunately other parameters that could have been affected during gait, such as step and stride length or stance time, were not evaluated in this study. Further studies focused on temporal-spatial modification of gait in dogs wearing non-restrictive and restrictive harnesses would be needed. Carr *et al*[28] looked into the effects of four types of harnesses on gait, and found the type of restrictive harness used in the present study significantly decreased the step length and foot pressure of the forelimbs when the restrictive harness was worn in comparison with when dogs were not wearing the harness. It could be hypothesised that the decrease in step length could be caused by a decreased extension of the shoulder; however, to the authors' knowledge, there are no studies investigating the effect of different types of harnesses into shoulder range of movement.

Non-restrictive harnesses are commonly considered to influence the motion of the shoulder joints less than restrictive harnesses; however, the evidence in the study presented here suggests that this assumption may be inaccurate. It is unclear whether any differences in width or padding of the straps could have possibly influenced its impact on shoulder extension. Nevertheless, the x-back harness is sold as being non-restrictive, and thinner straps may exert too much pressure if the dog is pulling a load. A study investigating the pressure distribution under three different types of harnesses used for guide dogs found that in all harnesses, the highest pressures were localised in the right sternal region, with both right and left sternal regions being constantly loaded. They also found that the back regions had minimal loading.[21] However, this study did not look into the potential effect of the harness and the ROM of the forelimb.

Weights were attached to the harnesses to represent pulling of a load, as many working dogs are required to pull loads with their harness, whether it is attached to a sled, a cart or a person.[21 29 30] The fact of adding weights to mimic the action of pulling from the harness also showed interesting results. In general, the addition of weights decreased further the extension of the shoulder when comparing against not wearing a harness, although it was not significantly different for the restrictive harness with weights at walk. The greatest restriction was from the non-restrictive harness with weights at trot, which restricted shoulder extension by 11°. When using the restrictive harness, the addition of weight did not significantly change the extension of the shoulder at trot or at walk in comparison with the same harness without the weight. The addition of weights to the non-restrictive harness significantly increased the restriction in extension of the shoulder during walk, but not at trot. These results could be interpreted that for both the restrictive and non-restrictive harness, it would be the shape of the harness that is playing a bigger role in the restriction at the level of the shoulder, and not the application of resistance causing the harness to pull back on the forelimb. Also it looked like the addition of the weights was not significant to the restriction exerted by the harnesses at trot. The inherent differences in kinematics between a walk and a trot, with a suspension phase in the trot, as well as the inertia created during the trot, could be playing a role in these results. The weights used in this study were to simulate some resistance from the harness, but they were not applied proportionally to the dog's weight. They will likely not accurately represent all types of pulling activities that would occur in working dogs with harnesses. This means that in a practical setting the addition of a different type of resistance on any type of harness may still affect the level of restriction that harness produces. Additionally the size of the dogs in this study was variable, and therefore the effect of the pull of the harness could have been different across the individuals. Therefore, further studies are needed with resistance resembling more the activities these dogs are involved with or with resistance proportionally applied to the dogs' weight.

The restriction in shoulder movement caused by the harnesses is relevant in a clinical setting, as it means that forelimb restriction due to a harness may not only be a problem regarding working dogs that are required to pull a load. Many working dogs, such as guide dogs, need to wear a harness for the majority of the day, if not, all the time,[21] and the effect the harness could have on limb movement is still unknown. Biceps tenosynovitis and supraspinatus tendinopathy are thought to be caused by repetitive contractions while the shoulder is flexed.[4 5] Repetitive eccentric contraction and concentric contraction of the muscle in a lengthened state have been described as potential factors leading to tendon injuries in working and performance dogs.[4] The restriction in shoulder extension caused by the harness could keep the supraspinatus and bicipital tendons in a more lengthened position, although this is still unknown. If activities continued as normal, then these tendons could be at an increased risk of injury. However, to the authors' knowledge, there is no evidence of this association and further studies would be needed to prove this theory.

There are several limitations to this study. First, the population size was small. Although almost 30 dogs were brought in to attempt walking and trotting on the treadmill, only nine were successfully walked/trotted and filmed in each category. The lack of completion was due to suspected subject discomfort and fear of the treadmill. Some dogs had been exposed to treadmill exercise before and were much more familiarised during the study than other subjects. Time until treadmill habituation in dogs has also been debated, and it has been reported in greyhounds that reliable values can be achieved within both a 30-second test window and two-minute test window of trotting on a treadmill, indicating quick treadmill familiarisation.[31] However, different habituation times have been found in different breeds, which suggests that specific breed gait analysis and treadmill habituation studies are needed.[26 32–34] Although habituation time is uncertain, by the time the restrictive harnesses were placed in the present study, which was always the last harness put on in the present study, the dogs had been exposed to the treadmill for at least 30 minutes. This was more than enough time for subjects to grow at least somewhat more accustomed to the treadmill than they were at the outset of the study, potentially skewing results. Additionally, the fitting of the restrictive harness was modified to allow the application of weights to mimic pulling from the lead, and although the fitting appeared similar to the intended fitting, the modification may have affected the position of the straps. The subjects of this study were not working dogs, and therefore not used to pulling on weighted leads. In fact, the design of the restrictive lead is intended to stop dogs from pulling their owners. Interestingly, this harness shares the same chest-spanning strap design as many working dog harnesses and vests, which seems counterintuitive based on the original hypothesis and harness classifications. It would be important for working dogs to wear a harness that does not interfere with forelimb ROM, which could potentially affect their job performance. But based on these results, perhaps this harness style does not affect dogs in the way it is conventionally believed to with shoulder restriction. Also, working dog harnesses serve other purposes that may outweigh shoulder extension in importance, such as identification, tracking or ease of removal in dangerous situations.

Another limitation that may have affected the accuracy of the data is skin movement. It has been recorded both in horses and dogs that there is skin movement over the joints during locomotion, especially in the more proximal joints. This could affect the skin markers, and techniques for correcting for these inaccuracies have been developed,[35–40] but this has not yet been researched in dogs. In the present study, the shoulder extension values may have been affected in both harnesses, as they both came in contact with markers.

Despite several limitations in this study, the research of the effects of dog harnesses is beneficial for pets and working dogs alike. Further research into the effects of restrictive versus non-restrictive harnesses is warranted, and would benefit from the study of additional harness styles and brands, use of proportional weights, larger population size (perhaps of one breed), more secure markers, and subjects with treadmill or working dog experience.

As this study included a range of breeds and weights of dog, there is a risk that each type of harness may restrict shoulder movement differently in different dogs. It is reasonable to hypothesise that body conformation will have an impact on joint angles during gait.[41] Previous studies have suggested that comparisons of kinematic data cannot be made between different breeds of dogs or between groups of dogs of different conformation or bodyweight.[42] This may be due to the variability of conformation and gait of the dogs, or due to the different size of harnesses used. However, even if either of these effects are present, they may be hidden among the results. As only 12 angles were taken from each dog for each harness, there were not enough data to run statistical analysis for each dog and get statistically significant results. It may be beneficial in future studies to use a single breed of dog, or compare two different breeds to eliminate conformation bias.

Conclusions

As a preliminary study, this analysis of forelimb restriction in the dog has provided evidence that forelimb restriction does occur with two different types of harnesses and that providing resistance may further restrict shoulder extension.

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