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Effect of Grip Width on the Myoelectric Activity of the Prime Movers in the Bench Press

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Reference Data

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ABSTRACT

The purpose of this study was to determine the effect of grip width on myoelectric activity of the pectoralis major, anterior deltoid, triceps brachii, and biceps brachii during a 1-RM bench press. Grip widths of 100, 130, 165, and 190% (G1, 2, 3, 4, respectively) of biacromial breadth were used. Mean integrated myoelectric activity for each muscle and at each grip width was determined for the concentric portion of each 1-RM and normalized to percentages of max volitional isometric contractions (%MVIC). Data analysis employed a one-factor (grip width) univariate repeated measures ANOVA. Results indicated significant main effects for both grip width ($p = 0.022$) and muscles ($p = 0.0001$). Contrast analyses were conducted on both main effects. Significant differences ($p \leq 0.05$) were found between grip widths G4 and both G1 and G2 relative to %MVIC. Significant %MVIC differences on the muscles main effect were also found. All prime movers registered significantly greater %MVICs than the biceps and, in addition, the triceps %MVIC was greater than the pectoralis major.

Key Words: electromyography, repetition maximum, biacromial breadth

Introduction

The bench press is a popular lift among recreational weight lifters in addition to being a competitive event in the sport of powerlifting. It is also fairly common practice for physical education instructors and coaches at the high school and college levels to use a one repetition maximum (1-RM) bench press for assessing upper body strength.

Madsen and McLaughlin (12) have reported that expert lifters used wider grip widths than novices, resulting in a shorter vertical distance from bar to chest in the lockout position. It was also determined that larger lifters contacted the chest with the bar at a greater distance, inferior to the shoulders, than smaller lifters (13). It was postulated that the larger lifters may have been forced to use a narrower grip width than what may have been optimal for them, causing the bar path to be altered. The question was raised, but not answered, about whether a wider grip width produces movement dynamics that more optimally involve the prime movers.

In a treatise on bench pressing technique for powerlifters, McLaughlin (14) suggested that a wider grip will enhance performance. He pointed to an inverse relationship between grip width and the vertical distance the bar must travel, resulting in less work at wider grip widths. He also postulated a positive relationship between wider grip and pectoral involvement as well as between narrower grip and triceps involvement. McLaughlin advised against narrower grip widths due to increased triceps dependence.

Lander et al. (11) compared free-weight and isokinetic bench pressing and also clarified the technique requirements of a free-weight lift. A grip equivalent to trunk width and combined upper arm length was used as a reference. From this position, subjects were allowed to deviate ±5 cm. The adjustments resulted in narrow, medium, and wide grips with respective elbow angles of 80, 90, and 98° at the point during the ascent where the upper arm was horizontal (parallel to the floor). Lander et al. found that a narrow grip enabled lifters to generate considerably more force initially, but hindered force production near the end of the lift. For subjects using the widest grip width, initial explosiveness was compromised.

Moderate grip widths (i.e., trunk width plus bilateral upper arm length) appeared to have the positive characteristics of the other two grip widths. Initial explosiveness was not compromised and the slightly wider grip width may have better utilized the pectoralis major. Relative to the trunk, the upper arm moved to an angle of approximately 90° near the end of the lift, presumably to more optimally employ the pectoralis major. Results also indicated that the path of the elbow during the ascent, when viewed from the sagittal plane, more closely paralleled that of the bar, perhaps yielding greater mechanical efficiency.

Elliott et al. (7), in addition to biomechanical analyses, used surface electromyography to investigate the bench press. They found an initial increase in muscular activity for all prime movers at the beginning of the ascent, which was sustained with little change throughout the concentric portion of the lift. This might have been expected. However, it was also found that the triceps was slightly delayed in achieving maximal activity, and that the biceps brachii, an assistant mover or stabilizer, generally recorded its highest level of activity toward the end of the "sticking region" (11). A slight increase was observed in the moment arm about the elbow, near the end of the sticking region. However, no significant differences in the moment arm about the shoulder between expert and novice lifters were found.

Elliott et al. postulated that the sticking region might be caused by relatively poor mechanical force production, combined with the gradual release of strain energy as the bar moved away from the chest. Yet grip width was not an independent variable, nor were intermuscular comparisons made.

Wagner et al. (19) examined the effect of grip width on bench press performance. Investigators used grip widths almost identical to those in the present study. The G1 grip width in their study was 95% rather than 100% of biacromial breadth (BAB), G2 and G3 grip widths were identical, G4 grip width was 200% rather than 190% of BAB, and wider grip widths of 235% (G5) and 270% (G6) of BAB were examined.

Results indicated different horizontal and vertical bar paths relative to G1, G3, and G6 grip widths. During the ascent there was a decrease in the horizontal distance of the bar as well as the vertical distance as grip width widened. Additional analyses indicated that subjects at the G3 and G4 moderate grip widths were able to lift significantly more weight than the narrower G1 and G2 or the wider G5 and G6 grip widths. A strength difference was also found between G1 and G2, in favor of G2. The moment of force, however, was not considered a critical factor relative to grip width.

The purpose of this study was to make intergrip and intermuscular comparisons of myoelectric activity throughout the concentric phase of a 1-RM free-weight bench press in relation to that generated during maximum volitional isometric contractions (%MVIC).

Methods

Subjects

Twelve men were recruited from health and PE weight lifting classes in which a baseline 1-RM bench press for each participant had already been determined at the G1 grip width. Two subjects were varsity football players, 5 were active and committed recreational lifters, and 4, although experienced, were not currently training. One subject was excluded from the study due to his inability to complete the last 1-RM of the research protocol. None of the participants had ever been a competitive power lifter. Mean bench press experience was 7.1 ± 3.5 yrs; the range was 4 to 15 yrs. Mean age was 22 ± 2.6 yrs, height was 177.6 ± 10.5 cm, weight was 87 ± 20.8 kg. Subjects were screened by the Physical Activity Readiness Questionnaire (2). Approval for the study was obtained through the institutional review board at the University of Southwestern Louisiana.

Electromyography

All EMG measurements were taken on the right side of the body. Following alcohol cleansing and mild abrading of the sites, bipolar shielded silver-silver chloride 8-mm electrodes were placed parallel to the muscle fibers and on the central portion of the muscle belly (4, 5, 6, 16, 22). Electrodes were held in place with specialized double-sided adhesive tape at an interelectrode distance of 4 cm. Recommendations by Zipp (22) on anatomical reference points for bipolar electrode placement were followed with the triceps brachii. There were slight modifications to the biceps brachii and anterior deltoid procedures. These adjustments were based on origin and insertion measurements taken from an anatomical reproduction of a skeleton (15) cast from molds of an Indian male 157 cm tall. These modifications appeared to allow for a more optimal placement of the electrodes on the central portion of the muscle mass as recommended (4, 5, 6, 16, 22).

Several concerns emerged as to the placement of electrodes on the pectoralis major. No published anatomical reference points for bipolar electrode placement on the pectoralis major were found. In addition, it was necessary for both electrodes to be placed where there was the least likelihood of the bar making contact with them and where both would remain parallel to the muscle fibers during the lifting movements.

This was accomplished first by measuring from the suprasternal notch down to the small depression on the sternum just above the xyphoid process. At 60% of this distance, down from the suprasternal notch, chest breadth was determined. At 80% of chest breadth, on the right side of the body, a mark was made that served as the central lead point. Once the subject was positioned supine on the bench, the bar was grasped at the designated grip width. Each bipolar electrode was then placed 2 cm on each side of the central lead point (22), on an imaginary line formed from the estimated insertion on the humerus through the central lead point and on to the sternal attachment of the pectoralis major. A common ground was used on the rib (4).

EMG signals were recorded at a sampling rate of 500 Hz, amplified at a gain of 5000, and integrated to provide a positive envelope of EMG activity. The integrator consisted of a full-wave rectifier, followed by a 10-Hz, two-pole, low-pass filter. The common mode rejection ratio was set at 100 dB. The MP100WS, a data acquisition unit from Biopak® Systems, was used for the analog-to-digital conversion. A universal interface module (UIM100) from Biopak was used to connect the MP100WS to a synchronizer kit (MRMP-1) from Qualisys®. This enabled the electromyography and the motion analysis to be time-locked with a common trigger. The data were processed with a Macintosh 180C laptop computer equipped with a math coprocessor. AcqKnowledge® version 3.0 software was used to control data acquisition, perform postacquisition functions, and store the data for later analysis.

A number of strategies (4, 21) have been used to normalize the kinesiological EMG, for example, normalization to the highest peak activity in dynamic as well as isometric contractions, mean integrated EMG (MiEMG), and EMG per unit of measured force. For this study the MiEMG during the concentric portion of the 1-RMs was examined relative to the MiEMG obtained during an MVIC. The MiEMG was determined for each muscle during the concentric phase of a 1-RM and also during a portion of a 5-sec MVIC. This allowed for the calculation of a %MVIC.

To enhance accuracy, only the middle 2.4 sec of the 5-sec MVIC was used. This was equivalent to the mean time, to the nearest 1/10 sec, to complete all 1-RMs. This strategy was used to guard against EMG irregularities that might occur immediately after the signal to begin the MVIC, to control somewhat for a tendency to reduce effort near the end of the 5-sec maximal contraction, and to employ a similar duration for both the dynamic and isometric testing conditions.

The MVIC for both the biceps brachii and triceps brachii was determined at 90° of elbow flexion (7). The anterior deltoid was tested at 90° of shoulder flexion with slight rotation of the humerus so that the palm faced medially. The pectoralis major was tested with the subject supine, on the floor, at 90° of shoulder flexion with slight medial rotation and full elbow extension (10). The purpose of the humeral rotation was to reduce the involvement of the anterior deltoid (10). The arm was anchored in this position with a strap, allowing the subject to exert an MVIC obliquely toward the contralateral iliac crest, which was stabilized by the tester. This testing procedure for the sternal portion of the pectoralis major yielded greater myoelectric activity than any other attempted one involving either isometric or dynamic contractions.

All subjects were given verbal encouragement throughout the entire 5-sec MVIC (17). To eliminate the potential confounding effects of fatigue on the experiment, the isometric portion of the testing was conducted separately from the multigrip bench press protocol.

Cinematographic Analysis

A single infrared, high-speed camera was placed perpendicular to the horizontal plane approximately 2 meters from the head and in line with the long axis of the body. Reflective markers were attached to the bar, the ulnar styloid processes of both wrists, the lateral epicondyle of each humerus, and on each acromion. This arrangement allowed for full view of all markers at all grip widths throughout the bench press.

The camera was interfaced with a Macintosh 180C laptop computer equipped with a math coprocessor and an external video processor that calculated the centroid of each marker, recorded the x and y coordinates, and displayed the data in real time on the laptop. All data were acquired at a sampling rate of 50 Hz and stored using WingZ® for MacReflex® spreadsheet, version 2.3. Precise determination of bar position every 0.02 sec was possible using MacReflex, and the WingZ for MacReflex application made position/time and angle calculations possible. A stationary reflective marker was placed on the frame of the bench to serve as a reference to arm and bar markers for determining when the ascent began and the 1-RM ended. A model MRMP-1 synchronizer kit from Qualisys enabled the electromyography and motion analysis system to be time-locked with a common trigger.

Bench Press Protocols

Baseline 1-RM Lifts. Baseline 1-RMs were conducted using guidelines provided by Stone and O'Bryant (18) at a grip width equivalent to 100% of BAB. The BAB was determined for each subject by palpating and marking the acromion bilaterally, then measuring the distance between these points with a standard anthropometric measuring device. Since the same weight was to be lifted at each grip width, G1 was selected because it had been shown to be the weakest (19). In order to determine whether grip width affected muscle tension, it was necessary to hold other variables constant (e.g., weight lifted, electrode placement, warm-up and recovery between 1-RMs).

Multigrip Bench Press Protocol. The narrowest grip width examined was equivalent to that used for the baseline 1-RM (i.e., 100% BAB at G1). The present study employed 100% BAB for G1 instead of the 95% BAB used by Wagner et al. (19). The G2 (130%) and G3 (165%) grip widths were identical; however, the widest grip width (G4) in this study was 190% instead of 200%. Although wider grip widths have been examined (19), the bench press uprights available for this study would not safely permit the use of grip widths beyond 190% BAB. In addition, grip widths in excess of 200% BAB have not been shown to be any more effective (19).

The bar's entire length was marked in millimeters to ensure accurate grip width determinations. Grip widths for each subject were randomized in order to minimize fatigue as a confounding variable across the experiment. Two initial warm-up sets were required and involved 4 to 5 reps at 60% of baseline 1-RM, followed by a 1-min rest and another warm-up set of 4 to 5 reps at 80% of baseline 1-RM. After the last warm-up set, a minimum 2-min rest was required before the first lift at 100% of baseline 1-RM. Minimum 2-min recoveries were required between subsequent lifts at all remaining grip widths. No ceiling was placed on recovery time, but there was an attempt to use 2- to 3-min recoveries between all lifts. Recoveries of 1 min do not have a deleterious effect on repeat 1-RM performances (20).

Following an assisted liftoff, subjects provided a verbal cue to the tester, who then activated the common EMG/camera trigger at or just prior to the descent. General guidelines for proper bench pressing technique were required. Subjects were asked to show motionless control of the bar prior to the descent and to touch the chest lightly with no bouncing. The bar was not required to remain motionless at the chest before initiating the ascent, although this is standard practice in powerlifting competitions. Feet remained flat on the floor during the lift, and subjects were required to lock out and show control upon completion.

Although spotters were permitted for safety purposes, they were not allowed to touch the bar except in the event of a failed lift. This occurred only once, on the last 1-RM, which meant that the subject had to be eliminated from the study due to his inability to complete the entire bench pressing protocol. He was not allowed to repeat the protocol at a lighter weight due to the potential confounding effects of fatigue.

Data Analysis

The dependent variable for this study was %MVIC, which was determined using the following formula: MiEMG during the concentric phase of the 1-RM ÷ MiEMG for the MVIC × 100. With this method, a %MVIC was calculated for each subject's muscle at each grip width. The %MVIC data were analyzed through a repeated measures ANOVA using type III sums of squares (1). To address the extent to which the correlation between the repeated measures violated the validity of the calculated p, F-tests were adjusted by reducing the degrees of freedom before calculating the probability of the F-test. The reduction was determined by the factor Greenhouse-Geisser (G-G) epsilon (1). Contrast analyses were conducted on each main effect for grip width and muscles. The decision to reject the null and accept the alternative hypotheses was set at $p \le 0.05$.

Results

Results of the repeated measures ANOVA indicated a significant main effect for both grip width and muscles ($p = 0.0221$ and 0.0001, respectively). There was no significant grip width × muscle interaction. Removing the biceps brachii from the analysis did not alter the statistical conclusions. Contrast analyses on grip width indicated significant differences between both G1 and G2 with G4 (Figure 1). Contrast analyses on the muscles main effect (regardless of grip width) indicated significant differences on %MVIC between all prime movers with the biceps (Figure 2). A significant difference also occurred between the pectoralis major and the triceps. The triceps apparently used a higher %MVIC than the chest throughout the concentric part of the collective bench press. No other significant %MVIC difference were observed.

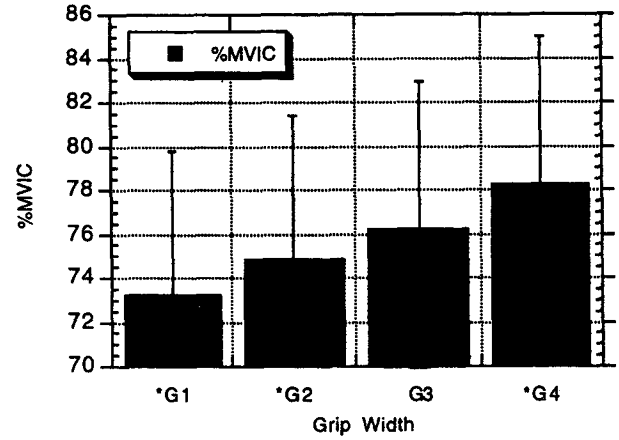

Figure 1. Results of contrast analyses on grip width main effect. % max volitional isometric contractions (%MVICs) for the collective set of prime movers—pectoralis major, anterior deltoid, triceps, biceps—at each grip width (mean ± *SE*). * G4 > G1 and G2 ($p \le 0.05$); no other signif. differences.

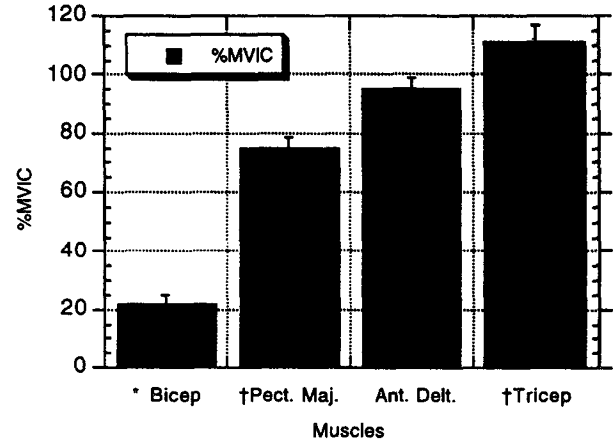

Figure 2. Results of contrast analyses on muscles main effect. % max volitional isometric contractions (%MVICs) for each involved muscle regardless of grip width (mean ± *SE*). *Pect. major, Ant. delt., & Triceps > *Biceps; †Triceps > †Pect. major ($p \le 0.05$); no other signif. differences.

Grip Width

The lower %MVICs observed with the narrower grip may be a result of reduced activity toward the end of the lift due to less shoulder transverse adduction and perhaps less torque on the shoulder. The increased myoelectric activity with the wider grip may have been due to greater torque about the shoulder. However, previous research suggests that the torque about the shoulder is not a critical factor in bench press strength at different grip widths, nor does it account for differences between expert and novice lifters (12). This study was delimited to the MiEMG throughout the entire concentric portion of the lift, therefore phasic inferences could not be made. More studies are needed to examine myoelectric activity at various phases of the ascent.

Grip widths, equivalent to trunk width plus bilateral upper arm length, result in elbow angles of 90° at a point in the lift where the upper arm is parallel to the floor. According to Lander et al. (11), this grip width resulted in bar paths that were more similar for bar and elbow than either the wider or narrower grip widths that caused respective elbow angles of 98 and 80°.

In the present study at the same point in the ascent, the mean elbow angle using the G4 grip width, when viewed from the transverse plane, was found to be 92.2 ± 7.8°, ranging from 82.3 to 109.1°. The mean elbow angle at G3 was 85.4 ± 7.4°, ranging from 73.7 to 100.2°. The intersubject variability is presumably due to differences in arm length. By extrapolating, it was estimated that a grip width of 182% BAB for this group would result in a mean elbow angle of 90° when the upper arm was parallel to the floor. All evidence to date supports a moderate to moderately wide grip width perhaps ranging from 165 to 200% of BAB that will also result in a concomitant elbow angle of 90° and a trunk-to-upper-arm angle of near 90° during the final phase of the ascent. This recommendation allows for good use of the pectoralis major while still enabling the triceps to augment initial explosiveness.

This recommendation, however, is not entirely consistent with McLauglin's suggestions (14). In his film studies he observed that an upper-arm-to-trunk angle of approximately 90°, coupled with an elbow angle of 90°, is the final position of nearly every bench presser who misses a lift. He also asserted that, for most lifters, this positioning of the elbow occurs at the onset of the sticking region. McLaughlin suggested moving the elbows medially to more actively engage the triceps during the final phase of the lift or the lockout. In all probability, this technique would reduce tension on the pectoralis major and increase the resultant moment arm about the elbow axis (7). Since elastic strain energy may already be dissipating (3), this would almost certainly result in an unsuccessful lift. Moving the elbows medially might result in dissimilar elbow and bar paths, thus compromising the efficiency of the lift.

Perhaps the lateral elbow movement consistently observed by McLaughlin at the sticking region is kinematically appropriate and represents an automatic attempt by most experienced lifters to reduce the moment arm about the elbow and more actively engage the pectoralis major. With regard to the elbow, this has been supported by Elliott (7), who found that the resultant moment arm about the elbow of elite male bench pressers actually reached a minimum value during the sticking region.

Force generation capabilities in humans increases when the muscle is slightly stretched (9). Madsen and McLaughlin (12) raised the question about whether a wider grip changes arm position in such a way as to permit the prime movers to act more expeditiously. Wider grip widths, up to a point, may stretch the pectoralis major more optimally than narrower grip widths. This wider position may result in more stored strain energy and perhaps greater pectoral force production, provided that the grip width is not excessive. It appears that grip widths ≥G3 but ≤G4 place the collective set of prime movers in a favorable mechanical position for generating greater muscle tension and perhaps greater overall force production throughout the lift.

The significant main effect for grip width and the absence of a significant grip width × muscle interaction suggests it is the increased collective myoelectric activity of the prime movers that is responsible for the differences across grip widths, rather than the activity of a certain muscle group. There is a point of diminishing returns relative to grip width, however, and it probably occurs at widths ≥235% of BAB. A wide grip that results in an elbow angle >90° when the bar is on the chest may reduce initial explosiveness and compromise overall performance (7). The more moderate grip width of G3 has been included in the recommendation, since no significant difference in %MVIC was observed between G3 and G4; however, the better recommendation would be closer to G4.

McLaughlin's hypothesis (14) that broad-shouldered powerlifters might be penalized by an 81-cm grip limit may be supported. These lifters are clearly unable to subject the pectoralis major to the same degree of stretch as lifters with smaller BABs at the same grip width. Only small-framed lifters who have a BAB ≤40.5 cm would be able to use a grip width equivalent to 200% BAB. It would not seem prudent for broad-shouldered lifters to intentionally use grip widths under 81 cm.

Muscles

There was no significant difference between the pectoralis major and the anterior deltoid relative to %MVIC. This suggests they are similarly challenged during the lift. The %MVIC differences found between the prime movers and the biceps were not remarkable since the biceps is not a major contributor. The intermuscular differences relative to the triceps and the pectoralis major might be regarded with some caution (Figure 2). The mean myoelectric activity of the triceps during the concentric portion of the 1-RMs actually exceeded that obtained during the MVICs, resulting in a %MVIC for the triceps at each grip width exceeding 100%. The mean %MVIC across all grip widths for the triceps was 111.2%.

Other investigators have had similar results when examining myoelectric activity in dynamic movements relative to that obtained in maximal isometric contractions (4). In the present study the phenomenon may have been due to the MVICs for the triceps being determined at 90° of elbow extension. MVICs conducted at angles above 90° might have yielded greater muscle tension and therefore slightly lower %MVICs for the triceps. Despite the %MVIC discrepancy, the heavy involvement of the triceps at all grip widths was evident from observation of the EMG recordings.

Practical Applications

The simplest way to estimate the best lifting grip width is to have the lifter lie supine on the floor while supporting an Olympic bar. Upper arms should be abducted to 90° (frontal plane), with the elbows at 90° (transverse plane) and the posterior portion of the upper arms resting comfortably on the floor. At this point the forearms should be perpendicular to the floor with the shoulders, elbows, and wrists all lying in the transverse plane. While in this position, the inside distance from index finger to index finger can be measured or the lifter may simply examine hand position relative to the 81-cm bar markings.

For most lifters this strategy should result in grip widths close to G4 or approximately 190 to 200% of BAB. If it results in grip widths that seem awkward, one might experiment within the range of G3 (165%) to G4 (190–200%) of BAB. Although the present study found no differences between G3 and G4 widths relative to %MVIC, Lander et al. (11) observed considerably different bar paths and elbow angles when subjects were allowed to adjust grip widths by as little as ±5 cm.

To determine a grip width between G3 or G4, simply measure the shortest distance between each acromion and multiply it by a value between 1.65 (G3) and 2.00 (G4). Actual grip width will be half that distance on each side of the center of the bar. To test the width that is most comfortable, assume the grip and measure the distance between the hands. Divide that distance by the lifter's BAB. This should result in a value between 1.65 (G3) and 2.00 (G4). Grip widths as close as comfortably possible to 2.00 (G4) are recommended. It may not be prudent to make gross changes in grip width immediately prior to competition. Wider grip widths may feel awkward at first, and one should allow time for a possible motor learning or practice effect.

These recommendations have to do with grip width as it relates to bench press performance, and not from a bodybuilding or general sports training perspective. Wider grips reduce the vertical distance from bar to chest, concomitantly reducing the range of motion at the shoulder and elbow joints. This may not be desirable if one is concerned about hypertrophy or the development of strength at shoulder and elbow angles different from that typically experienced at wider grip widths.

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