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Original Article

A macroscopic anatomical study of the appropriate palpation zone of the gluteus medius muscle

Masayuki Tsuchida, RPT, PhD[1)*], Masakazu Shibata, PhD[1)], Akira Iimura, PhD[2)], Takeshi Oguchi, PhD[2)], SungHyek Kim, RPT, PhD[3)], Yoko Nakao, RPT, PhD[1)], Hisashi Nakamura, RPT, PhD[1)]

[1)] *Department of Rehabilitation, Shonan University of Medical Sciences: 16-48 Kamishinano-cho, Totsuka-ku, Yokohama-shi, Kanagawa 244-0806, Japan*
[2)] *Department of Anatomy, Kanagawa Dental University, Japan*
[3)] *Faculty of Health Science, Tokoha University, Japan*

Abstract. [Purpose] Few previous studies have delimitated the palpation zone of the gluteus medius muscle with a focus on its fiber bundles. The purpose of this study was to clarify the morphological characteristics of the gluteus medius muscle using an anatomical approach, and to define its proper palpation zone. [Participants and Methods] In this study, we evaluated thirteen halves of the pelvic region in seven formalin-fixed cadavers. We identified the borders between the iliotibial band and gluteus medius muscle, and between the gluteus medius and gluteus maximus muscles, on the iliac crest. Furthermore, we quantified the border points of the gluteus medius' fiber bundles and observed its anatomical and morphological characteristics. [Results] We identified two fiber bundles in the gluteus medius muscle, an anterior and a posterior fiber bundle, and detected that a portion of the posterior fibers was located subcutaneously. [Conclusion] We propose that the region where the posterior fibers of the gluteus medius muscle are located subcutaneously is an appropriate zone for the palpation of this muscle.
Key words: Gluteus medius, Palpation, Gross anatomy

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INTRODUCTION

The gluteus medius muscle (GMed) contributes to hip joint stability during gait. Since it works to control lateral swaying, especially during the stance phase, dysfunction of this muscle has a significant effect on gait stability[1)]. Therefore, functional improvement exercises are widely applied to the GMed in physical therapy, wherein physical therapists are required to provide clients with effective treatments based on the morphological characteristics of the GMed.

The relationship between the activity of the GMed and the action of the hip joint depends on the direction of the fibrous bundles[2–4)]. Several studies have reported the effects of rehabilitation exercises on strength in the GMed based on the morphology of fiber bundles[5–8)]. When providing rehabilitation exercises focusing on the morphology of these fiber bundles, the therapist usually uses muscle palpation to ensure that it contracts with the appropriate intensity and timing. This is because it provides real-time information on muscle contraction without the need for special equipment, which facilitates feedback to the patient. To improve the effectiveness of the exercise under palpation, it is essential to understand the morphological characteristics of the fiber bundles of the GMed.

However, the morphological characteristics of fiber bundles in the GMed remain unclear. In particular, the number and location of the fiber bundles is controversial. Some studies have reported three fiber bundles segments (anterior, middle

*Corresponding author. Masayuki Tsuchida (E-mail: masayuki.tsuchida@sums.ac.jp)

and posterior)[9–11], while others have reported two (anterior and posterior)[12, 13]. Moreover, quantitative information on the borders of the fiber bundles has not been provided in these reports. Therefore, the effect of the morphological characteristics of the fiber bundle on hip motion requires further elucidation.

In addition, it is not easy to palpate the entire muscle belly of the GMed from the body surface because it is mostly covered by the tensor fasciae latae (TFL), the iliotibial band (ITB), and the gluteus maximus muscle (GMax). Particularly in degenerative diseases of the hip joint, such as osteoarthritis, the process of muscle atrophy around the hip joint differs for each muscle, and each soft tissue has characteristic atrophy and fatty infiltration depending on the phase of the pathology[14, 15]. Specifically, when the GMed is dysfunctional, hypoactivity of the GMed is associated with hyperactivity of the superficially located muscles (mainly TFL)[16]. Therefore, when palpation of the GMed during exercise is inaccurate, it may be strongly influenced by the stiffness of these superficial muscles. Such inaccurate palpatory exercises may promote divergence in activity between GMed and superficial muscles, consequently further aggravating the instability of the hip joint. Therefore, it is essential to palpate accurately in locations that are not affected by these superficial muscles, in other words, where the muscle fibers of GMed are located below the body surface.

Most previous studies on the palpation of the GMed have been conducted in the context of “tenderness” or “trigger points”[17, 18], however, to the best of our knowledge, no studies have focused on the anatomical relationship between the GMed and other soft tissues or contributed to improving the accuracy of palpation techniques. Despite increasing attention on the morphology of the GMed fiber bundles in exercise, understanding of the morphological characteristics of the GMed fiber bundles remains inadequate. The purpose of this study was to investigate the morphological characteristics of the fiber bundles of the GMed and to define their proper zone for palpation.

PARTICIPANTS AND METHODS

Thirteen halves of the pelvic region in seven adult Japanese cadavers (three males and four females, mean age: 74.8 ± 13.5) were obtained from the dissecting room of Kanagawa Dental University. The sampling technique used involved simple random sampling, which can extract all elements of the population with equal probability[19]. Specifically, 7 identity (ID) numbers were randomly extracted from 25 specimens that had been assigned ID numbers and preserved in the laboratory. Randomization was performed using a random number table via the RANDBETWEEN function in spreadsheet software (Microsoft Excel 2019). This study was conducted with the approval of the Kanagawa Dental University ethics committee (approval number 210). In this study, an observational, quantitative, and descriptive approach was adopted as the research design. The measurement method of the border points between the GMed and the peripheral tissues and the border points of the fiber bundles of the GMed are shown in Fig. 1. The dissection was performed with the cadaver in the lateral position. After excising the skin and subcutaneous tissue, the length of the iliac crest from the anterior superior iliac spine (ASIS) to the posterior superior iliac spine (PSIS) was measured and defined as the iliac crest length.

The posterior edge of the proximal attachment of the ITB at the iliac crest was defined as the border point between the ITB and the GMed, and the length from the ASIS to the border point along the iliac crest was measured and defined as the length between the ASIS and the posterior edge of the ITB (LAIB).

Likewise, the anterior edge of the proximal attachment of the GMax at the iliac crest was defined as the border point between the GMed and the GMax, and the length from ASIS to the border point along the iliac crest was measured and defined as the length between the ASIS and the anterior edge of the GMax (LAGM).

After the above measurements were completed, the fiber bundles of the GMed were observed (Fig. 2). The TFL, ITB, and GMax were then detached from the ilium and reflected posteriorly. Segmentation of the GMed fiber bundles was performed as follows: orientation of the fiber bundles was observed from the superficial layer of the GMed, and the points where the directions crossed were identified as the border of the fiber bundles. The border was then traced proximally to the iliac crest, which was defined and recorded as the border point of the fiber bundles. After that, the length from the ASIS to the border point was measured using the method described above and defined as the length between the ASIS and the fascicle border (LAFB).

A plastic measuring tape was fixed with a pin so that the zero scale indicated the most prominent part of the ASIS, which was the criterion for measurement. The iliac crest was traced with the plastic measuring tape until the target point was reached, and each length was recorded in millimeters. Each measurement was performed thrice. To analyze the values of LAIB, LAGM, and LAFB among samples, percentages were calculated by dividing LAIB, LAGM, and LAFB by the iliac crest length of each limb, defined as %LAIB, %LAGM, and %LAFB, respectively, and the mean and standard deviation were calculated.

In addition, the intraclass correlation coefficient (ICC1, 1), which is a measure of reliability, was calculated to examine the reproducibility of the LAIB, LAGM, and LAFB measurements. Statistical analyses were performed using R ver. 4.0.2 (the R Foundation for Statistical Computing, Vienna, Austria) and R commander ver. 2.7-0.

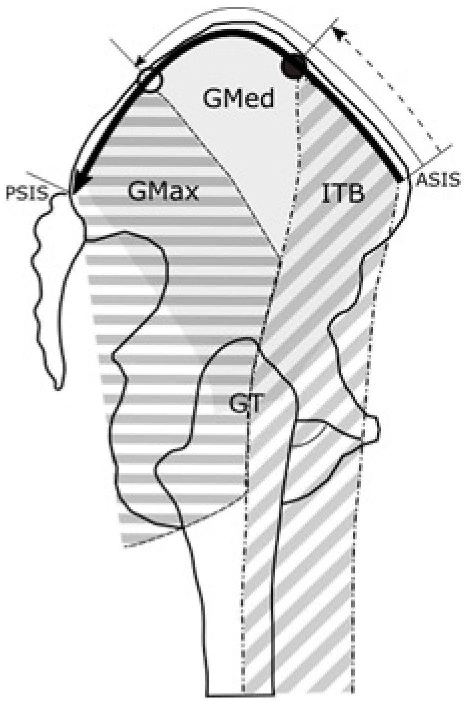

Fig. 1. A diagram showing the measurement points on the right iliac crest.
●: The border point between the iliotibial band (ITB) and the gluteus medius (GMed).
○: The border point between the GMed and the gluteus maximus (GMax).
⟵: The iliac crest length: the length of the iliac crest from the anterior superior iliac spine (ASIS) to the posterior superior iliac spine (PSIS) along the iliac crest.
⇠: LAIB; The length from the ASIS to the posterior edge of the ITB.
⟵: LAGM; The length from the ASIS to the anterior edge of the GMax.
GT: Great trochanter.

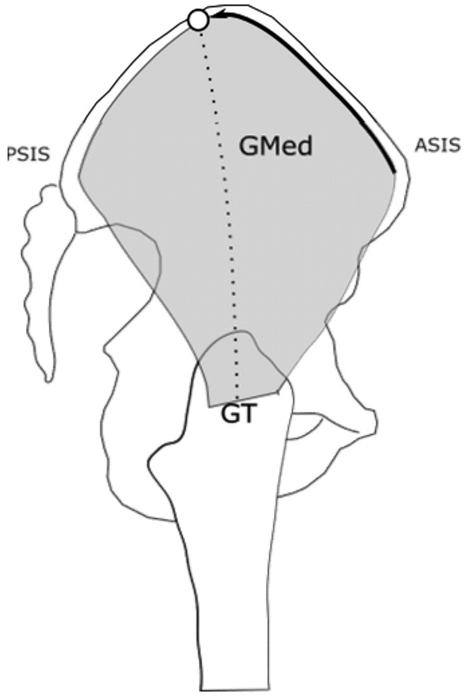

Fig. 2. A diagram showing measurement of the border point of the fiber bundle of the right GMed on the iliac crest.
○: The border point of the fiber bundle of GMed on the iliac crest.
⟵ : LAFB; The length from ASIS to ○

RESULTS

The individual mean of the thirteen limbs for the measured lengths is shown in Table 1. The mean %LAIB and %LAGM was 61.96 ± 6.94% and 83.37 ± 4.98%, respectively. The GMed muscle bulk was divided into two parts (anterior and posterior); hence, one LAFB indicated the border of the fiber bundle. The mean %LAFB was 60.18 ± 5.52% (Table 2). The ICCs (1.1) of LAIB, LAGM, and LAFB measurements were 0.983, 0.982, and 0.990, respectively (Table 3).

The anterior portion of the GMed had fibers running obliquely from the anterior outer lip of the iliac crest to the anterolateral aspect of the greater trochanter. The posterior part had fibers running obliquely from the posterior outer lip of the iliac crest to the apex of the greater trochanter (GT) (Fig. 3).

The anterior part of the GMed was attached broadly and thinly from the apex to the anterior facet of the GT, while the posterior part was attached thickly to the posterosuperior facet of the GT (Fig. 4).

The posterior border of the anterior fiber bundle was pinched up at the fiber bundle border, and the internal structure of the GMed was observed. An internal tendon was identified between the fiber bundles of the GMed. The anterior and posterior fibers each had a distal attachment to this internal tendon as well as to the GT. The anterior fibers terminated at this internal tendon in the superficial layer, and the posterior fibers stopped at the deep layer (Fig. 4).

DISCUSSION

The GMed was morphologically divided into two fiber bundles: anterior and posterior. In addition, each of them had an independent distal tendon and an attachment to the intramuscular tendon. For a muscle to be anatomically compartmentalized into fiber bundles, each bundle must be innervated by its primary nerve branch, and structural features, such as fiber angles and/or attachment sites, should be different from the surrounding compartments[20]. The most acknowledged morphological feature of the superior gluteal nerve (SGN), the innervating nerve of the GMed, is its two primary branches[14, 21], whose origins have been evidentially identified[21]. Therefore, morphologically, the two primary nerve branches of the SGN innervate

Table 1. Individual measurement data

Cavader	Right (R) / Left (L)	Iliac crest length	LAIB	LAGB	LAFB
A	R	232.33 ± 1.15	166.67 ± 0.58	202.00 ± 2.65	147.67 ± 0.58
	L	233.00 ± 0.00	166.33 ± 1.15	207.33 ± 1.53	145.67 ± 0.58
B	R	226.33 ± 2.31	147.67 ± 2.52	202.33 ± 2.08	130.67 ± 1.15
	L	218.33 ± 3.79	145.67 ± 1.15	201.67 ± 1.53	134.00 ± 1.00
C	R	246.67 ± 1.53	124.33 ± 1.15	199.67 ± 0.58	123.67 ± 0.58
	L	243.67 ± 1.15	117.33 ± 0.58	198.67 ± 0.58	118.00 ± 1.00
D	R	212.33 ± 1.15	133.00 ± 0.00	164.67 ± 0.58	130.67 ± 2.08
	L	219.33 ± 1.15	140.67 ± 3.06	173.00 ± 1.00	131.33 ± 1.53
E	R	263.67 ± 0.58	149.33 ± 0.58	198.67 ± 3.06	171.33 ± 1.15
	L	258.67 ± 1.15	149.33 ± 0.58	206.33 ± 1.53	178.00 ± 2.00
F	R	206.33 ± 1.15	132.33 ± 1.15	173.00 ± 0.00	123.00 ± 0.00
	L	206.33 ± 0.58	132.67 ± 1.15	176.33 ± 1.15	132.67 ± 1.15
G	R	215.00 ± 0.00	134.00 ± 0.60	178.00 ± 1.20	128.00 ± 2.00

Mean (mm) ± SD.
LAIB: The length between the ASIS and the posterior edge of the ITB; LAGM: The length between the ASIS and the anterior edge of the GMax; LAFB: The length between the ASIS and the fascicle border of the GMed.

Table 2. Location of each border point relative to the length of the iliac crest

Measured scale	Mean ± SD
%LAIB	61.96 ± 6.94
%LAGM	83.37 ± 4.98
%LAFB	60.18 ± 5.52

%LAIB: Location of the border point between ITB and GMed; %LAGM: Location of the border point between GMed and GMax; %LAFB: Location of the border point of the fiber bundles of GMed.

Table 3. The value of ICC (1,1) for each measurement

Measured point	ICC (1, 1)	95% Confidence interval	
		Lower limit	Upper limit
LAIB	0.983	0.958	0.994
LAGM	0.982	0.955	0.994
LAFB	0.99	0.976	0.997

LAIB: The length between the ASIS and the posterior edge of the ITB; LAGM: The length between the ASIS and the anterior edge of the GMax; LAFB: The length between the ASIS and the fascicle border of the GMed.

the GMed. When considering the compartmentalization of the GMed based on this feature, it is natural to assume that there are two fiber bundles in the GMed. In addition, it was observed that the anterior and posterior fibers not only independently inserted into the GT, but also inserted into the intramuscular tendon, which divided the fiber bundle of the GMed into two parts, anterior and posterior. These morphological features of the primary nerve branches and distal insertion of the GMed suggest that the fiber bundle of the GMed is anatomically compartmentalized into two parts: anterior and posterior fibers.

Regarding the action of the GMed, previous studies that divided the fiber bundle into three regions[9, 22)] reported that anterior fibers act on abduction, flexion, and internal rotation; middle fibers act on abduction; and posterior fibers act on abduction, extension, and external rotation. However, in the present study, the vertically oriented fibers corresponding to the "middle fibers" were noted to be part of the anterior fibers.

Using an ultrasound system, Mitomo et al.[23)] examined the muscle thickness of the anterior, middle, and posterior fibers of the GMed during abduction in three positions (hip flexion, mid-extension, and extension); they reported no significant difference in the rate of change of muscle thickness in the middle part of the GMed among the three positions. Relating the results of Mitomo et al. to those of the present study, the coordinated activity of the anterior and posterior fibers may be more important than the independent activity of the middle part in terms of abduction movement at the intermediate position of the hip joint.

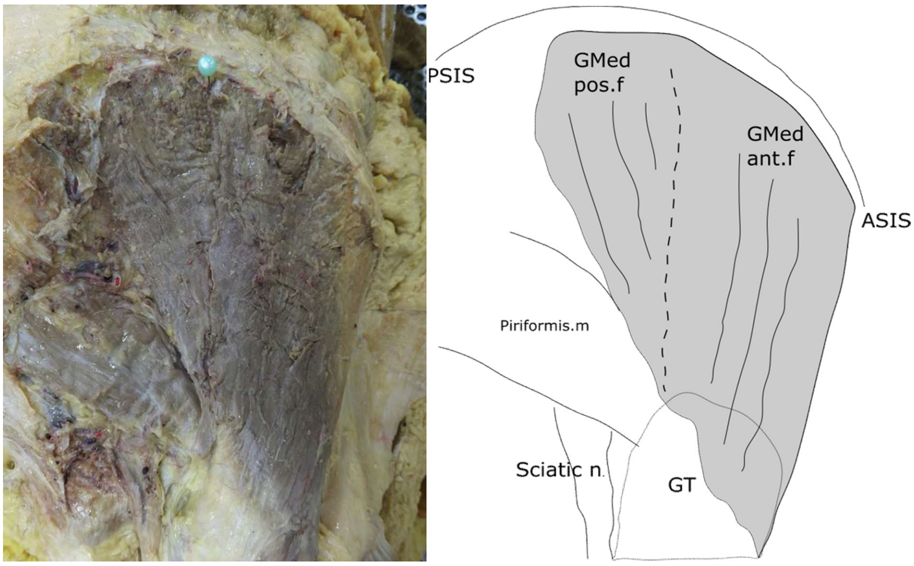

Fig. 3. A photograph and a diagram showing the border of the fiber bundle of the right GMed.

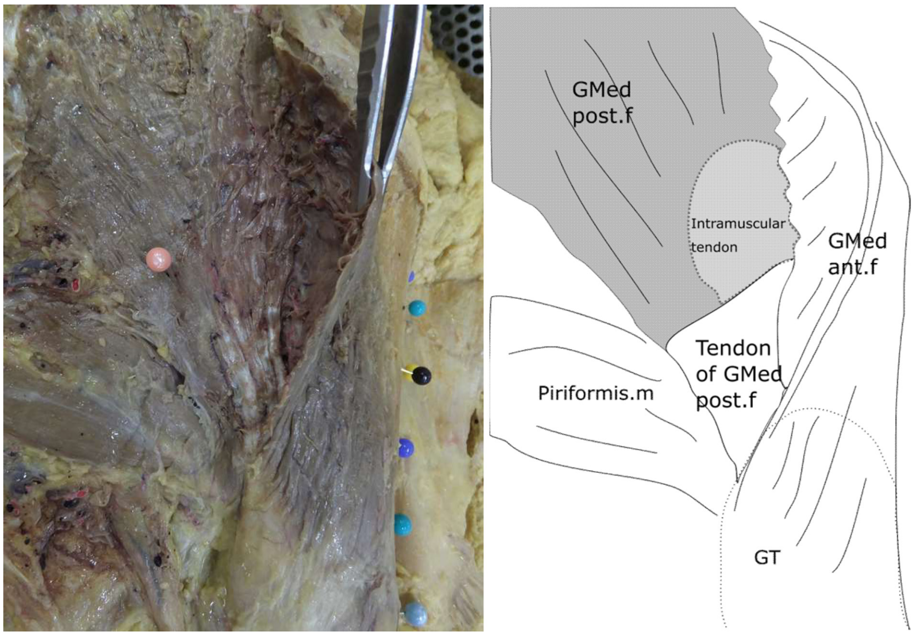

Fig. 4. A photograph and a diagram showing the structure of the the intramuscular tendon of the right GMed.
The posterior edge of the anterior fiber was pinched up to show the intramuscular tendon and the distal tendon of the posterior fiber.

The mean values of %LAIB and %LAGM revealed that a portion of the posterior fibers of the GMed was located subcutaneously (at between approximately 62% and 83% of the iliac crest length) without being covered by the superficial tissue (the TFL, the ITB, and the GMax). Thus, the posterior fibers of the GMed could be palpated at this zone without being affected by the stiffness of other tissues. The high ICC (1, 1) values for all measurements verified that the border points could be distinguished. The iliac crest length applied in this study consists of the ASIS, iliac crest, and PSIS, which can be easily palpated from the body surface. These have been applied as landmarks for the palpation of skeletal and muscular structures of the lower extremities and have been demonstrated to be highly objective. Hence, the method of this study, which defines the borders of the ITB, the GMed, and the GMax muscles based on the iliac crest length, might be effective as a simple and accurate palpation method for palpating the fiber bundles of the GMed from the body surface.

The results of this study suggested that the posterior fibers of the GMed could be palpated directly under the skin. This may have important implications for therapists when providing exercise programs to improve the stability of the lower extremities. For example, during landing following a vertical jump, activation of the GMed improves the stability of the knee joint as well as the hip joint[24]. The anterior cruciate ligament (ACL) is often injured when landing in the “valgus collapse” position, which is characterized by sudden excessive valgus of the knee joint[25]. In this position, the hip joint is forced into flexion, adduction, and internal rotation. Since the action of the posterior fibers of the GMed is hip extension, abduction, and external rotation, they may play an important role in preventing valgus collapse by interrupting the forced flexion, adduction, and internal rotation of the hip joint during landing. Therefore, a muscle-strengthening program under accurate palpation of the posterior fibers of the GMed with the method described in this study may prevent ACL injury.

As a limitation of this study, the ICC1,1 was applied as a measure of the reliability of the measurements by the same examiner; however, the inter-inspector reliability coefficient (ICC3,1) is superior in terms of objectivity. In the future, further accuracy of the research results will be improved by introducing the ICC3,1 with multiple examiners.

Regarding the strength of the present study, the measurements were performed using a flexible plastic measuring tape and anatomical landmarks were marked with pins, which might have caused some measurement deviations. Nevertheless, considering the high numerical value of ICC, deviations due to the measurement setup were considered to be insignificant. It should be noted that the participants of this study were all older individuals, a subpopulation that is not representative of the population, and the sample size was lower than that of previous studies on the GMed[20]. This might have affected the internal validity and research rigor of the study. Therefore, the existence of age-appropriate muscle atrophy and other characteristics of each specimen, such as disease and activity level, should be considered while interpreting the results of our study. Regarding innervation, the SGN of all cadavers was confirmed to be divided into two parts at the suprapiriform foramen. However, the subsequent arrangement into the GMed was not investigated; previous studies have been cited for the purpose of discussion. Further studies on the association between the GMed-related morphological findings obtained in this study and the innervation pattern may provide new insights.

In summary, the posterior fibers of the GMed muscle are located subcutaneously at between approximately 62% and 83% of the iliac crest length, without being covered by the TFL muscle and the GMax muscle, which could be useful as a palpation point for the posterior fibers of the GMed muscle (Fig. 5). Further interventional studies on in vivo participants using ultrasound imaging devices and surface electromyography need to be conducted.

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Conflict of interest

The authors declare no conflicts of interest associated with this manuscript.

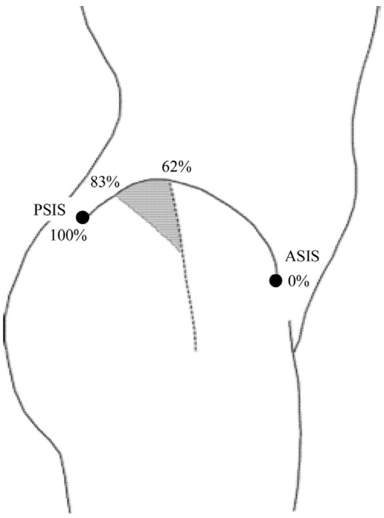

Fig. 5. Diagram of the zone where the posterior GMed fibers can be palpated subcutaneously (right lower limb).
The posterior GMed fibers should be palpated slightly distal to the iliac crest (shaded area) between 62% and 83% of the iliac crest length, which is 100% of the length from the ASIS to the PSIS.
Note that the iliac crest length is not the linear distance between ASIS and PSIS, but the length that follows the curve of the iliac crest.

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