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Spinal alignment in habitual standing position and while using smartphones in healthy young adults

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Abstract

Introduction. A cascade of biomechanical changes occurs with postural deviations. Therefore, this study aimed to determine the trunk position and spine shape during smartphone use.
Methods. Body posture was tested by the photogrammetric method in habitual standing position and while using smartphones in 39 healthy subjects of both sexes.
Results. While using smartphones, the trunk was shifted backwards ($F_{(1.37)}$ = 166.19, p = 0.0000), and the angle of the cervical spine increased in both sexes ($p < 0.05$). Furthermore, the depth of thoracic kyphosis and lumbar lordosis increased ($p < 0.001$), though only in the female group, but there were no differences in cervical load between groups ($p > 0.05$).
Conclusions. Using a smartphone caused backward displacement of the upper torso in both sexes. It was also found that using a smartphone increased the depth of thoracic kyphosis and lumbar lordosis in females, which should be interpreted as a compensatory mechanism.
Key words: smartphone, posture, spine, photogrammetry

Introduction

The smartphone is currently one of the most popular technological devices, with a recent study showing that 79% of the global population aged 18–44 use a smartphone daily [1]. Innovations in smartphone applications, including Internet surfing, social networking, gaming, portable media players, compact digital cameras, and high-definition touchscreens, have all contributed to their frequent use and smartphone ‘addiction’ [2]. The number of global smartphone users was estimated at 3.5 billion at the end of 2019 and is expected to reach 3.8 billion by 2021 [3].

It is estimated that children and young people spend an average of five to seven hours a day with their head tilted forwards using their smartphones and an average of 1,825 to 2,555 hours per year. The cumulative effects of this exposure have been found to produce alarmingly excessive strain on the cervical spine area [4]. One of the symptoms of overloading the cervical spine is musculoskeletal pain, mainly in its upper part, which is known as upper quadrant musculoskeletal pain (UQMP) [5, 6]. This depends on time, the activities performed while sitting [7–9], and the angular flexion of the head [10–13].

Inappropriate posture while using laptops and especially smartphones may be associated with the development of a complex set of clinical symptoms commonly referred to as ‘text neck’ [14], with neck pain being the fourth leading cause of disability worldwide [15]. The forward position of the head causes a mechanical load on the joints and ligaments of the cervical spine due to the increased gravitational moment [4, 16]. Furthermore, frequent forward bending of the head affects the magnitude of cervical lordosis and affects passive and active elements of the musculoskeletal system, causing changes in posture and increased pain in the neck and related areas [17, 18].

In a cross-sectional study, the total time using a smartphone was significantly associated with the occurrence of pain in the area of the left or right shoulder girdle and neck in university students and employees [19]. In other study, such a relationship was not found, although more than 50% of students felt (low or moderate) pain in the neck area [20]. According to a longitudinal population-based cohort study of young Swedish adults, prospective associations were found between text messaging on smartphones and disorders of the neck and upper extremities [21].

Motor disturbances were discovered during text messaging in a group with musculoskeletal symptoms, and almost all individuals had their necks flexed forward and did not support their arms. This caused muscular load in the neck and shoulders. Furthermore, they held the smartphone with one hand and used only one thumb, implying increased repetitive movements of the hands and fingers. This distinguished them from a group without symptoms, who were more likely to sit with a straight neck, support the forearm, hold the smartphone with two hands, and use both thumbs [22].

It is postulated that more research studies are required to understand and report on the cascade of biomechanical changes, starting with one of the deviations (forward head posture, rounded shoulders, and increased thoracic kyphosis [KP]), that lead to other deviations. Indeed, there is agreement that cervical lordosis values are significantly associated with KP values [23, 24].

Due to the overload mechanism described, it seems advisable to regularly monitor the quality of body posture of young people using a non-invasive method and without restrictions on age or availability. The data on the angles of the anteroposterior curvatures of the spine obtained using the photogrammetric method can be used to assess and monitor changes occurring during the rehabilitation process [24].

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To date, there are few experimental studies on the differences in body posture in young adults without pain symptoms, with only a few on the cervical spine [4]. Therefore, this study aimed to determine changes in the position of the trunk and the shape of the anteroposterior curvatures of the spine by computer photogrammetry in healthy young adults using a smartphone in a symmetrical manner, with two hands and both thumbs. It was hypothesised that phone position could alter the shape of the spine and increase in the angle of inclination of the cervical spine segment, but there was no change in the depth of kyphosis and lumbar lordosis. The compensatory displacement of the spine could occur in both sexes.

Subjects and methods

The study involved 39 health young adults, all students of the Faculty of Physiotherapy at the Wroclaw University of Health and Sport Sciences, aged 20–25 (22.5 ± 2.5 years), including 19 females (168.00 ± 5.68 cm; 61.6 ± 8.18 kg) and 20 males (182.1 ± 5.48 cm; 79.7 ± 10.3 kg). The inclusion criteria for the study were: the age of the subjects between 20 and 25, both sexes, no pain in the spine, and no previous injuries to the musculoskeletal system. The criteria for exclusion from the study were: lack of consent to participate in the study, injuries, and pain in the spine and/or other parts of the musculoskeletal system.

Methods

Body posture examination was performed by the photogrammetric method with the MORA4G system (CQ Elektronik System, Wroclaw, Poland) [25, 26]. Before the test, the participants provided their personal data (properly coded in the system), including age, height, and weight. Then, anthropometric points were marked on the subject's torso, including spinous processes of the spine (C7–S1), acromion processes of the shoulder blades (B2 and B4), lower angles of the shoulder blades (LL and LP), and posterior superior iliac spines (ML and MP). The participants took off their shoes to start the examination and were placed on a designated line at a constant distance of 2.6 metres from the device with their back to the camera, in semi-darkness. Next, the camera height was adjusted so that the entire torso image was visible on the computer monitor. The first image of the spine was taken when the subject was in their habitual position, with their hands loosely lowered and their head directed straight ahead. The second posture image was taken while the subject was spontaneously using a smartphone with both hands. A standard position of holding the device at the level of the nipple line was introduced. After registering several images of the examined person's silhouette, an image of the back was saved in the computer's memory. Next, the saved silhouette image was analysed, and the first stage of the analysis was to mark points on the spine, including the external occipital tuberosity (KS), the spinous process of the seventh cervical vertebra (C7), coracoacromial notches (B1 and B3), B2 and B4, axillary fossa (T1 and T2), greatest waist indentations (T3 and T4), LL and LP, lower shoulder blade angles, the peak of KP, the transition of KP into lumbar lordosis (PL), lumbar lordosis peak (LL), ML and MP, and the base of the sacrum (S1). The second stage of the analysis was to determine the shape of the spine line, which included the length of the spine curve and the maximum deviation of the line of the spinous processes, C7–S1. The last stage was the connection of the C7 and S1 summit lines [25]. Sample photographs of the subjects in their habitual position (Figure 1) and while using a smartphone are included in Figure 2.

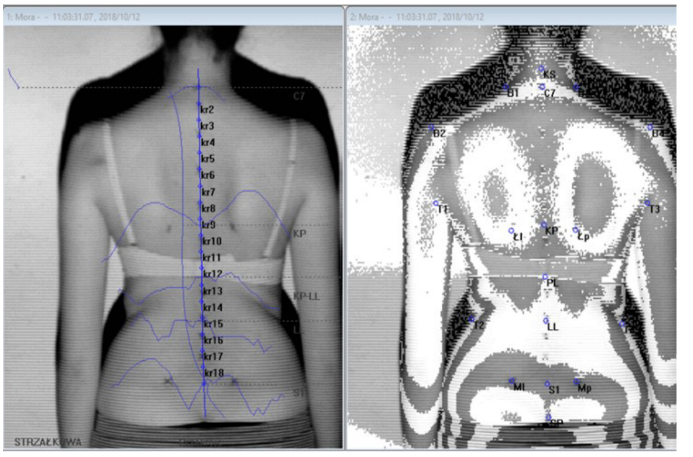

Figure 1. An examined person in habitual position (self-made)

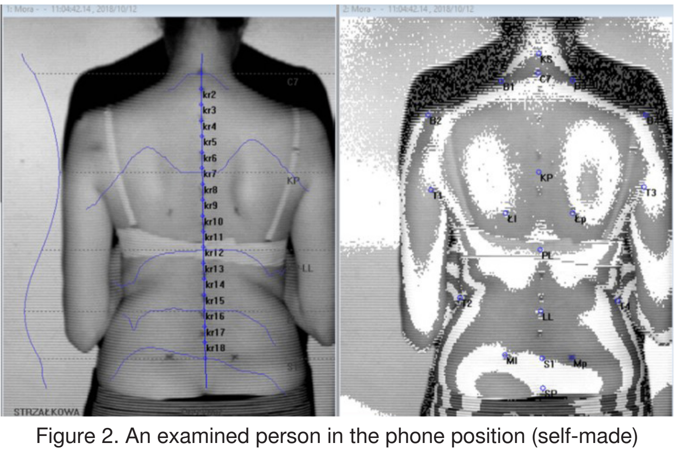

Figure 2. An examined person in the phone position (self-made)

The following parameters were analysed in the sagittal plane:

– KPT – angle of torso inclination forwards relative to the vertical (negative values) and backwards (positive values) positions.

– GLS – depth of cervical lordosis (maximum depression counted from the vertical passing through point C7).

– GKP – depth of kyphosis (KP) (maximum bulge counted from the vertical passing through the PL point – the thoracolumbar junction).

– GLL – depth of lumbar lordosis (LL) (maximum depression counted from the vertical passing through point PL).

– α – angle of inclination of the lumbosacral section of the spine (ALPHA).

– β – angle of inclination of the thoracolumbar spine (BETA).

– γ – angle of inclination of the upper part of the thoracic segment (GAMMA).

– δ – angle of inclination of the cervical spine (OMEGA) (Figure 3).

Statistical analysis

The results of spinal curvature parameters were statistically processed using Statistica software (StatSoft Poland, Krakow, Poland). Power analysis and sample size calculations were performed a priori. Assuming a clinically significant effect size of a change of 2 degrees in the angles of the spine, a sample size of 39 participants was determined to show acceptable power (0.8) at two-sided $p < 0.05$ [26]. The results of KPT, GLL, GKP, and GLS, as well as the angles of the anterior-posterior curvatures of the spine (ALPHA, BETA, GAMMA, and OMEGA), were subjected to a multivariate analysis of variance (ANOVA) (2 × group, 2 × position, 3–4 × area). The main effects of the factors and interactions were calcu-

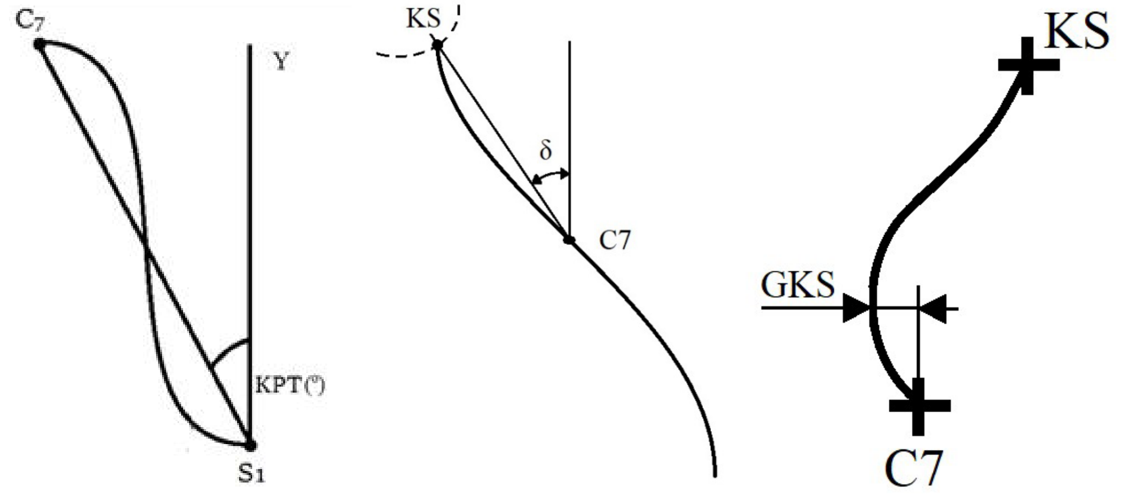

Figure 3. Parameters of anterior-posterior curvatures of the spine used for calculations

lated, and post hoc testing was performed using Bonferroni's correction. Means, standard deviation (*SD*), and confidence intervals (CI) (± 0.95) are presented in the tables. A significance level of $p < 0.05$ was assumed.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee of the University School of Physical Education (approval No.: 25/2016).

Informed consent

Before initiation of the study, each participant was informed of the study procedures and their right to refuse to participate or withdraw at any time. Informed consent was obtained from all individuals included in this study.

Results

Torso tilt angle

A significant effect of the position ($F_{(1.37)} = 166.19$, $p = 0.0000$) was observed for all subjects. In the post hoc test, a significant change was found in the angle of the torso tilting forwards relative to the vertical position of the torso in the habitual and tilting backwards phone position in both females ($p = 0.000$) and males ($p = 0.000$). There were no differences in the trunk tilt angle between males and females in either the habitual or the phone positions ($p > 0.05$) (Table 1).

Angles of the anteroposterior curvatures of the spine

A significant effect of the position ($F_{(1.37)} = 21.517$, $p < 0.0001$) was observed for all subjects. In the post hoc test, a significant increase in the angle of inclination of the cervical spine (OMEGA) was found in the habitual position and the phone position in both females ($p < 0.0001$) and males ($p < 0.05$). In addition, there was a statistical difference in the size of the ALPHA angle between the females and males in the habitual position ($p < 0.05$) and the phone position ($p < 0.05$). The females achieved greater ALPHA angular values compared to the males (Table 1).

Depth of the spinal curvatures

A significant effect of the position was observed ($F_{(1.37)} = 6.772$, $p = 0.01324$) for all subjects. In the post hoc test, a significant increase in GLL ($p < 0.001$) and GKP was observed ($p < 0.001$) in the females between the habitual and phone positions. There were no differences in GLS in either position in both groups ($p > 0.05$) (Table 2).

Discussion

This study aimed to assess changes in the body posture of students that occur when using a smartphone. The most important observations when comparing the influence of the adopted positions were changes in the angle of torso inclination forwards relative to the vertical (negative values) in the habitual position and backwards (positive values) in the phone position (KPT) and an increase in the angle of inclination of the cervical spine (OMEGA). However, the angle of inclination of the cervical spine increased in both the males and females, and GKP and GLL increased only in the group of females.

In the habitual position, it was found that the angle of the torso tilting forwards relative to the vertical position changed in relation to the backwards tilting of the torso while using a smartphone. This indicates that the mere positioning of the upper limbs with the telephone at the level of the nipple line forces a compensatory displacement of the upper torso backwards relative to the vertical. This deviation was of a similar angular value to the angle of inclination of the torso in the habitual position without the telephone, but in the opposite direction. Such a change in the position of the torso could have resulted from forcing the smartphone to be set at the same height for all participants. Research by Betsch et al. [27] showed a significant deepening of the torso inclination between the texting position, using one or two hands, and a simulated conversation position in a static position and while walking, which shifts the centre of gravity forwards. The participants of the experiment had no phone-holding position imposed and could hold the phone in their preferred position without any restrictions [27]. Furthermore, it has been shown previously that a more forward centre of gravity can lead to increased compressive and shear forces on the thoracic spine [28].

There was a change in the GKP and LL between the habitual position and when using a smartphone, but only in the females. This may be because the females had a significantly larger lumbosacral angle and a larger, though not significantly larger, thoracolumbar angle. Nonetheless, studies by other authors have shown no differences in the size of the LL angle, the angle of inclination of the sacrum, or the inclination of the pelvis between males and females in a free-standing position [29].

Table 1. Mean, standard deviation, and confidence intervals of the lumbosacral angle (ALPHA), thoracolumbar angle (BETA), upper part of the thoracic angle (GAMMA), cervical spine angle (OMEGA), and angle of torso inclination (KPT) relative to the vertical (negative values) and backward positive values in a habitual position and while using a smartphone for females and males

Variable	Female (*n* = 19)		Male (*n* = 20)	
	mean ± *SD*	CI (95%)	mean ± *SD*	CI (± 95%)
Habitual				
$ALPHA_h$	15.77 ± 5.10	13.31–18.23	10.72 ± 4.16	8.78–12.67
$BETA_h$	7.18 ± 4.40	5.06–9.30	8.49 ± 3.18	7.00–9.97
$GAMMA_h$	16.87 ± 7.87	13.07–20.66	16.11 ± 2.52	14.93–17.30
$OMEGA_h$	14.30 ± 3.19	12.76–15.84	17.69 ± 3.05	16.26–19.13
KPT_h	–8.27 ± 5.82	(–11.08)–(–5.47)	–5.29 ± 2.67	(–6.54)–(–4.04)
Phone				
$ALPHA_p$	14.65 ± 3.52	12.96–16.36	9.64 ± 3.43	8.03–11.25
$BETA_p$	9.43 ± 3.39	7.79–11.06	8.54 ± 3.24	7.02–10.06
$GAMMA_p$	17.21 ± 5.69	14.47–19.95	18.72 ± 3.20	17.22–20.22
$OMEGA_p$	21.06 ± 5.19	18.55–23.53	21.42 ± 2.97	20.03–22.82
KPT_p	6.42 ± 3.19	4.88–7.96	5.91 ± 2.75	4.62–7.20

standard deviation (*SD*) and confidence intervals (CI) (± 0.95), habitual position($_h$), phone-holding position($_p$)

Table 2. Mean, standard deviation, and confidence intervals for the depth of cervical lordosis (GLS), the depth of thoracic kyphosis (GKP), and the depth of lumbar lordosis (GLL) in habitual a habitual position and while using a smartphone in females and males

Variable	Female (*n* = 19)		Male (*n* = 20)	
	mean ± *SD*	CI (95%)	mean ± *SD*	CI (± 95%)
Habitual				
GLS_h	16.87 ± 9.35	12.36–21.38	15.85 ± 5.11	13.45–18.24
GKP_h	10.26 ± 8.00	6.41–14.12	14.84 ± 6.80	11.66–18.03
GLL_h	11.42 ± 7.89	7.62–15.23	15.89 ± 7.26	12.49–19.29
Phone				
GLS_p	16.90 ± 7.59	13.24–20.56	17.52 ± 5.21	15.08–19.96
GKP_p	14.87 ± 6.81	11.59–18.16	15.40 ± 7.00	12.12–18.68
GLL_p	16.02 ± 7.23	12.53–19.51	16.37 ± 7.33	12.93–19.80

standard deviation (*SD*) and confidence intervals (CI) (± 0.95), habitual position($_h$), phone-holding position($_p$)

Interestingly, there were no differences in the cervical lordosis depth when changing body position. This was probably due to the methodology of the study, which assumed the largest cervical lordosis depression along its external structure in relation to vertical from C7. When the head is tilted forward, the posterior muscles of the cervical region stretch, causing the 'outer' flattening of this section. It can also be assumed that the flexion of the head mainly takes place in the area of the cervicothoracic transition of the spine and the upper cervical section (the junction of the neck with the skull).

The C7 slope is a key parameter for studying the cervical spine statically, with a median value of 20°. Patients with a C7 slope greater than 20° had a lordotic cervical spine (lordosis between C2 and C7). However, patients with a C7 slope of less than 20° had a neutral or kyphotic cervical spine between C2 and C7, while a computed tomographic scan reconstruction showed a forehead posture with an increased C2 lordosis and decreased C2–C7 lordosis. The vertical cervical offset (SVA) corresponds to the horizontal distance of the C2 and C7 plumb lines and is a way to analyse the offset of the head [30].

There was a significant increase in the angle of inclination of the cervical spine between the habitual position and when using a smartphone, with the females having slightly greater angles than the males. Indeed, there was a significant flexion of the head while looking at the smartphone screen compared to the head position while relaxed. Earlier research by other authors confirmed the phenomenon of a greater forward tilt of the head when using a smartphone. The loss of the natural curvature of the cervical spine leads to increasing overloads of the cervical spine [4]. Similar results were reported by David et al. [14], with other authors showing a strong correlation with the gaze angle based on separately determined angles of head and neck flexion.

The novelty of the current research is the comprehensive approach to body posture in two positions: habitual and while using a smartphone, and all sections of the spine were recorded along the outer contour of the back. The method is non-invasive and safe for the health of the tested persons. Many previous studies have been limited to the assessment of the cervical spine only, by placing markers on the lateral side of the head and the cervical spine [4, 14, 23, 24]. An important observation would be to present changes in the body posture in relation to all its sections, not only taking into account the position of the head and the cervical spine.

The angle of bending the head may change depending on the activity performed while using a smartphone. The greatest angle of flexion was recorded when a person was typing and sending a text message, compared to just viewing websites or watching videos [31]. An increased head flexion angle requires more neck extensor muscle activity to maintain the head in a more flexed position, which has been identified as a risk factor for headache and neck pain in tablet users [16].

In modern times, a factor negatively affecting the physiological position of the spine is the too-frequent use of mobile devices, including smartphones. The problem of excessive use of smartphones is increasingly common in the 21st century. Moreover, abusing a smartphone, which is now almost an addiction, causes emotional and behavioural changes and negatively affects health [32]. Excessive smartphone use increases the strain on the cervical spine, which can lead to a pain syndrome called ‘text-neck syndrome’ or ‘tech neck’. Symptoms of this syndrome include cervical migraines, headache, pain in the shoulders, tingling in the arms and neck, numbness in the limbs, and intense pain in the neck that prevents twisting movements. Recently, the literature has drawn attention to issues that may become serious health problems, such as an increase in the number of people leading a sedentary lifestyle and excessive use of electronic devices among young people. The symptoms of chronic cervical and shoulder pain can sometimes be directed to the head, causing headaches and muscle tension, and are increasingly seen in younger people [14, 33]. In addition, as children use handheld mobile devices at an earlier age, parents and teachers need to be educated about the risks of prolonged use of these devices [14, 33], especially when children are characterised by a slim body build, disturbances in the setting of the anterior-posterior curves of the spine are more common [34].

A study using the modern DIERS 4Dmotion®Lab system discovered a significantly increased inclination of the lower cervical and thoracic spine when young men used a smartphone [35]. Prolonged smartphone use associated with greater cervical and thoracic spine tilt may result in increased pressure and shear forces on the vertebral bodies, intervertebral discs, and muscles, potentially increasing the risk of spinal pain and disease.

Regularly performing deep cervical flexor muscle exercises combined with corrective instructions for smartphone use was an effective therapeutic tool in reducing neck pain and disability in smartphone addicts [36]. A positive effect of wearing a special craniocervical orthosis was found on head positioning while typing on a keyboard for longer than 15 minutes [37].

Smartphones have a negative impact on body posture, but it is unrealistic to completely give up using them. It is worth paying attention to the postures taken when using the smartphone so that they put as little strain on the spine as possible. Indeed, incorrect habits in such a position may lead to the early appearance of spine pain in the future. As such, physical therapists need to educate their patients about correct posture when using handheld mobile devices. Correct posture includes: holding the device close to eye level, using the device while standing or sitting, holding the device with the line of sight perpendicular to the surface of the device, using a larger screen, and texting with both hands.

Limitations

The research was limited to only assessing changes in individual sections of the spine when the participants kept the smartphone on and looked only at the screen without doing any activities. It is worth expanding the research to assessing changes in body posture while performing other smartphone activities. An important limitation of the study was the lack of information on how long participants used their smartphones on a daily basis. Different times of using the smartphone may influence the differences in the shape of the anterior-posterior spine curvatures of young people.

The study is worth repeating with children because this group is most exposed to overload resulting from the excessive and incorrect use of smartphones. In addition, the spine is in the process of physiological development in this age group, and the changes in posture that occur when using a smartphone may be greater than in adults and may not only concern the sagittal plane.

Conclusions

In a standing position, using a smartphone with both hands at the level of the nipple line forced compensatory displacement of the upper torso backwards in relation to the vertical angle. An increase in the angle of inclination of the cervical segment was observed, but the depth of the cervical lordosis of the spine did not change in males or females. Using the smartphone with both hands caused an increase in the depth of kyphosis and lumbar lordosis in females, which should be interpreted as a mechanism of compensatory change.

Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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