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THE ACUTE EFFECT OF SELF-MASSAGE ON THE SHORT-TERM RECOVERY OF MUSCLE CONTRACTILE FUNCTION

AKUTNI UČINEK SAMOMASAŽE NA KRATKOROČNO REGENERACIJO MIŠIČNE ZMOGLJIVOSTI

ABSTRACT

Fast recovery is desirable in the performance of competitive sports. Foam rolling, a type of self-massage, has been shown to lower perceived ratings of fatigue, but physiological effects of foam rolling on short-term recovery have not been explored to date. The purpose of this study was to provide the preliminary data on the effects of self-massage via foam rolling on the recovery of muscle contractile function. Ten participants visited the laboratory on two occasions to perform 3 sets of 15 repetitions on a knee extension machine at 70% of 1 repetition maximum. This was followed either by foam rolling (intervention group) or passive rest (control group) for a period of ninety seconds, in a randomized order. Measures of muscle contractile function were performed prior to exercise, immediately following exercise, and after the control/intervention procedure. Main outcome variables included maximum voluntary contraction and response of the relaxed vastus lateralis muscle to a single electrical stimuli followed by two sets of double stimuli (10 Hz and 100 Hz, respectively). Both the foam rolling and passive rest promoted small recoveries (effect size = 0.2 – 0.6) on all main outcome variables (5.5 – 16.2 % and 4.7 – 8.3 % after foam rolling and passive rest, respectively) with no differences between them. Foam rolling appears to be equally effective as passive rest for short-term recovery of muscle contractile function.

Key words: foam rolling, self-myofascial release, peripheral fatigue

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IZVLEČEK

Hitra regeneracija je zaželena v svetu športa. Dokazano je bilo, da samomasaža s penastim valjem zmanjša lastno zaznavanje utrujenosti, vendar fiziološki učinki masaže s penastim valjem na utrujenost ostajajo neraziskani. Namen te raziskave je bil zbrati začetne podatke o učinkih samomasažne terapije s penastim valjem na regeneracijo po utrujajočem mišičnem naprezanju. Deset merjencev je dvakrat obiskalo laboratorij in izvedlo 3 serije po 15 ponovitev na napravi za izteg kolena pri 70% največje teže. Temu je v naključnem vrstnem redu sledila bodisi samomasaža s penastim valjem, bodisi pasivni počitek v trajanju devetdeset sekund. Pred in po utrujanju ter po samomasaži oz. pasivnem počitku smo izmerili največjo hoteno mišično naprezanje in odziv sproščene mišice vastus lateralis na enojni in dva dvojna električna dražljaja (10 Hz in 100 Hz) . Obe intervenciji sta spodbudili majhno regeneracijo vseh glavnih spremenljivk (5,5 – 16,2% po samomasaži s penastim valjem in 4,7 – 8,3 % po pasivnem počitku), brez razlik med njima. Zdi se, da je masaža s penastim valjem enako učinkovita kot pasivni počitek pri kratkoročni regeneraciji mišične zmogljivosti.

Ključne besede: masaža s penastim valjem, samo-mio-fascialno sproščanje, periferna utrujenost

INTRODUCTION

Short-term recovery is of great importance for athletes, particularly when optimal performance is desired within the same training session, between training sessions, in tournaments with several games on the same day, and in sports where competitions consist of heats, semifinals, and finals (e.g. track and field, swimming). A number of short-term recovery modalities have been considered, including active recovery, cryotherapy, contrast temperature water immersion, hyperbaric oxygen therapy, non-steroidal anti-inflammatory drugs, compression garments, stretching, electromyostimulation and massage (Barnett, 2006). Although the effectiveness of these modalities has been questioned (Barnett, 2006), the relative availability of some of them also precludes their use by many athletes.

Self-massage is a form of massage performed with a tool (e.g. a foam roller, a roller massage stick or a tennis ball) rather than a clinician (Beardsley & Škarabot, 2015). In essence, it provides some of the benefits of massage, but is potentially more available and practical for an individual. A recent review noted that self-massage appears to increase range-of-motion acutely, without impeding neuromuscular performance. It also reduces arterial stiffness, improves vascular endothelial function, and attenuates delayed onset muscle soreness (Beardsley & Škarabot, 2015).

Using massage as a tool to enhance the post-exercise recovery process has been of great interest in the field of sports medicine for many years (Best, Hunter, Wilcox, & Haq, 2008) and is being widely used in practice (Callaghan, 1993). It has been suggested that massage can improve an individual's psychological state, enhance range-of-motion and reduce perception of pain; however, evidence to date indicates that there are in fact, no positive effects on physical performance or physiological parameters related to delayed onset muscle soreness (Brummitt, 2008). Massage is believed to be a valid technique that athletes use to help overcome fatigue and reduce the recovery time (Weerapong, Hume, & Kolt, 2005). However, the literature on the beneficial effects of massage on short-term recovery is equivocal (Brooks, Woodruff, & Wright, 2005; Hemmings, Smith, Graydon, & Dyson, 2000; Rinder & Sutherland, 1995; Tanaka, Leisman, Mori, & Nishijo, 2002). On the other hand, perceived ratings of fatigue after massage (Hemmings et al., 2000; Ogai, Yamane, Matsumoto, & Kosaka, 2008; Tanaka et al., 2002) and self-massage (Healey, Hatfield, Blanpied, Dorfman, & Riebe, 2014) have consistently been reported to be lower, suggesting the beneficial effect of massage.

One of the ways that massage and/or self-massage may enhance the post-exercise recovery is through increased temperature and blood flow (Mohr, Long, & Goad, 2014), thereby augmenting the removal of metabolites (Pinar, Bicer, Kaya, Erzeybek, & Cotuk, 2012). However, while previous research has indeed shown increased blood flow after massage (Hovind & Nielsen, 1974), these claims have since been largely refuted as increases in blood flow after massage are likely to be limited to the skin and have little or no effect on the muscle (Hinds et al., 2004). On the other hand, psychological effects of massage have been consistently reported to positively affect the short-term recovery process (Hemmings et al., 2000; Ogai et al., 2008; Tanaka et al., 2002). Furthermore, reduced perception of fatigue has been reported following a self-massage intervention using a foam roller (Healey et al., 2014). Nevertheless, the potential physiological benefits have not been explored to date, and therefore the purpose of this study was to provide the preliminary data on the effects of self-massage via a foam roller on the recovery of muscle contractile function.

METHODS

Participants

Ten recreationally-active college-aged individuals (9 males, 1 female; 18-24 years old) volunteered for the study. All participants were physically active at the time of the study, but were not involved in any structured program of physical activity. None of them had previous experience with self-massage. All participants were healthy and free from any lower limb and/or lower back musculoskeletal injury that could affect the results of the study. Participants were informed of all the risks and benefits of the investigation and provided written consent prior to participation. All procedures were in accordance with Declaration of Helsinki. The study was approved by the ethics committee of Faculty of Sport, University of Ljubljana.

Study design

A randomized within-subject design was used to investigate the acute effects of foam rolling on peripheral fatigue. Participants visited the laboratory on two occasions at similar times during the day to avoid diurnal variations, with a minimum of 48 hours between the visits. One visit involved intervention with the foam roller, while the other served as a control, (conducted randomly). Foam rolling and all the measurements of the dependent variables were always performed on the dominant leg, defined as the leg that they would kick a ball with (Škarabot, Beardsley, & Štirn, 2015). At the beginning of the first visit the foam rolling technique was demonstrated by a lab technician. Participants were then allowed a brief familiarization, which was practised until participants displayed appropriate technique as assessed by the lab technician. A single familiarization session was deemed sufficient to learn the proper foam rolling technique (MacDonald et al., 2013). On both visits, the experiment began with determination of electrical stimulus intensity followed by a standardized warm-up, which consisted of a 6-minute stepping routine on a 25-cm bench at a frequency of 0.5 Hz with the stepping leg being changed every 1.5 minutes. During the first visit (Figure 1A), the warm-up was followed by determination of the one repetition maximum (1 RM) in concentric leg extension, which was later used to determine the loading during the fatigue protocol on both days. The 1 RM was obtained by progressively increasing the load by 2.5-5 kg increments until the load could not be lifted to the finishing position. The magnitude of increment was chosen based on the performance of the previous attempt. For example, if the participant was able to lift the load with relative ease, the load was increased by 5 kg rather than 2.5 kg, so as to minimize the number of trials. The last successful attempt was considered 1 RM. No more than five trials were made to determine the 1 RM. After a 30-minute break, which was sufficient for recovery based on pilot data and experience of the research team, participants performed two accommodation trials at 50% and 80% of perceived maximum contraction. After that, pre-measurements of dependent variables were performed consisting of maximal voluntary isometric contraction (MVC) torque and response of the relaxed vastus lateralis (VL) muscle to a single stimuli electrical stimulation followed by two sets of double stimuli (10 Hz and 100 Hz, respectively). Measures were performed on a custom-made leg extension chair with built-in force transducers (MES, Maribor, Slovenia). Participants were seated in the chair with the knee and hip joints flexed at 60 and 110 degrees, respectively, and stabilized by a belt across the hip to ensure minimal movement of the pelvis. Following the pre-tests, participants performed the fatigue protocol. After a 30-second break measures of dependent variables were performed again. Participants then proceeded to perform either the experimental or control condition selected at random via an online randomizer (https://www.randomizer.org/).The intervention consisted of foam rolling (FR), while the control condition involved passive rest in the prone position (PR), both lasting for 90 seconds. Thirty seconds after either FR or PR the dependent variables were measured again. Graphic representation of the study design is depicted in Figure 1.

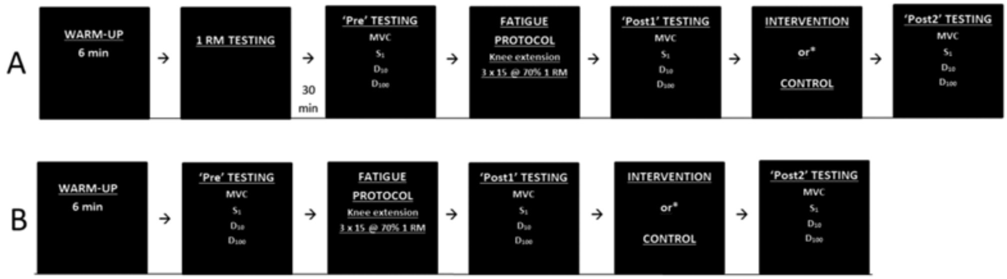

Figure 1. Graphic representation of the study design; A – first visit to the laboratory, B – second visit to the laboratory.

MVC = maximal voluntary isometric contraction, S_1 = responses of the relaxed vastus lateralis muscle to single twitch stimulation, D_{10} = responses of the relaxed vastus lateralis muscle to double twitch stimulation at 10 Hz, D_{100} = responses of the relaxed vastus lateralis muscle to double twitch stimulation at 100 Hz; RM = repetition maximum; 'INTERVENTION' = foam rolling; 'CONTROL' = passive rest; *As per randomization.

Procedures

Fatigue protocol

Fatigue was induced by performing 3 sets of 15 repetitions of knee extensions on a knee extension machine (TechnoGym; via Calcinaro, 2861 – 47521 Cesena, Italy) with 70% of predetermined 1 RM load. The tempo of the repetition was set so that the concentric and eccentric parts lasted one and two seconds, respectively. Each set began every second minute meaning that the rest period was 1 minute and 15 seconds in duration. If the participants had reached voluntary failure before the completion of 15 repetitions, they were assisted in order to complete the prescribed number of sets and repetitions. The assistance was performed by a lab technician. They would provide just enough pressure to the lever arm of the device for participants to complete the repetition, but not more. This fatiguing protocol has been chosen for the present study because it represents something that could be considered a part of a typical hypertrophy-type resistance training session (e.g. Schoenfeld, Contreras, Vigotsky, & Peterson, 2016).

Foam rolling

Foam rolling was performed using The Grid Foam Roller (14 cm diameter, 33 cm length, 0.65 kg; Trigger Point Technologies, 5321 Industrial Oaks Blvd., Austin, Texas 78735, USA). Participants were instructed to get themselves into a plank position and place the foam roller on the proximal part of the quadriceps femoris muscle. Furthermore, they were instructed to divide the muscle into three imaginary portions, i.e. proximal, middle, and distal. They started the foam rolling with small kneading-like motions at the most proximal portion of the quadriceps muscle followed by the middle and distal portion, respectively. After that they continued with more fluid, longer motions from the most proximal (spina iliaca anterior inferior) to the most distal part (patella) of the quadriceps muscle. If they felt an area of discomfort they were also instructed to maintain the pressure on that particular point. The foam rolling technique described was chosen as it was considered to be most commonly used in practice (Stevens, 2013).

Maximal voluntary isometric contraction

Upon receiving the command, the participants gradually applied the force, reaching maximum force in approximately 2 seconds and maintained it for an additional 2 seconds. Participants were given feedback of their performance via a visual display on a monitor and verbal encouragement was given during all trials. Torque was analyzed as peak torque achieved during MVC.

Electrical stimulation

Direct muscle stimulation was achieved via pairs of self-adhesive neurostimulation electrodes (9x5 cm; Axelgaard, Fallbrook, CA) with the distal and proximal electrode being placed over the distal and middle part of the muscle belly, respectively, over the VL muscle. The electrode position was kept constant throughout the experiment. Constant-current, rectangular biphasic electrical stimuli with 0.3 ms pulse duration were delivered to the muscle using custom-made computer controlled electrical stimulation (Furlan & Co., Ljubljana, Slovenia)(Tomazin, Dolenec, & Strojnik, 2008). Data was sampled at 1 kHz using a 12-bit AD converter (Burr-Brown, USA).

Single twitch (S_1) stimulation was performed by delivering supramaximal electrical stimulus directly to the relaxed VL muscle. Stimulus intensity was determined prior to the experiment by increasing the stimulation current until no further increase in torque was observed despite increases in amperage. After that, the amperage was further increased by 10% to ensure that it was supramaximal and was kept constant throughout the experiment. The torque signal was smoothed (triangular (Bartlett) window, window width 5 samples) and subsequently analyzed for peak value (S_1).

Supramaximal electrical double stimuli were delivered directly to the relaxed VL muscle at 10 and 100 Hz, respectively, during double twitch stimulation. This was done in order to differentiate between low- and high-frequency fatigue (Tomazin, Sarabon, & Strojnik, 2008). The torque signal was analyzed for its peak value achieved during stimulation at both frequencies (D_{10} and D_{100}, respectively).

All data was collected and analyzed using LabChart 8 software (Ad Instruments, New Zeland).

STATISTICAL METHODS

Data are presented as means and standard deviations (SD). A two-way (time [Pre – Post 1 – Post 2] x condition [passive rest – foam rolling]) repeated measures ANOVA was employed. When significant F values were achieved, pairwise differences between means were identified using Bonferroni post hoc procedures. Effect sizes using Cohen's *d* and percentage differences were also calculated. The percentage changes after each recovery condition ([Post 2 mean – Post 1 mean] / Post 2 mean × 100) were compared through paired samples t-tests to determine if differences existed between both recovery conditions (PR vs. FR). Significance was set at $P < 0.10$. We chose this value as it reasonably implies a clear outcome if the true value is very unlikely to be substantial (Hopkins, Marshall, Batterham, & Hanin, 2009). The criteria to interpret the magnitude of the effect sizes were as follows: <0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large, and >2 = very large (Hopkins et al., 2009). All statistical tests were performed using the software package SPSS (version 20.0: SPSS, Inc., Chicago, IL, USA).

RESULTS

Prior to the fatiguing protocol, no statistical differences between either of the testing days were observed as noted by a t-test (P = 0.37 – 0).

Following intervention with foam rolling, the fatigue protocol induced trivial to small reductions in MVC (- 2.8%, effect size: - 0.13), but moderate to very large decrements were observed for single-twitch stimulation (- 31.1%; effect size: - 2.87), double-twitch stimulation at 10 Hz (- 32.7%; effect size: - 2.16), and double-twitch stimulation at 100 Hz (- 21.3%; effect size: - 1.73) (see 'Post 1' in Table 1).

Similarly, following passive rest, the fatigue protocol resulted in trivial to small decrements in MVC (- 6.4%; effect size: - 0.38). However, moderate to very large decrements were observed for single-twitch stimulation (- 25.5%; effect size: - 1.19), double-twitch stimulation at 10 Hz (- 30.1%; effect size: - 1.3) and double-twitch stimulation at 100 Hz (- 17.9%; effect size: - 0.90) (see 'Post 1' in Table 1).

Both recovery conditions promoted small recoveries on MVC (effect sizes for PR and FR of 0.22 and 0.34, respectively), single-twitch stimulation (effect sizes for PR and FR of 0.22 and 0.42, respectively), double-twitch stimulation at 10 Hz (effect sizes for PR and FR of 0.25 and 0.39, respectively), and double-twitch stimulation at 100 Hz (effect sizes for PR and FR of 0.18 and 0.35, respectively) (see 'Post 2' in Table 1).

Table 1. Time course of torque responses (Nm) depending on the intervention.

	Pre		Post 1		Post 2	
	PR	FR	PR	FR	PR	FR
MVC	369.5 ± 62.4*a	365.7 ± 79.2	345.8 ± 73.7*c	355.6 ± 59.2	361.7 ± 81.5	375.9 ± 79.0
S_1	67.4 ± 14.5a,b	70.9 ± 7.7a,b	50.2 ± 14.0c	48.8 ± 14.0*b, c	53.2 ± 11.2c	54.7 ± 9.2*a,c
D_{10}	109.3 ± 25.2a,b	111.0 ± 16.8a,b	76.4 ± 20.8c	74.8 ± 22.3*b,c	81.6 ± 17.2c	83.4 ± 15.7*a,c
D_{100}	116.7 ± 23.3a,b	119.2 ± 14.7a,b	95.8 ± 21.9c	93.8 ± 21.1c	99.7 ± 19.0c	101.1 ± 18.4c

'Pre' = before the fatiguing protocol, 'Post 1' = after the fatiguing protocol, 'Post 2' = after either foam rolling or passive rest; FR = foam rolling, PR = passive rest; MVC = maximal voluntary isometric contraction. S_1 = responses of the relaxed vastus lateralis muscle to single twitch stimulation, D_{10} = responses of the relaxed vastus lateralis muscle to double twitch stimulation at 10 Hz, D_{100} = responses of the relaxed vastus lateralis muscle to double twitch stimulation at 100 Hz; [a], Significantly different versus Post 1; [b], Significantly different versus Post 2; [c], Significantly different versus Pre. $P < 0.10$. $*0.10 > P > 0.05$.

No statistical differences were noted between FR and PR in recovery of any dependent variable (Table 2). Foam rolling showed a greater percentage change in recovery of all dependent variables after the intervention in comparison with PR, but this was not statistically significant.

Table 2. Comparison of percentage change after passive rest and foam rolling and mean differences between them with 90% CIs.

	Passive rest % of change	Foam rolling % of change	P-value	Foam rolling – Passive rest (%) Mean difference (90% CI)
MVC	4.7 ± 10.6	5.5 ± 10.7	0.717	0.85 (-3.33 to 5.03)
S_1	8.1 ± 12.2	16.2 ± 19.6	0.104	8.11 (-0.12 to 16.35)
D_{10}	8.3 ± 10.8	15.5 ± 17.3	0.200	7.20 (-2.34 to 16.74)
D_{100}	4.9 ± 7.1	9.3 ± 12.4	0.166	4.34 (-0.93 to 9.61)

PR = passive rest, FR = foam rolling; MVC = maximal voluntary isometric contraction, S_1 = responses of the relaxed vastus lateralis muscle to single twitch stimulation, D_{10} = responses of the relaxed vastus lateralis muscle to double twitch stimulation at 10 Hz, D_{100} = responses of the relaxed vastus lateralis muscle to double twitch stimulation at 100 Hz.

DISCUSSION

The major finding of our study was that both PR and FR had a small effect on acute recovery parameters, with no significant differences between the two interventions. This concurs with most of the literature on massage suggesting that its effects on short-term recovery are not superior to passive rest (Barlow et al., 2007; Hemmings et al., 2000; Pinar et al., 2012; Tanaka et al., 2002).

The fatigue protocol utilized in the present experiment induced only a trivial to small reduction in MVC. Other studies that examined acute neuromuscular responses to a hypertrophy protocol in leg extensor muscles have shown a greater reduction in MVC compared to ours (Häkkinen, 1994; Walker, Davis, Avela, & Häkkinen, 2012). However, the fatigue model used in those studies included the squat (Häkkinen, 1994) and the leg press (Walker et al., 2012) exercises, but the MVC measures were performed in an isometric leg extension chair. It is possible that they were able to induce greater fatigue, i.e. greater reduction in MVC, due to larger muscle mass involved in the exercise. Moreover, the total volume of the protocol was much higher than in the present study (Häkkinen, 1994).

MVC was different after the fatigue protocol in only one visit to the laboratory (PR condition). This could suggest that the fatigue protocol was insufficient to induce fatigue, which makes the comparison between the intervention and control condition difficult. This variability could potentially be explained by the fact that no MVC form of practice was performed prior to the actual experiment. It has been suggested that not performing some sort of practice would result in submaximal and variable contraction levels (Gandevia, 2001). It is, therefore, possible that the performance on subsequent MVC trials compared to the pre-tests was potentiated due to learning. While presumably randomization would have likely minimized this variability, the activity of our participants in the days prior and on the day of the experiment was also not controlled and thus it seems plausible that they were better rested on certain days thereby exhibiting variability in their force producing capacity. It should be noted that the potential reasons mentioned above are speculative and future investigations should involve a more strenuous fatiguing protocol that would ensure attenuation of MVC, and include a familiarization session to reduce the likelihood of the learning effect. The protocol used in the present study had been chosen due to its ecological validity, as it likely represents a part of a typical hypertrophy-type resistance training session. However, in order to induce the appropriate amount of fatigue in the future studies, more than 3 sets would probably be needed.

A reduction in all the resting twitches was observed after the fatigue protocol and none of them had returned to baseline levels by the time of the second set of measures, i.e. after either FR or PR. While central fatigue cannot be discounted, this is fairly typical response after induction of low-frequency fatigue, which is characterized by a slow recovery process (Jones, 1996). A reduction in single-twitch torque, an indicator of peripheral fatigue, is in agreement with Walker et al. (Walker, Peltonen, Avela, & Häkkinen, 2013), who investigated neuromuscular function after hypertrophic resistance training protocol.

Percentage differences (Table 2) would suggest a tendency towards greater recovery following FR based on the responses of relaxed VL muscle to single twitch and low-frequency (10 Hz) double twitch stimulation (16.2 vs. 8.1 %, and 15.5 vs. 8.3%, respectively). However, these differences were not found to be statistically significant and were also accompanied by large variability of the responses as noted by standard deviations.

The purpose of this study was to provide a pilot data for future research and hence only a small sample size was used. Based on the above mentioned results, 37 participants would be needed to achieve sufficient statistical power (effect size = 0.47, $\alpha = 0.05$, $1 - \beta = 0.8$)(Faul, Erdfelder, Lang, & Buchner, 2007). Thus, future studies that wish to revisit this question should aim for the number of participants suggested. Furthermore, they should consider a more strenuous fatiguing protocol, and possibly include measures of perceived ratings of fatigue.

Interpretation of the results of the study should be made with caution due to its limitations. Firstly, the sample size was not based on an a priori power analysis and was small. The goal of the study was to serve as a pilot for future research; hence the measures were performed on a small number of participants. Secondly, the sample size had an unequal distribution of genders (only 1/10 participants were females). However, when we ran a separate analysis excluding the female from our sample, the significance of the results did not change. Regardless, future studies looking into the effects of self-massage on fatigue, should use a sample that includes equal number of male and female participants, especially considering differences in fatigability between genders (Hunter, 2016). Thirdly, FR protocol employed in the study was very flexible, possibly resulting in a large variation in the time spent on each action and the pace at which the participants used the foam rolls, thereby reducing internal validity. However, our protocol can also be regarded as having a higher validity as it more likely represents a real situation. Lastly, our fatigue protocol may be considered as representative of only a part, rather than the whole of a resistance exercise session. Thus, whilst it remains unclear if similar or different outcomes would have been observed had the full session been performed, this is worthy of further exploration in future studies.

In conclusion, foam rolling does not appear to have a superior effect over passive rest on short-term recovery of muscle contractile function. However, no detrimental effects were noted. The existing literature suggests that massage or self-massage may provide an athlete with a sense of relaxation and lower perceived ratings of fatigue (Healey et al., 2014), which may make foam rolling a worth while option for short-term recovery.

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