Science & Sports (2020) 35, 161—167

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ORIGINAL ARTICLE

The effect of a new geometric bicycle saddle on the genital-perineal vascular perfusion of female cyclists

Effets d'une nouvelle selle de vélo pour femmes sur la perfusion vasculaire vaginale et périnéale

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Received 14 August 2018; accepted 15 July 2019
Available online 28 December 2019

KEYWORDS
Perineal compression;
Urogenital disorders;
Pelvic floor;
Female Sexual Dysfunction;
Pudendal nerve

Summary
Purpose. — Female cyclists undergo a perineal compression of the pudendal nerve and genital-perineal area, with underexplored effects on genital injuries and sexual dysfunctions. This study tests the effects of a new geometric bicycle saddle (SMP) on perineal compression, blood perfusion, genital sensation and sexual function.
Methods. — Thirty-three professional female athletes were monitored when using both the new saddle and a traditional professional saddle, in a randomized order. Short-term effects are estimated by measuring the partial pressure of vagina transcutaneous oxygen (PtcO2) before using the saddle, after 10 minutes of static sitting, after riding 20 minutes. Long-term effects are estimated by measuring athletes Female Sexual Distress Scale (FSDS) before using the new saddle and after 6 months using it.
Results. — From an initial average of 70 mmHg, PtcO2 decreases by 30 mmHg after riding on a traditional saddle, 10 mmHg on the new saddle (respectively 20 and 7 after just sitting). When using the traditional saddle all FSDS scores are well over the 12 ''normality'' threshold, with an average of 41, while after using the new saddle the average falls to 12. All differences between the saddles are strongly significant: paired t-tests > 6; $P < 0.001$; 95% confidence intervals respectively 13 ± 3 mmHg after sitting, 20 ± 3 mmHg after riding, 29 ± 2 FSDS scores.

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https://doi.org/10.1016/j.scispo.2019.07.010
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Conclusion. — Traditional saddles have strong negative effects on the vascular perfusion of the vulva, with possible consequences on female sexual functions. The SMP saddle reduces the compression on the pelvic floor and can help reducing the incidence of urogenital pathologies for female cyclists.
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MOTS CLÉS
Compression périnéale ;
Dysfonctionnement urogénital ;
Plancher pelvien ;
Dysfonctionnement sexuel féminin ;
Nerf pudendal

Résumé
Objectifs. — Les femmes cyclistes subissent une compression périnéale du nerf pudendal et de la zone genito-périnéale, avec des effets souvent sous-estimés, à type de lésions génitales et de dysfonctionnements sexuels. Cette étude teste les effets d'une nouvelle selle au design spécifique (SMP) sur la compression périnéale, la perfusion sanguine, la sensation génitale et la fonction sexuelle.
Méthodes. — Trente trois femmes cyclistes professionnelles ont été étudiées lors de l'utilisation d'une selle professionnelle traditionnelle et une nouvelle, en ordre aléatoire. Les effets à court terme sont évalués en mesurant la pression partielle de l'oxygène tissulaire au travers de la peau de la région vaginale (PtcO2), avant d'utiliser la selle, après 10 minutes de session statique et après 20 minutes de pédalage. Les effets à long terme sont estimés par l'échelle de Female Sexual Distress Scale (FSDS), avant d'utiliser la nouvelle selle et après 6 mois d'utilisation régulière de ce matériel. Les effets spécifiques de la selle expérimentale sont comparés à ceux d'une selle professionnelle classique.
Résultats. — À partir d'une moyenne initiale de 70 mmHg, PtcO2 diminue en moyenne de 30 mmHg après l'utilisation à l'exercice d'une selle traditionnelle et 10 mmHg avec la nouvelle selle (baisses respectives de 20 et 7 mmHg en position assise seule). Lors de l'utilisation de selle traditionnelle tous les scores FSDS sont bien au-dessus du plafond de « normalité » de 12, avec une moyenne de 41, par contre, après l'usage de la nouvelle selle, la moyenne retrouve des valeurs conformes avec la normale (autour de 12). Toutes les différences statistiques entre les selles sont très hautement significatives: valeurs du t de Student pour données appariées traduisant une différence à $p < 0{,}001$; 95 % intervalle de confiance respectivement 13 ± 3 mmHg après séance assise, 20 ± 3 mmHg après course, 29 ± 2 score FSDS.
Conclusion. — Les selles traditionnelles ont de forts effets négatifs sur la perfusion vasculaire de la vulve, avec des conséquences potentielles sur les fonctions sexuelles féminines. La selle SMP réduit la compression du plancher pelvien et peut aider à réduire l'incidence de pathologies urogénitales des femmes cyclistes.
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1. Introduction

Cycling is a popular sport among women and men; both health and quality of life benefits have been reported on riders [1,2]. However, bicycle riding is also associated with a number of health risks including pelvic neurovascular compromise. The primary mechanisms leading to these symptoms in both genders are perineal compression of the pudendal nerve and genital-perineal area [3].

The existing literature reports genital symptoms and pelvic floor dysfunction in male cyclists, the most common urogenital problems associated with cycling being perineal numbness, pudendal nerve entrapment syndromes and erectile dysfunction [4—6].

Literature on genital overuse injuries and sexual dysfunctions in female cyclists is comparatively much smaller [6]. A recent review [7] concludes that ''the quality of existing studies is generally low, but there is evidence that female cyclists suffer from similar problems to male cyclists''. This lack of analysis is particularly important because more than half female cyclists reported in a survey at least one genital complaint after cycling among pain, numbness and edema of pelvic floor, dysuria, stranguria, vulvar discomfort, dyspareunia [8]. According to another large scale survey [9], women cyclists are more likely than non-cyclists to report urinary tract infections, genital numbness and saddle sores.

Female cyclists' position on the bicycle and the type of saddle used have more effect on resultant sexual dysfunctions than simply participation in cycling [6,10]. Prevailing results suggest that neurovascular damage occurs during cycling as a result of chronic compression of the genital area against the saddle [11,12]. Therefore, the symptoms were attributed to a compression of the pudendal nerve in Alcock's canal and from stretching the nerve during pedaling, as it spans between the sacrospinous and sacrotuberous ligaments, as well as the compression of the nerve against the saddle where it innervates the perineum and symphysis [13]. Altered nerve conduction and reduced blood flow to the vagina and clitoris can result in delayed vaginal engorgement, pain or discomfort with intercourse, less vaginal lubrication, reduced vaginal and clitoral sensation and may lead to Female Sexual Distress (FSD) [14—16].

There are significant anatomical differences that affect how the bodies of females and males interact with the bicycle [17]. When compared to men, women have a wider pelvis, a lower center of gravity, a greater pelvic tilt when riding and a higher peak saddle pressure in the anterior region of the saddle when they move from the tops to the drops [18—20]. To date, few studies have evaluated the associations between saddle design, seat pressure and neurovascular compromise in women [7,8,21]. The outcome of typical interest used in experiments [21,22] is saddle pressure in different regions of the saddle, measured by means of pressure mats. Still, the different results are not consistent one another and ''the positive relationship between discomfort and pressure remains a matter of debate'', thus ''pressure may not necessarily be a direct mediator of perceived discomfort'' [21].

The aim of this study is to test the effects of two different kinds of saddle on different outcomes, related to perineal compression, blood perfusion, genital sensation and sexual function of female professional bikers. Specifically, we compare traditional saddles used in professional female road cycling to the SMP Carbon saddle (Fig. 1). The latter is a commercially available high-performance geometric saddle designed to reduce rider discomfort [6], and it was derived from a new conception saddle which was previously proved to be effective for men [23].

2. Materials and methods

2.1. Subjects

Study subjects are 33 professional female road cyclists from 6 Italian top teams running in the UCI Women's World Tour. All athletes signed an informed consent before being involved in the tests. Their average age is 24 (standard deviation 4.8; range 19—36), average weight is 57 kg (4.8; 50—69), average height is 167 cm (4.9; 159—179) and average BMI 20 (1.8; 18—24).

2.2. Design and methodology

We tested the effectiveness of the new SMP saddle by comparing it with standard saddles used by professional female road cyclists, flat and with a narrow protruding nose. The new saddle is the result of in-depth ergonomics studies. It supports the cyclist's weight precisely distributing it over pelvic bones and buttocks and keeps the perineal area free from compression. It protects the coccyx from bruises and shocks caused by the roughness of the terrain.

In order to test short-term effects of using different kinds of saddle, the outcome of main interest is the change in blood perfusion of genital-perineal area caused by the compression on the perineal structures. Each of the 33 athletes used both her own saddle and the new saddle in two sessions separated by a lag of about 30 minutes. The choice of which saddle they used first was randomized: 17 athletes used the new saddle during the first session, 16 begun using the traditional one. In both sessions the main measurements were repeated in three different moments: standing before using the saddle, after sitting on the saddle for 10 minutes, after riding for 20 minutes over the rollers with a constant gear ratio of 53:19 and a 90 RPM pedaling frequency. The athletes wore shorts without padding to show the direct compressive effect of the saddle, and they used their own bicycle, in order to not interfere in their habitual kinematic characteristics.

The blood perfusion was measured by means of the partial pressure of oxygen [23—25] in the vulva through the transcutaneous way (PtcO2), by using the TCM TOSCA/CombiM equipment with a Clark electrode. The electrode was applied through an adhesive ring to the labia

Figure 1 The new geometric saddle.

majora of the cyclists' vulva, interposing a special electrolytic solution between membrane and vulva. As a general principle, PtcO2 depends on the oxygen content of the capillaries of the vulva and on the oxygen spread through the epidermis [25,26]. The oxygen content of the cutaneous capillaries depends on the local blood perfusion. In order to obtain the PaO2 from the PtcO2, the capillaries oxygen content has to be independent from the local blood flow. So, the increase in the local temperature is an essential factor that increases the cutaneous blood flow [23—25]. The electrode temperature is routinely maintained to 43—44 °C to avoid burning risks; therefore, we set up the machine at 44 °C and the experiment was performed in a room with fresh air.

Finally, in order to evaluate long-term effects of using a different saddle we adopted a different strategy, by using the 12-items version of the Female Sexual Distress Scale (FSDS) questionnaire [27] as a diagnostic tool. Each item analyses an aspect of sexual distress on a 0—4 scale, thus the sum of the items has a 0—48 range, with 48 representing the maximum sexual distress and values under 12 as a ''normality'' threshold, corresponding to an average item response 1 (in the following we will also present results using other thresholds of interest: 24 represents an average response 2, 36 an average response 3 on the 0—4 scale). All athletes were using traditional saddles before being involved in the project, while they used the new saddle for the following 6 months continuatively during their training and races. We asked each athlete to answer to the same FSDS questionnaire before and after the 6-months period.

2.3. Statistical analysis

Six different PtcO2 levels are available for each athlete, as in both sessions the measurements were repeated in three different moments: before using the saddle, after sitting for 10 minutes, after riding for 20 minutes. In order to test short-term effects of different saddles on oxygen levels, we focus on individual variations on time of PtcO2 levels. According to the timing of observations, we calculate for each athlete three different outcomes of interest:

- ''Sitting'': PtcO2 after sitting vs. initial level;
- ''Riding'': PtcO2 after riding vs. after sitting;
- ''Total'': PtcO2 after riding vs. initial level (equivalent to ''Sitting'' + ''Riding'').

As a formal hypothesis test exploiting the design of our study, we compare the variations in PtcO2 occurring for the same athlete when using the two kinds of saddle. We first calculate for each athlete the difference between the two saddles separately for each outcome, and then test the null hypotheses that the mean differences between saddles are zero. Typical statistical methods fitting this study design are two-sided paired t-tests allowing for dependent observations. We also checked whether all results are independent on the order in which the saddles are tested, as expected due to the randomization. Finally, a two-sided paired t-test is also applied to test whether the mean FSDS score changed after the use of the new saddle.

As usual, t-statistics from the paired t-tests are compared with the Student t distribution in order to evaluate P-values and 95% confidence intervals. All analyses are carried on by using Stata software (Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC).

3. Results

Table 1 and Fig. 2[1] describe the observed distribution of the PtcO2 measures. The average starting levels are about 70 mmHg (range 59—80). After sitting on a traditional saddle PtcO2 shows a marked decline (average 51 mmHg, range 20—72), while sitting on the new saddle takes to a lower decrease (average 66 mmHg, range 51—79). Similar evidence comes from oxygen levels after riding (average 41 vs. 63, range 16—62 vs. 40—75).

Fig. 3 shows the different distributions by saddle of the outcomes of interest, which are variations in PtcO2 over different measurements for the same athlete. The average variation is 6.42 mmHg after ''Sitting'' on the new saddle (< 10 for thirty athletes out of thirty-three), while with a traditional saddle the average is 19.36 mmHg (only seven < 10): the 12.94 mmHg average difference between saddles is highly significant (s.e. 1.75; $P < 0.001$) when applying a paired t-test, thus rejecting the hypothesis of a null saddle effect. The average additional effect of ''Riding'' is 3.09 mmHg when using the new saddle, 9.76 with a traditional saddle, with a significant effect of 6.67 mmHg (s.e. 1.03; $P < 0.001$). Average ''Total'' variations are 9.51 mmHg with the new saddle (most effects < 20), 29.12 with the traditional saddle (all effects > 10, some values > 50): the average saddle effect is 19.61 and significant (s.e. 1.62; $P < 0.001$).

As regards FSDS scores (Table 1 and Fig. 4), the average is 40.82 when using traditional saddles, very close to the maximum of 48 (all scores > 24, 88% over 36). When using the new saddle, the average is 12.09 (all scores < 24, 73% under the 12 ''normality'' threshold), and the 28.73 average difference is significant (s.e. 1.09; $P < 0.001$).

4. Discussion

The awareness of a connection between cycling and male sexual dysfunction has caused the bicycle industry to develop various saddle designs to take into account these disorders. Less is known about the effects of cycling on female riders, but there is evidence that female cyclists may suffer from similar problems to male cyclists [7].

This study provides new insights about how using different saddles affects differently the blood perfusion of the vulva for female bikers. Thanks to its ergonomic characteristics, the new SMP saddle turns out to be more efficient for the protection of the blood perfusion of the vulva when compared to traditional saddles used by road cyclists who cover long distances.

[1] Graphs in Figs. 2—4 are boxplots obtained by the graph box command in Stata: boxes represent quartiles of the distributions, whiskers represent upper and lower adjacent values, points are observed values out of the whiskers [28].

Table 1 PtcO2 levels and FSDS scores.

Variable	Mean	S.D.	Min.	25th	Med.	75th	Max
Initial PtcO2 level (mmHg)							
Compared saddle	70.33	5.13	59	68	70	73	80
New saddle	72.03	4.22	64	70	71	75	80
PtcO2 level after sitting (mmHg)							
Compared saddle	50.97	12.06	20	41	53	59	72
New saddle	65.61	6.10	51	62	65	70	79
PtcO2 level after riding (mmHg)							
Compared saddle	41.21	12.26	16	32	44	50	62
New saddle	62.52	7.54	40	59	63	68	75
Female Sexual Distress Scale (FSDS)							
Compared saddle	40.82	4.96	24	39	42	44	48
New saddle	12.09	3.80	7	10	11	13	23
Number of observations	33						

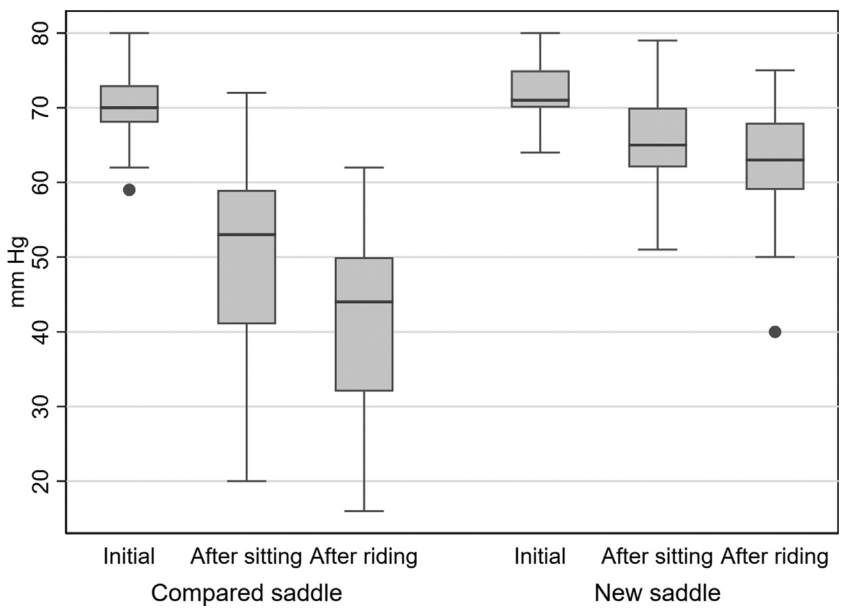

Figure 2 Distribution of oxygen levels by time of observation and saddle.

Our first key finding is that traditional saddles are associated to very high absolute changes in PtcO2 levels, and average variations are about 3 times higher than those observed when using the new saddle for every outcome of interest. Among the others, when compared to a common starting level about 70 mmHg, the average overall variation after riding is close to 30 for the traditional saddle, less than 10 for the new saddle.

The evidence about the short-term effects of using the two kinds of saddle is striking, and the randomized order of the sessions allows us to give a causal interpretation of these results (as a robustness check, the results are never significantly affected by the order in which the athletes used the saddles). As the evidence is particularly clear for ''Sitting'' and ''Total'', it turns out that just sitting on a traditional saddle has immediate negative effects on blood perfusion, while riding has just an additional effect, even if this is still significantly higher when riding on traditional saddles.

A second key finding is that the higher local compression is associated to important long-term negative effects in sexual functions, while these effects are strongly lowered when using the new SMP saddle. All FSDS scores observed after using the new saddle are lower than those observed before its use, even when comparing different athletes, and the average difference of 29 points is highly significant and empirically very strong on a 0—48 range. Admittedly, the non-experimental before-after strategy for long-term effects is potentially weaker than the experimental one used for short-term ones, because of the absence of a control group which continued to use the traditional saddle over the same 6-months period. Still, we assume that there are no other reasons why the FSDS score should have changed so strongly in a relatively short time spell, in absence of a change of saddle. The only potential reason could be related to the 6-months aging of all athletes with time, but all our results turn out to be essentially the same for athletes at different ages. Thus we maintain that it is also possible

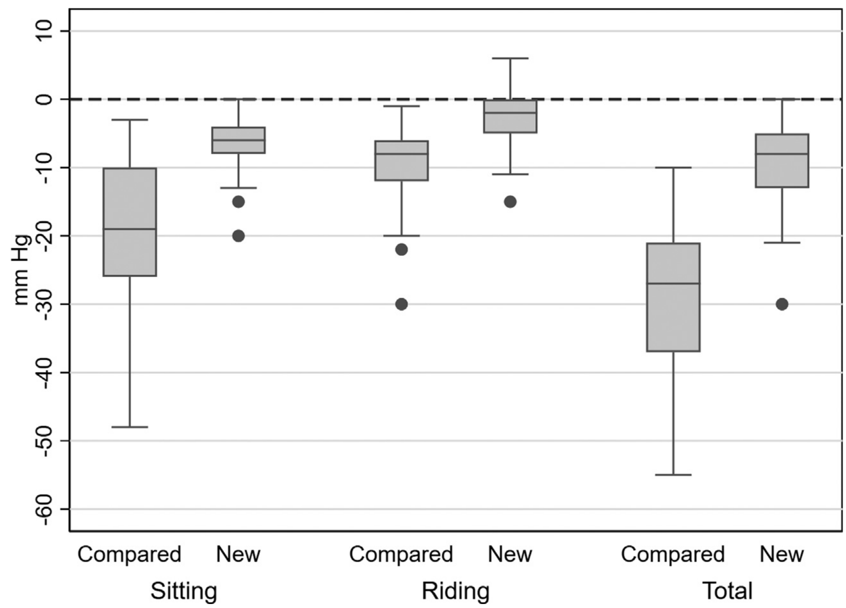

Figure 3 Distribution of variations in oxygen levels, by time periods and saddle.

to interpret changes in FSDS scores as an effect of using a different kind of saddle.

In order to understand the reasons of these strong effects, the geometric saddle was suggested as one of the main important factors in order to protect the blood perfusion of the genital-perineal area on female cyclists [17]. The absence of the nose of the saddle prevents a hard compression on the blood vessels, especially on women [29]. The geometry of the SMP saddle, by redistributing the body weight among the buttocks, the ischiatic tuberosity and the ischium, and thus freeing the perineal plane, prevents the squashing of the neurovascular structures that run medially to the ischiatic tuberosity. Furthermore, the depression in the rear part prevents the coccyx from touching the saddle, thus preventing repercussions caused by the unevenness of the ground that may affect the spine. Finally, the geometric shape of the saddle conforms to the shape of the thigh muscles [23]. As professional road cyclists pedal with their knees medially toward the chassis of the bicycle to increase their power [30], these characteristics prevent the gracile muscle from rubbing with the adductor muscle that could annoyingly disturb the legs during cycling.

As a consequential practical implication, when considering the development of a new ergometric conception of seat designs, which have to be suitable for professional cyclists to whom this study is addressed, we must not forget their effect on pelvic and trunk angle and on comfort [29,31,32]. The true innovation brought about by the SMP saddle is its capacity of interfering scarcely on the blood perfusion of the genital-perineal area on female cyclists, maintaining limited dimensions, especially in width, which is considered as an essential factor in the protection of the compression on the perineal structures [23].

An additional contribution could be checking potential heterogeneous effects of the new saddle when comparing different athletes in terms of observable characteristics. In some robustness checks we allowed for heterogeneous

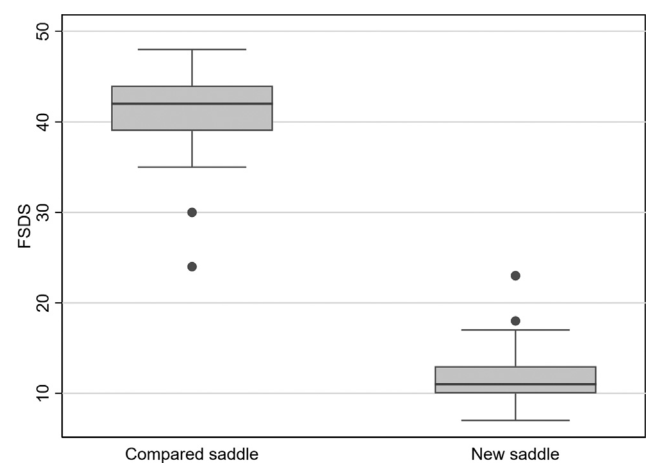

Figure 4 Distribution of Female Sexual Distress Score (FSDS), by saddle.

effects by age, height, weight and BMI, but our main results are never affected. There is only a slight evidence that the two only athletes weighing more than 65 kg show the largest decrease in PtcO2 when sitting on the traditional saddle, while they face a variation in line with other athletes when sitting on the new saddle. As a potential future research, larger samples with more detailed information about the athletes could allow for more detailed analyses on potential heterogeneous effects of different seat designs.

As for the limitations of the study, the available sample is apparently small, but the 33 athletes involved in our tests represent a relevant quote of top female professional bikers and almost the whole population of riders from top teams located in Northern Italy; moreover, this sample size showed off to be sufficient in order to detect very significant effects on averages, without having to discuss potential problems of statistical power. Other potential limitations are related to our identification strategy: while our experimental strategy has a strong internal validity, there could be some concern about its external validity. As an example, results for professional athletes could be potentially different when applied to amateurs or everyday bikers. Thus, additional research is needed in order to test the effectiveness of the new kind of saddle for different populations of interest.

5. Conclusions

Traditional saddles have strong negative effects on the vascular perfusion of the vulva with possible consequences on female sexual function, while a new kind of saddle is able to strongly lower these effects. The SMP saddle avoids affecting the blood perfusion, while maintaining desirable dimensions, mainly in width, and protecting the cyclists against compression on the perineal structures. As an important practical implication, the geometry of a bicycle saddle is an important parameter to consider in the attempt to reduce the compression on neurovascular structures of the pelvic floor.

Disclosure of interest

The authors declare that they have no competing interest.

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