PRESSURE DISTRIBUTION ON BICYCLE SADDLES
(a comparison between normal “flat” saddles with gel and saddles with a “hole” in the perineal area)

Milan, November 8th, 2002

This study is the conclusion of a former study presented in 2002 at the Symposium of the International Society of Biomechanics in Sports published in the Proceedings of ISBS 2002

Introduction

When riding a bicycle, body posture and movement causes a cyclist to distribute body weight and resultant inertial forces through the pedals, handlebar and saddle. In fact, in competitive road and mountain bike cycling, 30 – 40% of a cyclist’s body weight will be loaded onto the saddle. Also, due to the anatomical characteristics of the pelvis, riding position and pedalling action, the load distribution affects different biological tissues, glands and organs.

Studies have shown that, “shocks from rough terrain and vibrations of the saddle cause repeated micro trauma to the perineum, resulting in chafing, perineal folliculitis, furuncles and subcutaneous perineal nodules”. Additionally, it has been reported that, “96% of a group of 45 mountain bikers presented pathological abnormalities of the scrotal content compared with 16% of a control group”.

In addition, “bilateral pudendal nerve injury secondary to excessive biking has been reported to be a saddle related condition, and if the blood supply to penis is compromised, male erectile dysfunction may develop.” These scientific findings are supported by practical experiences reported by clinicians working with cycling teams.

It is safe, therefore, to assume that ergonomically designed saddles,
fitted to a correct height and regulation, combined with padding and shock absorbing devices, can contribute to lessening the risks of injury.

In general, a saddle offers approximately 200 cm\(^2\) to support a load of between 20-50 Kg. For homogenous weight distribution, the pressure to area ratio should range between 100-250 g/cm\(^2\); but, as has been shown by previous research, homogenous load distribution, whilst great in theory, cannot be accepted as a true condition and, therefore, we can expect higher values of localised pressure. This is of great interest to saddle designers as prolonged pressures lower that 100g/ cm\(^2\) are considered the limit to prevent tissue damage.

As a result of these considerations, Selle Royal has collaborated with Centro di Bioingeegneria (Politecnico di Milano - Fondazione Don Carlo Gnocchi ONLUS) to specifically study and evaluate the design solutions produced by various saddle manufacturers in recent years. The study categorised the designs into three specific styles of saddle, the first and last being the two extremes in terms of shape:
1. traditional saddles with a “flat” surface and different/innovative padding materials
2. saddles with an “anatomic” shape
3. saddles with a deep groove, or a “hole”, in the prostate/pubis area

Pressure distribution measurement is a powerful scientific method in assessing, quantitatively, the concept of “comfort”. On this basis, the aim of the study was to compare the pressure distribution patterns recorded from a group of cyclists, riding their own bicycles, using different models of “racing” saddles, comprising those manufactured by Selle Royal and also competitor saddles. The rationale is that optimal saddle shape, and/or padding material, should reduce the peak of pressure in the anatomical areas most frequently subjected to injury or dysfunction, as shown in figure 1.

*Figure 1. Estimation of the alignment human body – saddle. The helix show the anatomical area most subjected to injury during cycling.*
This report presents some significant results from the research, comparing the behaviour of 2 “flat” surfaced saddles, with 2 saddles that have a “hole” in the perineal area.

Materials and method
Five experienced street cyclists, using their own personal bikes, underwent a number of cycling sessions. In each session, a saddle from the sample was selected at random and mounted in such a way to maintain the correct body position (height, distance from the handlebar).

The rear wheel of the bicycle was fixed to a magnetic ergometer to guarantee a consistent mechanical output of power by the cyclists (figure 2) and the gear ratio was chosen by each cyclist in order to maintain a consistent pedalling rate (90 rpm).

After each trial the cyclist was asked to give a personal evaluation on the comfort of the saddle used.

The T-Scan system was utilised to measure the pressure distribution. The transducer of the system is depicted in figure 3A and consists of a 16 x 11 matrix of sensors. The sensors are made with piezoresistive material housed in two sheets of plastics. Strict control was maintained over the relative position between the transducer and the saddle and, consequently, by the transducer and the bicycle reference system (figure 3B).

After ten minutes pedalling per trial, to properly condition the transducer, two 20 second measurements were recorded.

Figure 2. Experiment set-up: the athlete is pedalling on his own bicycle, the posterior wheel of which is fixed to a magnetic ergometer.
During each cycling trial, the force exerted on the saddles fluctuates between a minimum and a maximum level. For the purposes of this study, only data from the maximum loads was analysed.

Special software was designed and used for data processing, parameter computing and graphic representation. The program, named “SELLLE”, provided the following steps:
1. numerical cut off of the transducers not involved in the measurement
2. spatial over-sampling of the matrix (from 11 x 16 to 110 x 160)
3. pressure normalisation
4. graphic representation of the pressure distribution through chromatic maps, scaled on 6 colours (see figure 4)
5. load distribution among the anterior, posterior left, posterior right areas of the saddle and corresponding baricenters
6. asymmetric index between posterior left and right loads

Figure 3. A) T-Scan transducer. B) The transducer fixed to the saddle.

Figure 4. Pressure distribution map of a saddle. The colours from white to black show increasing levels of pressure.
**Results**

This report presents a selection of the results from the whole sample. The saddles here analysed are the LOOKIN 2004G and three other saddles labelled S1, S2 and S3 (figure 5). Both LOOKIN 2004G and S1 are saddles with a “flat” surface and different padding; S2 and S3 are both saddles with a “hole” in the perineal area.

![Figure 5. The saddles analysed. From left to right: LOOKIN 2004G, S1 (“flat” surface). S2 and S3 saddles with a “hole” in the perineal area.](image)

**Comfort index**

The comfort index has been computed by assigning separate values, ranging from +1 to –2, to individual sensations reported by each of the subjects. The numerical scale of values versus sensation is:

1 = comfortable; 0 = neutral; -1 = uncomfortable; -2 = source of pain.
Figure 6. Average comfort index obtained through the separation on four levels of the subjective evaluation of saddle given by the testers.

Figure 6 shows the average of the indices collected by all the subjects during the analysis. Saddle 2004G averaged the best evaluation, with no cyclist reporting pains of any kind. S1 shows similar results to 2004G, while all the cyclists reported pain with S2 and S3.

Posterior – anterior load distribution
As previously reported, a saddle is loaded with approximately 40% of a cyclist’s body weight. The portion of load acting on the posterior portion of the saddle mainly involves the muscles and the ischiatic bones, while the anterior portion affects the perineum, the bilateral pudendal nerve, the vessels of blood supply to penis and, potentially, the prostate. Assuming that these latter biological components are more sensitive to high pressures, than the muscles and bones, a lower portion of the total load on the anterior part of the saddle could be identified as a positive characteristic. Figure 7 shows the average load distribution, obtained by the cyclists that tested all four saddles.

Although the load distribution is a factor strongly dependent on the individual’s characteristics (i.e. anatomy and pedalling position), 2004G is the saddle that demonstrates the lowest amount of load on the anterior part. This percentage increases by 2.5% for saddle S1, and 6% and 8%, respectively, for saddles S2 and S3.
Figure 7. Average posterior (green) and anterior (red) load distribution on the saddle.

Baricenter’s triangle
The position of the baricenters of the loads acting on the three sections of the saddle, and the shape of the triangle defined, could lead to identifying factors related with saddle comfort. Through these variables it is possible to check if the saddle design influences the symmetry of the seat and the significant involvement of specific sections of the saddle.

The main results obtained demonstrate that patterns for the baricenter co-ordinates and for the triangle are individual to each cyclist. The symmetry of the triangle is another typically individual characteristic. The saddle modifies these patterns because the profile, shape and construction material, influence the impact on the biological tissues which are in contact with the saddle.

Figure 8 shows the patterns of one subject.

Figure 8. Graphic representation of the baricenter’s coordinates of one subject of the study.
Figure 8 shows that 2004G and S1 originate more symmetric triangles than saddles S2 and S3. The anterior baricenter is more advanced for saddles S2 and S3, meaning a potentially stronger compression of the pudendal nerves that, in this region, approach each other. At the same time, S2 and S3 show a reduced base of the triangles (the line connecting the two posterior baricenters). These characteristics may be related to a load mostly sustained by muscles and the perineum, rather than by the ischiatic bones, in contrast to what occurs with 2004G and S1. This situation may be considered potentially dangerous for cyclists that ride S2 and S3.

**Pressure distribution maps**

In order to show individual comparisons on the pressure distribution patterns, chromatic maps have been designed to give 100% to the highest pressure measured on the saddle 2004G by each cyclist. Six colours have been selected to represent intervals of pressure of 25%, ranging from 0% to 150% for reference. One of the main findings is that each cyclist, when using the same saddle, shows an individual pressure distribution map. This is demonstrated by figure 9, which shows the results of five cyclists riding the 2004G. Despite the individual differences, it is evident that the area connecting the front and the rear part of the saddle, shows the highest levels of pressure (see the amplitude of the yellow and blue surfaces). It is important to note that the records are strictly related to the posture assumed by the cyclist during the experiment. Different postures, due, for instance, to changing the grip of the hands on the handlebars, can modify the pelvis rotation, the body’s areas in contact with the saddle and, consequently, the pressure distribution.

![Chromatic maps of the pressure distribution recorded by 5 cyclists when using the saddle 2004G.](image)

In order to assess the relationships between saddle and pressure distribution, figure 10 illustrates the maps recorded by two cyclists riding the four sample saddles. By taking the data of 2004G as a reference, it is possible to recognise that the model of saddle influences the amplitude of pressure distribution and/or pressure distribution surfaces. In five records, there are red areas pointing out pressures belonging to the 100%-125% band of maximum pressure recorded on the 2004G. In two records there are also black areas, pointing out pressures belonging to the 125%-150% band. These records may be seen as potentially negative for the biological
system. This fact becomes more severe when the position of the highest pressures is considered: in all the cases the area most involved is the perineal area.

Saddles S2 and S3 also significantly modify the shape of the areas corresponding to the higher level of pressure. The modification consists of an alignment of the highest pressures along longitudinal lines that are placed where the pudendal nerve is judged to pass. Consequently, even when the amplitude of pressure is comparable to the reference (cyclist 2, saddle S3), the load seems to be applied in a negative way for the cyclist.

**Discussion**

From the results of this study, it appears that when a cyclist maintains the race position, the greatest amount of load is transferred to the area connecting the anterior and the posterior part of the saddle.
Each cyclist has an individual pattern of pressure distribution that is significantly influenced by the model of saddle used. Nevertheless, the shape and the surface of the saddle influences both the perceived comfort (as shown in figure 6) and the pressure distribution of the load in the delicate part of the perineum, where most injuries or dysfunction can occur.

From the results it can therefore be interpreted that the saddles with a “hole” or deep grooves in this area, substantially transfer the load that potentially acts on the prostate (placed deeper inside the human body) to the perineum and other delicate organs such as the bilateral pudendal nerve and arteries. Furthermore, these saddles lead to an increase of the anterior load (see figure 7) and can indirectly compress the prostate. Finally, the bilateral pudendal nerve and artery, are most likely positioned along the edges of the “hole”. Therefore, as the contact surface is drastically reduced by the “hole”, a greater amount of the load is on the edges, where the bilateral pudendal nerve and artery are judged to pass.

**Conclusion**

The study shows that high quality saddles with a “flat” surface and gel (LOOKIN 2004G and S1) do not have relevant pressure peaks in the areas where pudendal nerves and arteries pass. In addition, saddles with a “hole” (S2 and S3) show greater levels of pressures in these areas; a direct consequence of applying a load to a support whose surface is reduced by a hole.

The distribution of pressure determined by the “hole” increases the pressure in critical areas, with a potential risk for bilateral pudendal nerve injury and reduction of blood flow to the penis in the male, responsible for erectile dysfunction. For females, the “hole” can lead to a concentration of pressure on other soft tissues along the edges and can contribute to cutaneous irritation in the genital area or to other more serious problems, as documented by gynaecologists.

Flat gel saddles tested significantly more positive from several view points:

- subjective evaluation
- antero-posterior load distribution (approximately -15% of pressure in the front part of the saddle vs the 2 saddles with hole)
- positioning of the loads’ baricenters
- pressure distribution maps and peaks of pressure (in different tests up to 50% lower than on the other 3 saddles)

All these points make the flat saddles with gel, LOOKIN in particular (probably due to the polyurethane gel), better than saddles with hole.

It must also be noted that this analysis does not take into account the extra amount of load produced by dynamic factors. For these aspects, the effectiveness of shock
absorption and reduction of vibration characterised by a saddle, can significantly reduce the “input of force” distributed upon the body and, consequently, the amplitude of the peaks of pressure.

References


