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The effects of different saddle pads on the pressure exerted on the equine back by correctly fitting dressage saddles

Marie T. Dittmann, Nina Hess, Samuel Arpagaus, Jasmin Müller-Quirin, Michael A. Weishaupt and Selma N. Latif

Equine Department, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland

Summary: In order to improve saddle fit and comfort for the horse, many equestrians use a saddle pad in addition to an ordinary saddle cloth or blanket. To date, only a few scientific studies have investigated if such pads lower the magnitude of pressure exerted on the horse's back. The results of these studies are highly variable, presumably due to the different materials of the examined pads. The present study investigated the effect of five different, commercially available saddle pads on the mean pressure, the highest mean pressure, and the loaded area below the saddle, as well as the range of motion (ROM) of the centre of pressure (COP) on the horse's back. Electronic saddle pressure measurements were carried out with eight horses ridden by the same person, using five different pads and a thin saddle cloth as control. Saddle pressure measurements were carried out at all gaits and on both reins, using the Pliance®-S system (Novel). The results revealed that all tested pads except for the gel pad significantly lowered mean pressure below the saddle (range in reduction: 0.8 to 1.8 kPA) as well as in areas with the highest mean pressure, representing pressure points (range: 2.1 to 5.8 kPA). None of the pads increased pressure. The loaded area below the saddle was decreased slightly, but not significantly, when pads were used. The effect of the pads on the ROM of the COP was inconsistent; certain pads significantly increased this variable, but only at certain gaits. This may indicate a loss of stability in the horse-rider system, but if the magnitude of the observed changes is relevant needs further investigation. The results indicate that none of the investigated pads affected mean pressure in an unfavourable way and that the thicker pads may help to reduce the pressure acting on the horse's back.

Keywords: equine, horse, equestrian, half pad, saddle pressure measurement, centre of pressure, back health

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Correspondence: Dr. Marie Dittmann, Vetsuisse Faculty Zurich, Equine Hospital, Winterthurerstraße 260, 8057 Zurich, Switzerland; mdittmann@gmx.ch

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Introduction

High or punctual pressure below the saddle has been linked to discomfort, soreness and pain in riding horses (*Dyson* et al. 2015, *Harman* 1999, *Nyikos* et al. 2005, *von Peinen* et al. 2010). In an attempt to determine the clinical relevance of saddle pressure, *Von Peinen* et al. (2010) found an association between mean pressure magnitude and clinically relevant signs of soreness on the horse's back, such as swelling or distinct dry spots within an area of sweaty fur. The latter were presumably caused by a decrease in blood circulation and thereby sweat excretion. Furthermore, high pressure below the saddle has been linked to the horse extending its back (*de Cocq* et al. 2004) and a decrease in gait quality (*Murray* et al. 2017). Given these findings, it is in the best interest of riders to prevent excessive pressure being exerted on their horse's back, not only to ensure its welfare, but also because healthy, pain free athletes presumably perform better. In order to reduce the pressure acting on their horse's back, many equestrians of all disciplines frequently use saddle pads in addition to, or in place of, an ordinary, thin saddle cloth or numnah. While the purpose of the latter is mainly to protect the saddle from dirt or sweat, a large range of commercially available saddle pads is now sold under the claim to optimise pressure or saddle fit. A recent survey of riders of different disciplines revealed that 45% of the respondents used more than one layer (i.e. more than one pad) between the saddle and the horse's back when riding, and 87% of the respondents reported that they were using a layer between horse and saddle to increase their horse's comfort (*Hawson* et al. 2013). These findings are confirmed by a study investigating saddle fit in Swiss riding horses (*Dittmann* et al. 2020), where 46.4% of the participating riders stated that they regularly used at least one pad in addition to, or instead of, an ordinary saddle blanket (unpublished data). Despite the frequent use of saddle pads, comparatively few studies have investigated their effect on the pressure below the saddle and the results are far from conclusive, partly due to the large variety of available pads, which differ widely in shape, size, thickness and material. Due to this variability, there is inconsistency in the effect of the different saddle pads on the mean pressure below the saddle. In a study by *Harman* (1994) nine out of 14 tested pads (open- and/or closed-cell foam, gel pads and combination pads) increased the pressure below the saddle. The authors conclude that changing the pad can worsen or improve the saddle's fit, depending on the material it is made of. Other studies found that fur pads potentially alleviate mean pressure in certain situations: *Dittmann* et al. (2021) reported lower saddle pressures in horses which were ridden with a sheepskin pad. This finding is supported by *Kotschwar* et al. (2010a), who found that a reindeer fur pad decreased the maximum overall force (MOF) below a fitting saddle at walk and sitting trot. The other pads investigated in the same study (made of gel, leather or foam) had no significant effect on MOF (*Kotschwar* et al. 2010a). However, when investigating all four pads below a saddle with an excessively wide tree, the results were inconsistent: At walk, gel and foam pads reduced MOF, at trot gel and reindeer-fur reduced MOF, while leather increased MOF at both gaits (*Kotschwar* et al. 2010b). Similar differences between pads were reported by *MacKechnie-Guire* et al. (2021): When assessing three different pads (wool, foam, gel) beneath dressage saddles which had not been fitted to accommodate a half pad, a wool or foam half pad decreased mean pressure at sitting trot and canter, while a gel pad increased mean and peak pressure at both gaits.

In summary, the effect of pads on pressure appears to vary between different models and materials, as well as the saddle's fit and the gait the horse is moving in. This makes it impossible to make general statements regarding the benefit of using saddle pads and it underlines the importance of evaluating the range of available pads under different situations.

The aim of the present study was to investigate the effect of five commercially available saddle pads on pressure acting on the horse's back at different gaits. The hypothesis was that, compared to an ordinary thin saddle blanket, each of the pads would result in lower mean pressure values. As it is a general aim of saddle fitting to distribute the load acting on the horse's back as evenly as possible (*Dyson* et al. 2015), it was further assessed if the pads in- or decreased the loaded area on the horse's back. Many riders report that a thick pad induces instability in the horse-saddle-rider system. Therefore, it was also investigated if the excursion of the centre of pressure (COP) below the saddle was influenced by the different pads. This variable has been used as a measure for the rider's stability in previous studies (*Peham* et al. 2010). The hypothesis was that the investigated pads would increase the range of motion (ROM) of the COP, when compared to a thin saddle cloth.

Material and methods

Horses, rider and saddles

Eight adult Warmblood horses (five geldings and three mares, average age 12.3 ± 3.6 years) participated in this study. All horses were declared sound by their owners and were in regular work (leisure, dressage and jumping). Before the study, they were clinically examined by an experienced veterinarian (SNL) to make sure none of the horses suffered from lameness or back pain. In order to minimize the variability in saddle pressure due to different riding styles, all measurements were carried out with a single professional female rider (63 kg, 1.67 m). Every horse was ridden with its own, fitting, dressage saddle. The eight participating horses were selected from a larger population based on their saddles fitting particularly well. An experienced veterinarian, with specialist training in assessing saddle fit (SNL), inspected all saddles manually to make sure they had no significant defects or deficiencies in their fit.

Saddle pads

The study's aim was to investigate five pads of different materials and commercially available in Europe. The following descriptions of the pads are based on the information supplied by the manufacturers. The pads are shown in Figure 1: A) Acavallo Gel Pad Anatomic (Acavallo – Amahorse Trading S.r.l., San Giustino, Italy): soft-gel material, 7 mm thickness; B) Equiline Tecno Air Shock Absorber (Equiline S.r.l., Trebaseleghe, Italy): lower surface tecnocoolmax®, middle padding shell, upper surface air space fibres, 12 mm thickness; C) Horst Becker Body Move Pad Basic Relax Dressage (Equiment GmbH, Wittorf, Germany): lower inlay mat from medical industry developed for decubitus patients, upper inlay non thermo reactive foam, upper and lower surface cotton, 22 mm thickness; D) Mattes Half Pad Dressage size M (E. A. Mattes GmbH, Mühlheim an der Donau, Germany): lower surface lambskin, upper surface cotton and nylon fibres, 33 mm thickness; E) Winderen Saddle Half Pad Dressage size 18'' (Winderen sp. z o.o, Zamość, Poland): cover ballistic nylon, inlay from top to bottom: dynamic stabilization layer, force equalizer (non-Newtonian material), biomechanical connective tissue, Kevlar bottom shell, 18 mm thickness. As a control (F), a thin, quilted saddle cloth made of cotton (hereinafter referred to as the control saddle cloth) was used. It is common practice of equestrians to use half pads in combination with a saddle cloth, and the manufacturers of the half pads assured that it was possible to use their pads in addition to a normal saddle cloth. Therefore, the half pads (A) Acavallo, B) Equiline, D) Mattes and E) Winderen) were placed on top of the control saddle cloth for the measurements. The larger C) Body Move pad was used on its own, without the control saddle cloth.

Saddle pressure measurement

Mean pressure below the saddle was measured with a Pliance®-S System (novel GmbH, Munich, Germany), which has been validated in previous studies (*de Cocq* et al. 2009, *de Cocq* et al., 2006). The system consists of an electronic pressure mat, which is divided in two halves containing 128 sensors each, and a backpack including the battery and data logger, which is connected to the pressure mat.

Study protocol

The measurements took place in an indoor arena. All horses were warmed up for approximately 15 minutes, either being led by their owner or walked in a horse walker. After this, the electronic saddle pressure mat was placed on the horse's back and all pressure sensors were set to zero. Subsequently, the horse was saddled with one of the five pads or the control saddle cloth (see Figure 2 for an example of the setup) and further warmed-up under the rider for another 10 minutes at all gaits.

The measurement series started with the horse standing square, followed by measurements at walk, rising trot, sitting trot and canter on both reins. Each horse was ridden following the same protocol, and for each gait measurements were taken on the two long sides of the riding arena (20 m

Fig. 1 Picture of the different pads investigated in this study: A) Acavallo Gel Pad, B) Equiline pad, C) Body Move Pad; D) Mattes Half Pad, E) Winderen pad, F) control saddle cloth (Photo: *Nina Hess*) | *Fotos der Unterlagen, welche im Rahmen dieser Studie untersucht wurden: A) Acavallo Gel Pad, B) Equiline Pad, C) Body Move Pad; D) Mattes Lammfell Pad, E) Winderen Pad, F) herkömmliche Baumwollschabracke als Kontrolle (Fotos: Nina Hess)*

× 40 m). The program started on the left or on the right rein in alternating order for each saddle pad. After the series of measurements with one pad, the saddle was removed leaving the saddle pressure mat in place, and pads were exchanged. The order of the pads was randomised for each horse and measurements were split into two sessions on two consecutive days, each including measurements of three pads. In addition to the objective measurements, after each ride, the rider was asked for her subjective opinion of the pad, which was noted.

Data analysis

Raw data were exported from Pliance®-X (novel GmbH, Munich, Germany) into MATLAB (The Math Works Inc., Massachusetts, USA) for further processing. The following variables of interest were created based on the raw data. Mean pressure (MP in kPA): average pressure value over one measurement based on all sensors of the mat, which are loaded on average with more than 2 kPA. Highest mean pressure (hMP in kPA): Average pressure value over one measurement within the area of the four adjacent sensors (7.5 × 7.5 cm) which show the highest mean pressure value. The hMP therefore represents the most prominent pressure point below the saddle. The calculation of both variables (MP, hMP) corresponds to *Dittmann* et al. (2021). Furthermore, the following variables were calculated: Loaded area (LA in cm^2): The area of the mat including all sensors which are on average loaded with at least 2 kPA over one measurement. Range of movement of the centre of pressure below the saddle in the latero-lateral direction i.e. transversally to the direction of travel (COP_{lat} in cm) and the cranio-caudal direction, i.e. in the direction of travel (COP_{cc} in cm).

Fig. 2 Example picture of the measurement setup including the electronic measurement mat below the saddle cloth and the battery pack fitted to the rider's back (Photo: *Marie Dittmann*). | *Beispielhafte Abbildung der Ausrüstung, welche während einer Messung verwendet wurde. Die elektronische Satteldruckmessmatte wurde unter der Schabracke platziert und der Akku der Messmatte war während der Messung am Rücken der Reiterin befestigt (Foto: M. Dittmann).*

Statistical analysis

Statistical analysis was performed in R Studio (R version 4.0.3) using the packages lmerTest, and ggplot2 for illustrations. Separate linear mixed models were computed for the outcome variables MP, hMP, LA, COP_{lat} or COP_{cc}, each with pad and gait as fixed effects, and horse and measurement session as random effects.

Results

The following mean values (averaged over all pads and gaits) and standard deviations (SD) were recorded: MP 5.5 ± 1.7 kPA, hMP 10.1 ± 3.9 kPA, LA 858 ± 369 cm^2, COP_{lat} 4.7 ± 4.1 cm, COP_{cc} 14.5 ± 9.0 cm. The initial linear mixed models revealed that all outcome variables differed significantly between gaits ($P < 0.001$). For all pads, the MP at walk was lower than the MP at rising and/or sitting trot, and the latter was lower than the MP at canter. The same applies for the variables hMP, LA, and COP_{cc}, while COP_{lat} was highest at sitting trot and lowest at canter (except in the control, where it was lowest at walk).

To evaluate the effect of the pads on the outcome variables within gaits, separate linear mixed models were computed for each gait or situation (stance, walk, sitting trot, rising trot, canter). Compared to the control, the following pads reduced the MP significantly at all gaits: Body Move, Equiline, Mattes and Winderen (Table 1, Figure 3). Over all gaits, this reduction was in the range of 0.8 to 1.8 kPA. The Acavallo pad showed no significant reduction in MP compared to the control saddle cloth. Similar results were found for the variable hMP (Table 2, Figure 4): the pads Body Move, Mattes and Winderen lowered hMP at all gaits. Equiline lowered hMP at all gaits except for rising trot. The Acavallo pad only lowered hMP at stance, but did not show significant differences to the control at any of the moving gaits. Significant reductions in hMP were in the range of 2.1 to 5.8 kPA.

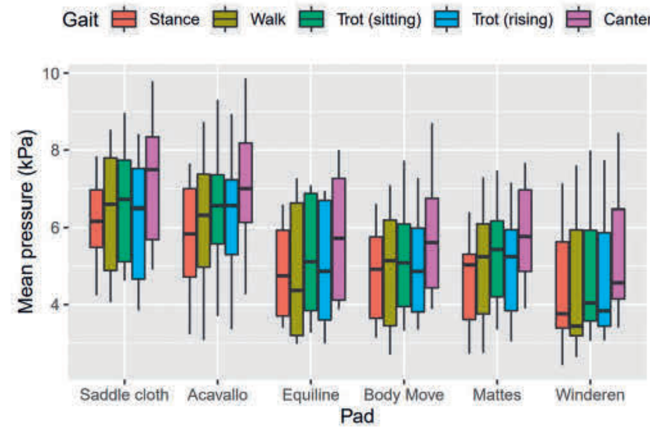

Fig. 3 Mean pressure (MP, in kPa) beneath the investigated pads at all gaits. The box indicates the 25% and 75% quartiles, the horizontal line indicates the median. Compared to the control, the Equiline, Body Move, Mattes and Winderen pads decreased the MP significantly at all gaits. | *Mittlerer Druck (MP, in kPa) unter den verschiedenen Unterlagen in den einzelnen Gangarten. Die Box entspricht jeweils den 25% und 75% Quartilen; der horizontale Strich entspricht dem Median. Im Vergleich zur Kontrollschabracke zeigten die Unterlagen Equiline, Body Move, Mattes und Winderen signifikant niedrigere MP-Werte in allen Gangarten. Stance = Stand, Walk = Schritt, Trot (sitting) = ausgesessener Trab, Trot (rising) = leichtgerittener Trab, Canter = Galopp.*

Table 1 Means and standard errors of mean pressure (MP) in kPA, based on the linear mixed model estimates. P-values refer to the difference between the pad in question and the control saddle cloth at the same gait. Significance codes: ***≤0.001, **≤ 0.01, *≤ 0.05 | *Mittelwerte und Standardfehler des mittleren Drucks (MP) in kPA, basierend auf den linearen gemischten Modellen. Die P-Werte beziehen sich jeweils auf den Unterschied zwischen dem betreffenden Pad und der Kontrollschabracke innerhalb einer Gangart. Signifikanzniveaus: ***≤0,001, **≤ 0,01, *≤ 0,05*

	Control saddle cloth	Acavallo	Equiline	Body Move	Mattes	Winderen
Stance	6.2 ± 0.5	5.8 ± 0.4	5.2 ± 0.4**	4.5 ± 0.4***	4.5 ± 0.4***	4.5 ± 0.4***
Walk	6.3 ± 0.6	6.3 ± 0.4	5.2 ± 0.3**	4.6 ± 0.4***	4.8 ± 0.3***	4.6 ± 0.4***
Sitting trot	6.6 ± 0.5	6.6 ± 0.3	5.6 ± 0.3**	4.8 ± 0.3***	5.1 ± 0.3***	4.8 ± 0.3***
Rising trot	6.2 ± 0.5	6.4 ± 0.4	5.4 ± 0.3*	4.7 ± 0.4***	4.8 ± 0.3***	4.7 ± 0.4***
Canter	7.2 ± 0.6	7.2 ± 0.3	6.1 ± 0.3***	5.5 ± 0.3***	5.6 ± 0.3***	5.4 ± 0.3***

Table 2 Means and standard errors of highest mean pressure (hMP) in kPA, based on the linear mixed model estimates. P-values refer to the difference between the pad in question and the control saddle cloth at the same gait. Significance codes: ***≤0.001, **≤ 0.01, *≤ 0.05 | *Mittelwerte und Standardfehler des höchsten mittleren Drucks (hMP) in kPA, basierend auf den linearen gemischten Modellen. Die P-Werte beziehen sich jeweils auf den Unterschied zwischen dem betreffenden Pad und der Kontrollschabracke innerhalb einer Gangart. Signifikanzniveaus: ***≤0,001, **≤ 0,01, *≤ 0,05*

	Control saddle cloth	Acavallo	Equiline	Body Move	Mattes	Winderen
Stance	12.8 ± 1.4	10.0 ± 1.2*	8.4 ± 1.1***	6.9 ± 1.2***	7.3 ± 1.2***	6.9 ± 1.2***
Walk	11.4 ± 1.1	10.4 ± 0.7	8.6 ± 0.7***	7.1 ± 0.7***	7.9 ± 0.7***	7.1 ± 0.7***
Sitting trot	12.5 ± 1.0	11.6 ± 0.7	10.3 ± 0.7**	8.8 ± 0.7***	9.3 ± 0.7***	8.5 ± 0.7***
Rising trot	12.0 ± 1.1	12.3 ± 0.8	10.8 ± 0.8	9.1 ± 0.8**	9.0 ± 0.8***	9.0 ± 0.8***
Canter	15.0 ± 1.3	14.0 ± 0.7	12.2 ± 0.7***	11.1 ± 0.7***	11.2 ± 0.7***	10.5 ± 0.7***

None of the pads showed a significant difference in the loaded area (LA) compared to the control (Table 3, Figure 5) although at all gaits, the pads tended to slightly reduce the LA compared to the control.

Compared to the control, the Winderen pad showed a significant increase in COP_{lat} and COP_{cc} at stance and walk. Compared to the control, the Body Move pad significantly increased COP_{cc} at walk, while it did not alter the COP_{cc} at any other gait. The Mattes pad significantly increased the COP_{cc} at sitting trot. No other significant differences were found in the COP variables between the control and the other pads (Table 4–5, Figure 6–7).

Discussion

In the present study, all pads except the gel pad (Acavallo) decreased the mean pressure variables at almost all gaits

Fig. 4 Highest mean pressure (hMP, in kPa) beneath the investigated pads at all gaits. The box indicates the 25% and 75% quartiles, the horizontal line indicates the median. The Body Move, Mattes and Winderen pads reduced the hMP at all gaits significantly compared to the control. The Equiline pad significantly reduced hMP at stance, walk, sitting trot and canter. The Acavallo pad only reduced hMP significantly at stance. | *Höchster mittlerer Druck (hMP, in kPa) unter den verschiedenen Unterlagen in den einzelnen Gangarten. Die Box entspricht jeweils den 25% und 75% Quartilen; der horizontale Strich entspricht dem Median. Die Unterlagen Body Move, Mattes und Winderen zeigten in allen Gangarten im Vergleich zur Kontrollschabracke signifikant niedrigere hMP Werte. Die Unterlage von Equiline zeigte im Stand, Schritt, ausgesessenen Trab und Galopp niedrigere hMP-Werte als die Kontrollschabracke, jene von Acavallo zeigte nur im Stand niedrigere hMP-Werte.*

compared to the control saddle cloth. The size of the loaded area below the saddle decreased slightly (but not significantly) when the pads were used. At certain gaits, the thicker pads increased the ROM of the COP below the saddle, but there was no consistent pattern of this effect.

While the gel pad used in this study did not show a significant effect on any of the investigated variables, previous studies reported no (*Kotschwar* 2010a), a beneficial (*Kotschwar* 2010b) or an unfavourable effect of gel pads on saddle fit (*MacKechnie-Guire* et al. 2021, *Harman* 1994). This difference may be due to different materials of the investigated gel pads. None of the authors named the made or model of the studied pads, which makes it difficult to interpret the results, as the discrepancy between different studies may be due to the different properties of the gel material. This underlines how much the effect of specific pads can vary, even if made of – presumably – similar material. Therefore, it is important to specify pads tested in objective studies to make the results applicable for horse owners, riders and trainers.

The lambskin pad used in this study showed a significant decrease in mean and highest mean pressure below the saddle.

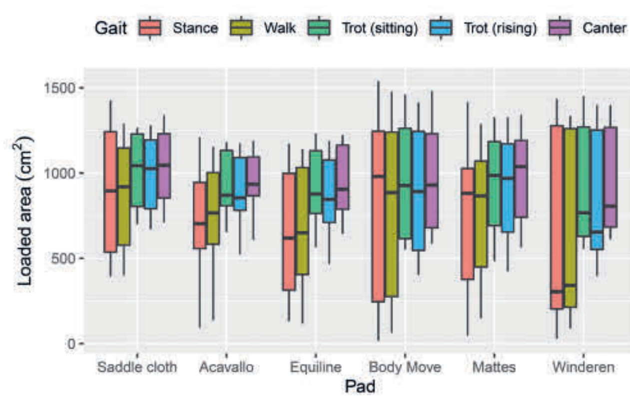

Fig. 5 Loaded area (LA, in cm^2) beneath the investigated pads at all gaits. The box indicates the 25% and 75% quartiles, the horizontal line indicates the median. All pads tended to slightly, but not significantly, reduce the LA compared to the control. | *Auflagefläche auf dem Pferderücken (LA) in cm^2 unter den verschiedenen Unterlagen in den einzelnen Gangarten. Die Box entspricht jeweils den 25% und 75% Quartilen; der horizontale Strich entspricht dem Median. Im Vergleich zur Kontrollschabracke war die Auflagefläche bei allen Unterlagen etwas kleiner. Dieser Unterschied war aber nicht statistisch signifikant.*

Table 3 Means and standard errors of loaded area (LA) of the sensor mat in cm^2, based on the linear mixed model estimates. P-values refer to the difference between the pad in question and the control saddle cloth at the same gait. Significance codes: *** ≤ 0.001, ** ≤ 0.01, * ≤ 0.05 | *Mittelwerte und Standardfehler der Auflagefläche auf dem Pferderücken (LA) in cm^2, basierend auf den linearen gemischten Modellen. Die P-Werte beziehen sich jeweils auf den Unterschied zwischen dem betreffenden Pad und der Kontrollschabracke innerhalb einer Gangart. Signifikanzniveaus: *** ≤ 0,001, ** ≤ 0,01, * ≤ 0,05*

	Control saddle cloth	Acavallo	Equiline	Body Move	Mattes	Winderen
Stance	860 ± 159	739 ± 127	723 ± 115	737 ± 127	707 ± 119	661 ± 125
Walk	852 ± 146	760 ± 112	746 ± 101	711 ± 113	733 ± 105	656 ± 110
Sitting trot	990 ± 82	953 ± 76	971 ± 67	902 ± 76	922 ± 70	934 ± 74
Rising trot	976 ± 106	905 ± 83	910 ± 75	845 ± 83	902 ± 78	848 ± 82
Canter	1016 ± 76	970 ± 66	998 ± 59	916 ± 66	960 ± 61	949 ± 65

This is in line with previous studies, which report a positive effect of reindeer fur (*Kotschwar* 2010a and b), wool pads (*MacKechnie-Guire* et al. 2021), or sheepskin (*Dittmann* et al. 2021) on pressure or saddle fit. This is a reassuring result, as sheepskin pads are widely used among riders: 57% of the participants of a study investigating saddle fit in Swiss

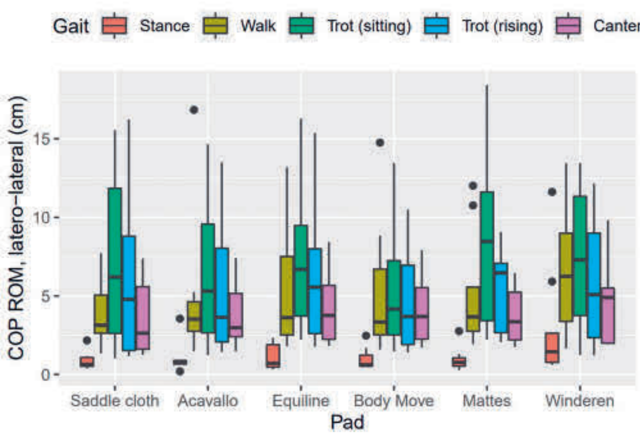

Fig. 6 Latero-lateral range of movement of the centre of pressure (COP_{cc}, in cm) beneath the investigated pads at all gaits. The box indicates the 25% and 75% quartiles, the horizontal line indicates the median. The Winderen pad significantly increased the COP_{lat} at stance and walk. No other significant changes in COP_{lat} were found. | *Auslenkung des Druckmittelpunktes unter dem Sattel in seitlicher Richtung (COP_{lat}) in cm unter den verschiedenen Unterlagen in den einzelnen Gangarten. Die Box entspricht jeweils den 25% und 75% Quartilen; der horizontale Strich entspricht dem Median. Im Stand und Schritt zeigte das Winderen Pad signifikant höhere COP_{lat}-Werte als die Kontrollschabracke. Die übrigen Unterschiede zwischen Kontrollschabracke und Unterlagen waren nicht signifikant.*

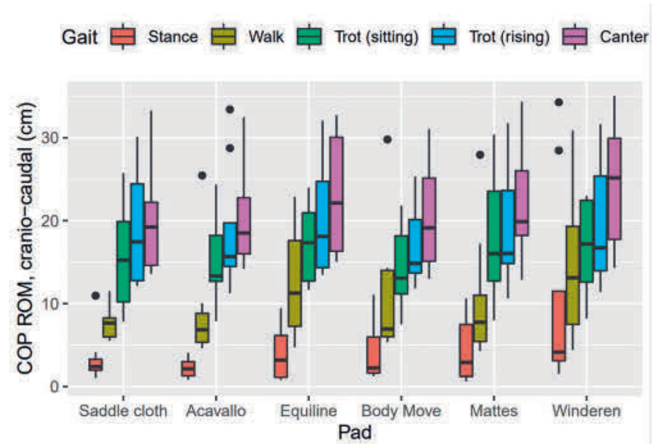

Fig. 7 Cranio-caudal range of movement of the centre of pressure (COP_{cc}, in cm) beneath the investigated pads at all gaits. The box indicates the 25% and 75% quartiles, the horizontal line indicates the median. The Winderen pad increased the COP_{cc} significantly at stance and walk, the Body Move Pad at walk, and the Mattes Half Pad at sitting trot. No other signficant changes were found. | *Auslenkung des Druckmittelpunktes unter dem Sattel in kranio-kaudaler Richtung (COP_{cc}) in cm unter den verschiedenen Unterlagen in den einzelnen Gangarten. Die Box entspricht jeweils den 25% und 75% Quartilen; der horizontale Strich entspricht dem Median. Das Winderen Pad zeigte im Stand und Trab, das Body Move Pad im Schritt und das Mattes Pad im ausgesessenen Trab höhere COP_{cc}-Werte als die Kontrollschabracke. Die übrigen Unterschiede zwischen Kontrollschabracke und Unterlagen waren nicht signifikant.*

Table 4 Means and standard errors of COP_{lat} (lateral range of movement of the centre of pressure below the saddle in cm), based on the linear mixed model estimates. P-values refer to the difference between the pad in question and the control saddle cloth at the same gait. Significance codes: ***≤0.001, **≤ 0.01, *≤ 0.05 | *Mittelwerte und Standardfehler der Auslenkung des Druckmittelpunktes unter dem Sattel in seitlicher Richtung (COP_{lat}) in cm, basierend auf den linearen gemischten Modellen. Die P-Werte beziehen sich jeweils auf den Unterschied zwischen dem betreffenden Pad und der Kontrollschabracke innerhalb einer Gangart. Signifikanzniveaus: ***≤0,001, **≤ 0,01, *≤ 0,05*

	Control saddle cloth	Acavallo	Equiline	Body Move	Mattes	Winderen
Stance	0.9 ± 0.6	0.9 ± 0.8	1.1 ± 0.8	1.1 ± 0.8	1.1 ± 0.8	3.0 ± 0.8*
Walk	3.7 ± 1.4	5.0 ± 1.2	4.8 ± 1.1	5.8 ± 1.2	5.2 ± 1.2	6.8 ± 1.2*
Sitting trot	7.4 ± 1.5	5.8 ± 1.3	6.2 ± 1.2	6.7 ± 1.3	9.7 ± 1.2	7.3 ± 1.3
Rising trot	6.6 ± 1.2	4.6 ± 1.1	5.8 ± 1.0	5.3 ± 1.1	6.4 ± 1.1	5.6 ± 1.1
Canter	3.8 ± 0.7	3.5 ± 0.5	3.9 ± 0.5	4.5 ± 0.5	4.1 ± 0.5	4.3 ± 0.5

Table 5 Means and standard errors of COP_{cc} (range of movement of the centre of pressure below the saddle in the cranio-caudal direction in cm), based on the linear mixed model estimates. P-values refer to the difference between the pad in question and the control saddle cloth at the same gait. Significance codes: ***≤0.001, **≤ 0.01, *≤ 0.05 | *Mittelwerte und Standardfehler der Auslenkung des Druckmittelpunktes unter dem Sattel in kranio-kaudaler Richtung (COP_{cc}) in cm, basierend auf den linearen gemischten Modellen. Die P-Werte beziehen sich jeweils auf den Unterschied zwischen dem betreffenden Pad und der Kontrollschabracke innerhalb einer Gangart. Signifikanzniveaus: ***≤0,001, **≤ 0,01, *≤ 0,05*

	Control saddle cloth	Acavallo	Equiline	Body Move	Mattes	Winderen
Stance	3.5 ± 2.1	2.1 ± 2.9	4.0 ± 2.8	4.1 ± 2.9	4.5 ± 2.9	10.5 ± 2.9*
Walk	7.4 ± 2.5	9.2 ± 2.3	11.5 ± 2.1	12.3 ± 2.3*	11.0 ± 2.2	14.4 ± 2.3**
Sitting trot	15.7 ± 1.6	14.5 ± 1.3	15.9 ± 1.1	15.3 ± 1.3	19.0 ± 1.2**	16.6 ± 1.2
Rising trot	19.2 ± 2.1	17.8 ± 1.6	18.4 ± 1.4	18.5 ± 1.6	20.5 ± 1.5	19.1 ± 1.5
Canter	21.0 ± 1.9	19.8 ± 1.5	22.0 ± 1.3	21.8 ± 1.5	23.2 ± 1.3	23.5 ± 1.4

riding horses regularly used a sheepskin pad (*Dittmann* et al. 2021). Throughout the whole study, the three thickest pads (Body Move, Mattes and Winderen all ≥ 18 mm) decreased the values of the measurements the most noticeably. This was somewhat surprising, as saddlers or saddle fitters often discourage riders from using thick pads. *Harman* (1999) compared putting a thick pad under a fitting saddle with adding a pair of thick wool socks in snug shoes, which would presumably result in higher pressure values. The measurements in this study revealed no increase in mean pressure when using thicker pads. This might be because the thicker pads consisted of two longitudinal halves, which in the middle were connected with a thinner material. This prevents direct pressure being exerted on the spine, as the whole saddle is slightly lifted. Furthermore, most saddles nowadays are produced with a wider gullet, which may lower the risk of higher pressures induced by additional layers under the saddle.

Some riders object to the use of thick saddle pads as they feel that they introduce imbalance to the horse-saddle-rider system. The rider in this study occasionally reported a feeling of instability and being "far away from the horse" for certain thicker pads. This effect, quantified by the ROM of the COP below the saddle, was found only in the thicker pads and only at certain gaits. While the latero-lateral movement was only slightly affected by the thicker pads (only Winderen increased it significantly at walk), the cranio-caudal movement was increased by Winderen and Body Move at walk and by Mattes at sitting trot. Therefore, the effect described by riders can be somewhat quantified, albeit not in a systematic manner. Perhaps, certain thicker pads could lead to a degree of instability by lifting the rider further off the horse's back, thereby decoupling the movement of horse and rider. It is also possible that a thick pad lifts the cranial aspect of the saddle further off of the horses back, thereby causing the saddle to tip backwards. In such a situation, a rider would have problems to remain in a balanced position in the saddle, which could result in an increase in COP_{cc}. However, to the authors knowledge there are not scientific studies supporting these theories. *Peham* et al. (2010) suggested that stability in the seat is a requirement for efficient communication between rider and horse. This raises the question, whether the beneficial effect of a pad on pressure can be outweighed by the potentially detrimental effect of the rider's imbalance. However, as an increase in the excursion of the COP in the present study only occurred in a few cases, the pressure reduction may be of higher relevance for the horse's welfare.

Both mean pressure variables increased with increasing velocity of gait, which is in agreement with results of previous studies (*Fruehwirth* et al. 2004). The same pattern was found for LA and COP_{cc}. This indicates that with increasing velocity of the gait, pressure points become more prominent, the loaded area below the saddle becomes larger, and the weight of the rider shifts more back and forth on the horse's back. However, in almost all pads, the variable COP_{lat} was lowest at canter and highest at sitting trot, indicating that gait has a bigger impact on the latero-lateral movement of the rider's weight than velocity. These results highlight the relevance of pads when riding at faster gaits. The mean pressure at canter was lower for the thicker pads than the mean pressure at walk with the control saddle cloth. For particularly sensitive horses, a reduction of the pressure acting on its back may increase their comfort at faster gaits. A previous study on saddle pressure in Swiss riding horses (*Dittmann* et al. 2021) helps to put the data recorded in this study in perspective. In that study, where saddle pressure measurements were carried out with 196 horse-rider-pairs using their own saddle and pad, the reported hMP values averaged at 11.0 ± 3.5 at walk, 11.6 ± 3.8 at sitting trot, 12.4 ± 4.1 at rising trot and 14.2 ± 4.2 at canter. This dataset not only included ill-fitting saddles, but also novice riders and horses with orthopedic problems. However, these values are very close to the average hMP for the control saddle cloth in this study (Table 2), indicating the present findings are applicable to average horse-saddle-rider combinations. It has previously been attempted to link saddle pressure with clinical symptoms, such as dry spots or swellings below the saddle (*von Peinen* et al. 2010): For horses with dry spots, hMP values averaged at 15.3 kPA at walk, 18.1 kPa at rising trot and 21.4 kPA at canter. For the control group without signs of saddle pressure, hMP averaged at 7.8 kPA at walk, 9.8 kPA at trot and 10.9 kPA at canter. This indicates that a difference of 7 to 10 kPA may be clinically relevant for horses. Assuming that saddle pads have the same effect for the average rider as they did for the professional rider in this study, a pressure decrease of 4 kPA, as observed in some pads, may be a relevant reduction for the horse, i.e. increasing its comfort. However, there is limited data to link pressure magnitude with clinical symptoms of saddle soreness. In a previous study based on population level data, the relationship between equine back pain and hMP was weak (*Dittmann* et al. 2021). This leads to the question, how relevant the magnitude of pressure is for a healthy, well-trained horse. While the measured pads certainly decreased mean pressure, their effect on the horse's wellbeing or performance was not assessed. Further scientific studies are needed to investigate the effect of pressure-reducing pads on gait quality, movement of the back, heart rate or other welfare-related variables, and to evaluate if the differences between pads are actually relevant for the horse.

Peham et al. (2010), who quantified the excursion of the COP below the saddle at trot, reported that the fore-back motion was higher at sitting trot than rising trot, while the lateral motion was higher at rising than at sitting trot. In the present study, fore-back movement (COP_{cc}) was higher at rising than sitting trot, while the ROM of COP_{lat} was higher at sitting than at rising trot. These opposite results may be due to both studies being carried out with a single rider (male in the cited study, female in this study). While using only one person for all measurements reduces variation, it has to be noted that the effect of the pads may differ between riders. It was impossible to blind the rider in this study to the different pads, and the results may be somewhat influenced by a person-specific reaction to, or preference for, certain pads, as well as individual riding style.

Despite the significant differences between pads, the results should be interpreted with caution. Data were obtained from a single professional, female rider and the effect of the different pads may differ from our findings when used by other persons, e.g. in an unbalanced, male, novice rider. Furthermore, there was a limited sample size of eight horses, which were sound and showed no signs of back problems, and the saddles in this study were a good fit for the horses. The effect of the pads on horses with back problems or below ill-fitting saddles may be quite different. For example, a thick pad may increase mean pressure under a saddle with a narrow tree head. Lastly, the pads investigated in this study were fairly new, and it is not possible to predict how frequent use over a longer period would affect the pressure-reducing properties of the pads. Further studies are needed to replicate these results, and to understand the effect of these pads under different saddle types (e.g. jumping) and with other riders and horses.

Conclusion

In the present study, none of the investigated saddle pads increased the mean pressure below the saddle. In fact, four of the five pads decreased mean pressure variables in most situations (compared to the control saddle cloth). This indicates that some saddle pads may help increase the horse's comfort by reducing the pressure acting on its back.

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Animal welfare statement

The experimental protocol was approved by the Animal Health and Welfare commission of the Canton Zurich, Switzerland (TVB-Nr. ZH003/17–28698).

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