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The Effect of Screw-in Studs on Equine Hoof and Limb Kinematics while Cantering and Jumping on an Artificial Surface

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Abstract

Studs are used to optimize hoof grip upon contact with the surface to prevent slip and enhance performance. Previous research has explored the influence of uniaxially placed studs on a grass surface during canter, the influence of stud length on braking forces, and the effect of restricted foot slip on bone strains. However, previous work has not addressed the influence of biaxially placed screw-in studs during canter and jumping on an artificial surface. A study was designed using seven actively competing showjumping horses which were subjected to two treatments: no studs (control) and studs. Studs were placed biaxially in the heel of each shoe. Kinematic analysis was conducted using high-speed video footage during canter and jumping. The test fence was set at a height of 1.20m with a width of 1m. No differences in slip distance or slip duration were observed across all phases ($P > 0.05$). A decrease in stance duration of the leading forelimb was seen at jump landing ($P < 0.05$). Take-off angle increased by 4.5° ($P < 0.05$), elbow angle during suspension was more acute ($P < 0.05$) and landing distance from the fence was greater by 0.31m ($P < 0.05$). The study demonstrates that canter kinematics were largely unaffected by stud use on an artificial surface; however, unexpectedly, some jumping parameters significantly improved. A reduction in the stance duration at jump landing is concerning as this may lead to higher braking forces in the distal limb, potentially resulting in an increased risk of overload injuries.

Keywords

Slip; traction; shoes; grip; biomechanics; performance

1. Introduction

The use of screw-in studs is a significant aspect of horse sport and competition **[1]**. The aim of using studs is to maximize the amount of grip the hoof has as it contacts the surface to reduce foot slip and optimize competitive performance. Studs are most commonly used in show jumping, eventing, and polo when competition surfaces have a greater potential for the horse to slip **[1]**. In recent years, many horses have competed successfully at the top level barefoot, with others remaining shod; this has sparked debate relating to competition surfaces, injury, shod versus unshod, and the hoof-surface interaction. Studs are most frequently employed on grass surfaces, with anecdotal evidence suggesting their use on artificial surfaces as well. However, studding decisions remain largely based on personal experience and preference rather than consultation of reliable scientific knowledge because there is a lack of evidence to support such guidance **[1]**.

The hoof-surface interaction and the subsequent action of generated forces on the distal limb tissues are believed to be a principal element in the incidence of injury **[2]**. It has been previously suggested that studding choices may play a role in injury, as highlighted at the 2004 Olympic Games in Athens when several horses sustained injuries which were later thought to be due to the interaction of studs used and the competition surfaces **[3]**. At impact, a certain amount of foot slip is suggested to be a desirable part of the natural mechanism of shock attenuation [4,5]. This sliding mechanism of the hoof as it decelerates, dissipates the forces associated with impact [6,7]. The hoof-surface interaction is a complex process influenced by a myriad of factors. Peterson *et al.* [8] have previously divided the stance phase of the limb into stages: primary impact, secondary impact, support, and rollover. It is a secondary impact that the leg is pushed forward by the body, in turn causing the hoof to slide forward over the surface [4]. The amount of hoof slip will be influenced by surface properties, speed of the horse, interaction between the layers of the surface, surface material, and the coefficient of friction between the hoof-surface interface [3,9]. Therefore, the use of traction devices, such as screw-in studs, alters this natural mechanism and may have injury implications [1,10,11].

To date, research relating to the effect of traction alterations and screw-in studs is lacking and has largely focused on grass surfaces. Early investigations focusing on toe grabs, a projection made into the shoe at the toe used in Thoroughbred racehorses in the past, have been identified as a potential factor for fatal musculoskeletal injury due to the resulting kinematic changes [12,13]. Furthermore, Harvey *et al.* [1] investigated the effect of a uniaxial stud placed at the lateral heel during canter on a grass surface. In this context, it was shown that the use of studs significantly shortened the hoof slip distance with stud efficacy also varying between limbs [1]. More recently, in vitro studies using cadaveric forelimbs demonstrated that restriction of the forward sliding of the equine hoof during loading can affect bone strains more proximal in the limb [10]. In addition, investigations of factors influencing rotational shear resistance of arena surfaces have shown that the use of studs resulted in increased maximum torque and rotational shear resistance increased as stud length increased [11]. Alteration of hoof-surface interaction on artificial surfaces remains largely unexplored. The current study aimed to investigate the effect of biaxially placed screw-in studs on hoof and limb kinematics during canter and jumping on an artificial surface. Information relating to the effect of studs during jumping or on an artificial surface is currently lacking. The null hypothesis was that biaxially placed screw-in studs would not alter hoof and limb kinematics in horses cantering and jumping on a sand and fiber surface.

2. Materials and Methods

2.1. Horses

Seven warmblood show jumping horses, 7.85 ± 2.04 years of age, with a height at the withers of 168.57 ± 1.03 cm, were included in the study (mean ± standard error). This group of subject horses was chosen as they were actively competing and accustomed to wearing studs, to give a more accurate representation of competition conditions. All horses were in active-ridden exercise at the time of data collection. Horses were shod with standard steel shoes, tapped with regular stud holes, on all four feet. To reduce variability in riding style, the same test rider was used for the duration of data collection. All horses undertook testing in their respective saddle and bridle, with only studs altering between treatments. All horses wore protective boots on each limb during each treatment. Subject horses were randomly split into two groups **(Table 1)**, with testing taking place over four days. Group 1 was tested on Days 1 and 3; Group 2 was tested on Days 2 and 4. This was done due to time constraints on behalf of the test rider. For all procedures carried out, consent was obtained from the horse owner.

2.2. Study Design

The studs chosen for this study were those routinely used in competition **(Figure 1)**. Two studs were placed in the heel of each shoe; therefore, larger studs were placed in the hind shoe as compared to the front shoe. For kinematic analysis, reflective markers were placed at palpable anatomical locations: these included the lateral aspect of the carpal joint, lateral aspect of the metacarpophalangeal joint, posterior part of the greater tubercle of the humerus, and the distal tibia at the lateral malleolus **(Figure 2)**. White titanium-based solvent (correction fluid) was used to create circular markers on the toe of each hoof, lateral aspect of the leading limbs, and the medial aspect of the trailing limbs. This procedure was similar to that used by Harvey *et al.* [1] **(Figure 2)**.

An outdoor arena with a surface that consisted of (by weight) 97% silica sand and 3% fiber (EqueFibre, Belgium) was used for the trial duration. The arena surface was harrowed to a depth of 2.5 inches using a standard equine arena harrow (Falcon Harrow, Equine Engineering) as per manufacturer recommendation, one hour before data collection began on each trial day. The test fence was set at a 1.20m high oxer fence with a width of 1m. This height was chosen to simulate competition conditions as it was comparable to the competition level of the subject horses. To reduce any variability in horse position at take-off, a ground-line pole was placed 30cm from the base of the fence, with another placing pole set 650cm from the ground-line pole. Two high-speed cameras (Casio Exilim EXZR800) were used for video recording during the trial. All footage was recorded at 120 frames/sec. One high-speed camera (camera 2) was used to record an overall view of the horse while cantering and jumping. The second camera (camera 1) was used to record a closer view of the hoof-surface interaction. Trial area setup and camera placement are illustrated in **Figure 3**. The setup design was decided after the analysis of the pilot study data.

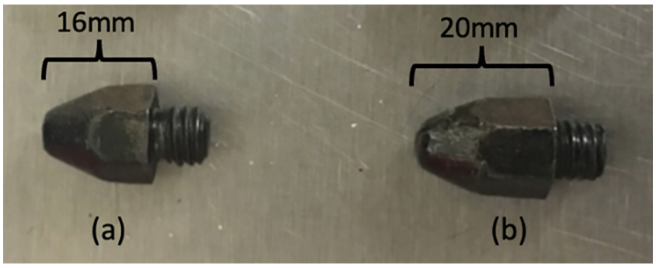

Figure 1: Studs used during the trial period. Studs (a) placed in the front shoes. Studs (b) placed in hind shoes.

Figure 2: Anatomical marker placement for data collection and kinematic analysis.

2.3. Experimental Procedure

Horses were subjected to two treatments: Treatment 1 with no studs (control) and Treatment 2 with studs. Treatments were assigned to each horse on a randomized basis **(Table 1)**. To begin the trial, horses completed a warm-up ranging between 20 to 25 minutes in duration to mimic their standard competition warm-up. This included walk, trot, canter, on both reins and over small warm-up fences until the rider felt the horse was ready to begin. All canter variables were collected first by cantering the horses through a chute three times **(Figure 3a)**. This was an overall view of the horse (camera 2) and a closer view of the hoof-surface interaction (camera 1), recorded simultaneously. Camera 1 captured slip distance, slip duration, and stance duration only, while camera 2 captured all other variables.

All jumping variables were captured as each horse progressed through the jump chute six times **(Figure 3b)**. For all six jumping efforts, an overall view of the horse from take-off to landing was recorded (camera 2). For jump trials 1–3, a closer view of the hoof-surface interaction at take-off was captured (camera 1), then for jump trials 4–6, this camera was moved to record the hoof-surface interaction at landing, as shown in **Figure 3b**. This was due to limited high-speed camera availability at the time of the study. No fences were knocked during the trial period by any of the subject horses. Following completion of the trial, each subject horse was cooled off, brought back to the stable, and the next horse was prepared. All footage was recorded from the left side of each horse and on the left rein.

2.4. Kinematic Analysis

Kinematic analysis was carried out in Image J Analysis software **(www.imagej.net)** and was blinded to the treatments. The resulting data was exported to Microsoft Excel (Excel 2021, Microsoft) for later statistical analysis. Foot-on was specified as the frame number (time) when any point of the hoof made contact with the surface. Toe-off was defined as the time when the toe was shown to leave the ground on high-speed footage. The method used to determine all indicators during footage analysis was validated and demonstrated to be a repeatable procedure, compared to alternative approaches, as adapted from **[1]**. Anatomical movement was calculated as the distance between markers in a horizontal plane, parallel to the ground. Similar to **[1]**, slip distance was defined as the horizontal distance moved by the toe marker from foot-on to heel-lift, with toe marker coordinates alone being used in the calculation of slip distance. Kinematic parameters measured are detailed in **Figure 4**. All joint angles at canter, jump take-off, and jump landing were measured at mid-stance. Bascule angle was measured from jump take-off, through suspension, to jump landing.

2.5. Statistical Analysis

Statistical analysis was carried out using IBM SPSS software Version 29. The data was initially tested for normality, and based on this, the appropriate statistical tests were used. These were the Paired T-Test and Wilcoxon Signed-Rank Test. A significance level of $P < 0.05$ was used for all statistical tests.

Table 1: Randomized Trial Order for the duration of data collection.

Horse No.	Day 1	Day 2	Day 3	Day 4
1	Treatment 2	-	Treatment 1	-
2	Treatment 1	-	Treatment 2	-
3	Treatment 2	-	Treatment 1	-
4	Treatment 1	-	Treatment 2	-
5	-	Treatment 1	-	Treatment 2
6	-	Treatment 1	-	Treatment 2
7	-	Treatment 2	-	Treatment 1

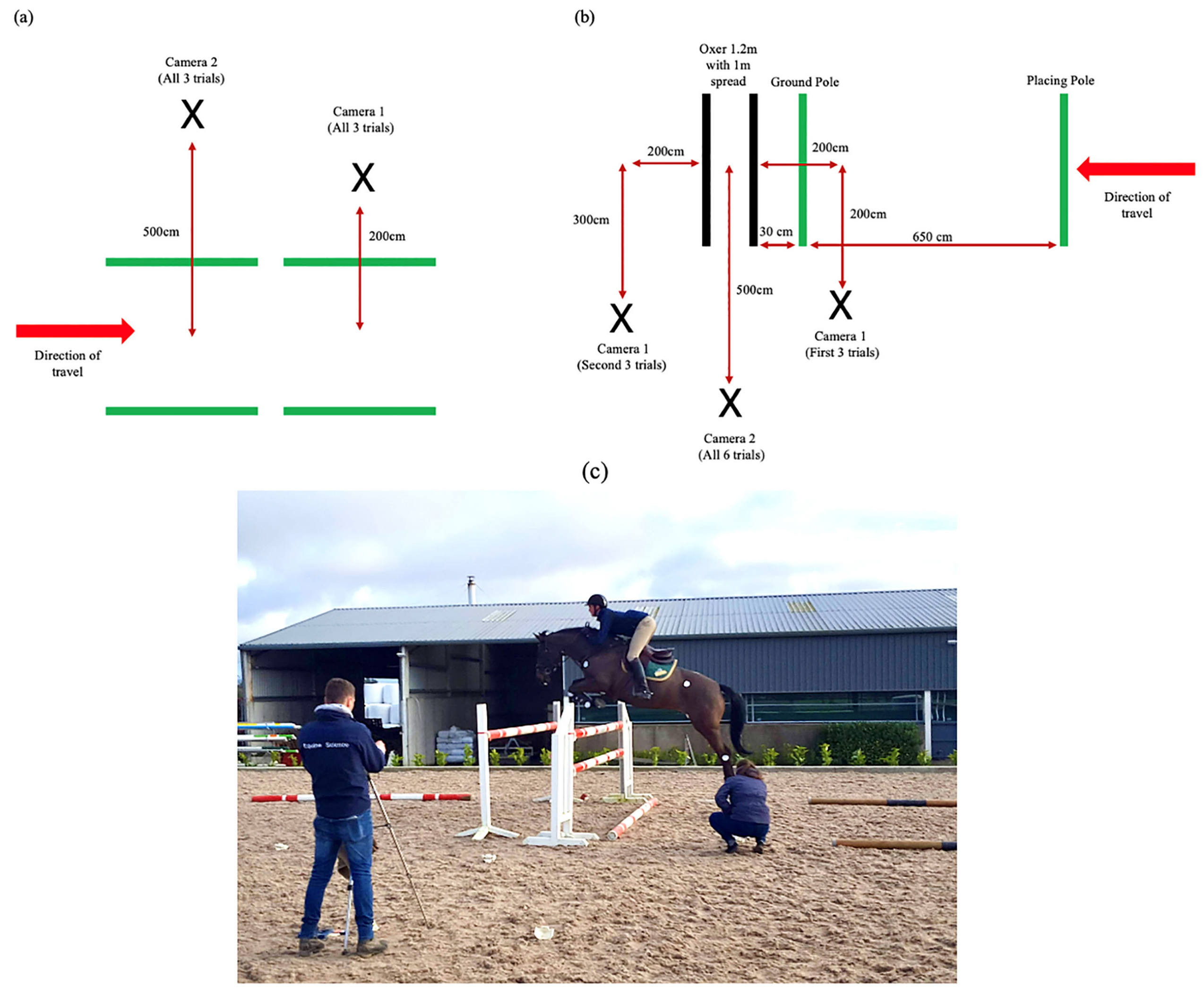

Figure 3: Trial area setup and camera placement for (a) the canter chute, (b) the jumping chute during the trial period, and (c) data collection at jump take-off.

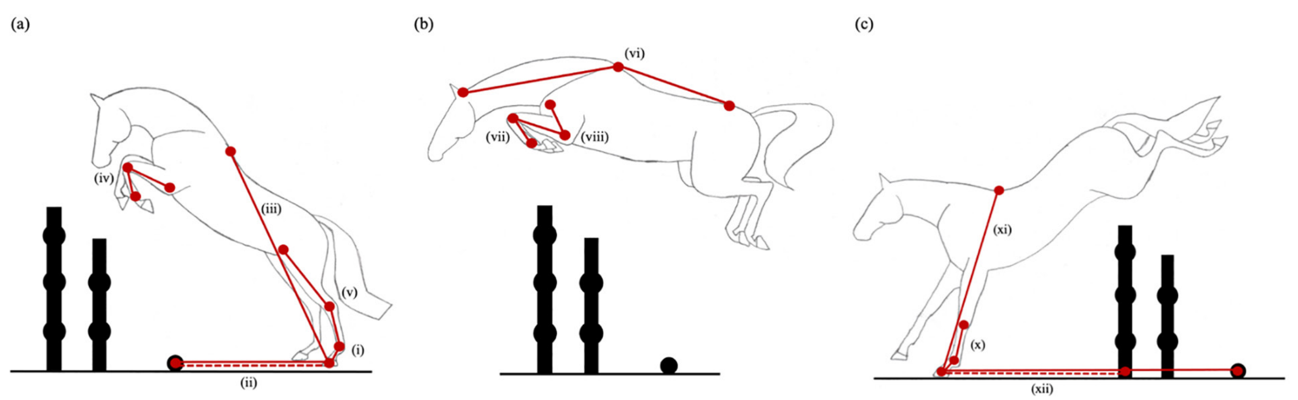

Figure 4: Kinematic parameters measured at jump: (a) take-off, (b) suspension, and (c) landing: (i) Hind fetlock angle (hoof – fetlock – hock), (ii) Distance from the fence (ground pole – hoof of the last limb to leave the ground), (iii) Take-off angle (ground pole – hoof – wither), (iv) Knee angle (fetlock – knee – elbow), (v) Hock angle (fetlock – hock – stifle), (vi) Bascule angle (shoulder – wither – stifle), (vii) Knee angle (fetlock – knee – elbow), (viii) elbow angle (knee – elbow – shoulder), (ix) Fore fetlock angle (hoof – fetlock – knee), (x) Landing angle (knee – hoof – ground pole), and (xi) Distance from the fence (hoof – fence).

3. Results

All results are illustrated as mean ± SE. A significant difference between treatments is denoted with an asterisk and/or highlighted in bold.

3.1. Hoof-Surface Interaction

3.1.1. Slip Distance

There was no significant difference shown in slip distance during canter, jump take-off, or jump landing with studs compared to without studs ($P > 0.05$; **Figure 5**).

Slip distance reductions at canter expressed as a percentage are by 22% in the LF, by 40% in the TF, by 28% in the LH, and by 46% in the TH. At jump take-off, hoof slip distances were reduced by 0.5% in the LF, by 46% in the TF, by 0.1% in the LH, and by 7% in the TH. However, at jump landing, hoof slip distances were increased by 2% in the LF, by 64% in the TF, by 21% in the LH, and by 7% in the TH.

3.1.2. Slip Duration

There was no significant difference shown in slip duration during canter, jump take-off, or jump landing with studs compared to without studs ($P > 0.05$; **Table 2**).

3.1.3. Stance Duration

Stance duration during canter and jump take-off showed no significant difference **(Table 3)**. It was only the leading fore limb at jump landing that showed a significant decrease in stance duration between treatments ($P < 0.05$; **Table 3**). This was a 14.78 ms reduction in stance duration.

3.2. Canter Kinematics

There was no significant difference shown in any kinematic parameters at canter ($P > 0.05$; **Table 4**).

3.3. Jump Kinematics

Jump kinematics are presented in **Table 5** and **Figure 6**, respectively. At jump take-off, hind fetlock angle appeared significantly decreased by 5.99° ($P = 0.025$) with studs. Take-off angle was significantly increased by 4.5° with the addition of screw-in studs ($P = 0.035$). Moreover, elbow angle at suspension was significantly decreased by 4.41° ($P = 0.045$). Landing distance from the fence was shown to significantly increase by 0.31 m with studs compared to without studs ($P = 0.015$).

4. Discussion

This study aimed to investigate the effect of screw-in studs on equine hoof and limb kinematics. Previous research has explored the influence of uniaxially placed studs on a grass surface during canter **[1]**, the influence of stud length on braking forces **[11]**, and the effect of restricted foot slip on bone strains **[10]**. However, previous work has not addressed the influence of biaxially placed screw-in studs during canter and jumping on an artificial surface.

The current study showed no significant difference in hoof slip distance with studs while cantering on an artificial surface. As previously illustrated by Harvey *et al*. **[1]**, a significantly shorter slip distance across all four feet was observed using a uniaxial stud placed on the outside of the foot while cantering on grass. While it would be expected to see a decrease in slip distance with the use of studs on a grass surface, the sand and fiber surface used in the current study is more deformable compared to grass, which may explain the results presented here **[6,14]**. The use of fiber in a sand-based surface is suggested to be advantageous in providing enhanced cushioning and stability to the surface **[3]**, while also creating a root-like structure similar to turf surfaces **[15]**. This may offer what is described as a more natural footing, yet it may not influence hoof kinematics, specifically hoof slip, to the same extent as a grass surface. However, exact surface properties were not measured in the current study. Additionally, canter speeds reported by Harvey *et al*. **[1]** were greater than those observed in the current work. This may further explain the reduced effect of screw-in studs in the current study, as hoof slip is influenced by horse speed and surface properties **[3,9]**. Future work should investigate the effects of screw-in studs across a range of speeds and surface types before a more definitive conclusion can be drawn.

Moreover, it was observed in the current study that studs had the greatest increase in grip at canter in the hind limbs compared to the forelimbs, and in the trailing limbs compared to the leading limbs, as shown by the percentage alteration in slip distances. Although these differences were not statistically significant, they align with the findings of Harvey *et al*. **[1]** and support the suggestion that the kinematic patterns of the fore and hind limbs are functionally different. During canter, the forelimbs are found to 'bounce' with higher vertical hoof velocity and accelerations at impact compared to the hind limbs, which 'slide' with increased horizontal hoof velocity and accelerations at impact **[16]**. Indeed, these findings reinforce the idea proposed by Harvey *et al*. **[1]** that stud choice is perhaps better tailored to the limb of interest. If a decrease in slip and an increase in grip is the desired outcome, it may be more prudent to apply studs solely to the hind limbs. In addition, the increased efficacy of studs in the trailing limbs may be made clear by the asymmetric nature of the canter gait, as such, there is greater loading and vertical force transmitted to the trailing limbs, thus generating a greater slip distance, which is then further restricted by the mechanism of heel studs **[17,18]**.

It was the leading forelimb alone that had a significantly shortened stance duration by 14.78 ms with the addition of screw-in studs, which may further increase jarring forces experienced by the limb at jump landing. Previous research attempting to characterize hoof kinematics while jumping showed that at landing, the leading forelimb functions as a brake to retard jump acceleration **[19,20]**, with significantly greater horizontal decelerations in the leading limb compared to the trailing limb **[21]**. The leading forelimb also experiences the largest braking forces compared to the other limbs **[18]**. However, larger vertical ground reaction forces have previously been associated with the trailing limb compared to the leading limb **[14]**. Additionally, it is the trailing limb that experiences almost exclusively vertical movement, with a lack of horizontal movement **[2]**. This previous research explains the lack of effect seen in the trailing forelimb at jump landing with the addition of studs. Therefore, as suggested by Rohlf *et al*. **[21]**, the leading forelimb may be at a greater risk of injury at jump landing, further compounded by the use of screw-in studs.

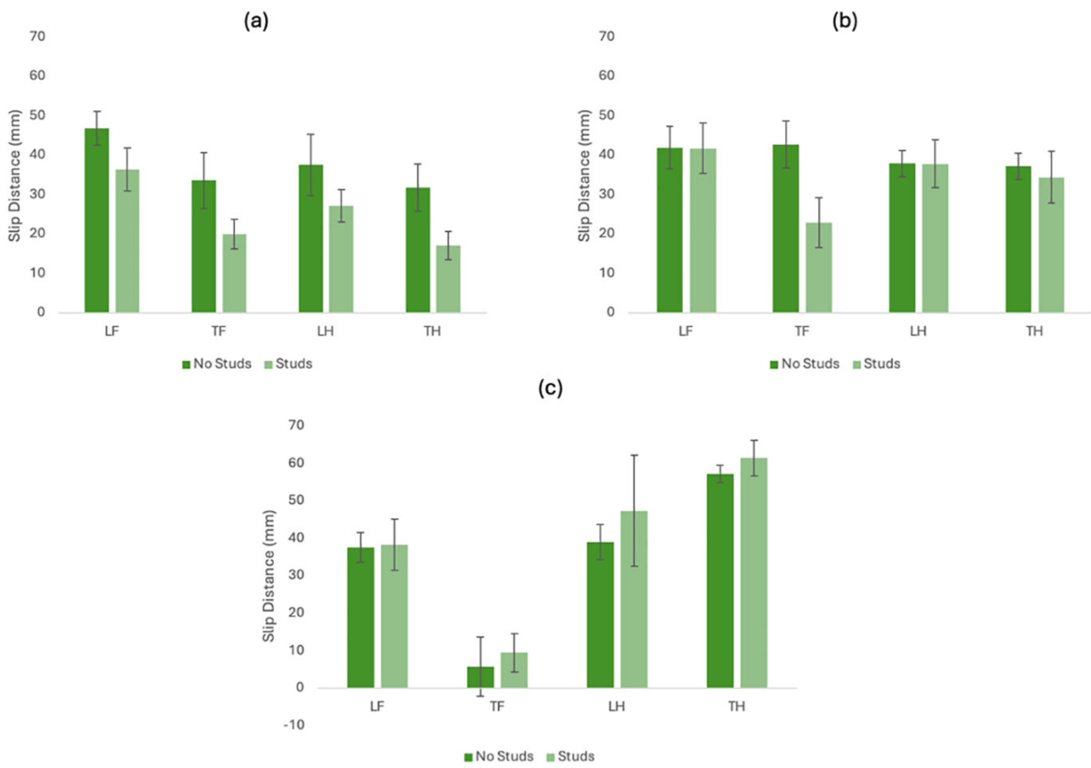

Figure 5: Mean slip distance in millimeters (mm) for each limb; Leading fore (LF), Trailing fore (TF), Leading hind (LH), and Trailing hind (TH) at (a) canter, (b) jump take-off, and (c) jump landing on an artificial surface with (right) and without (left) studs.

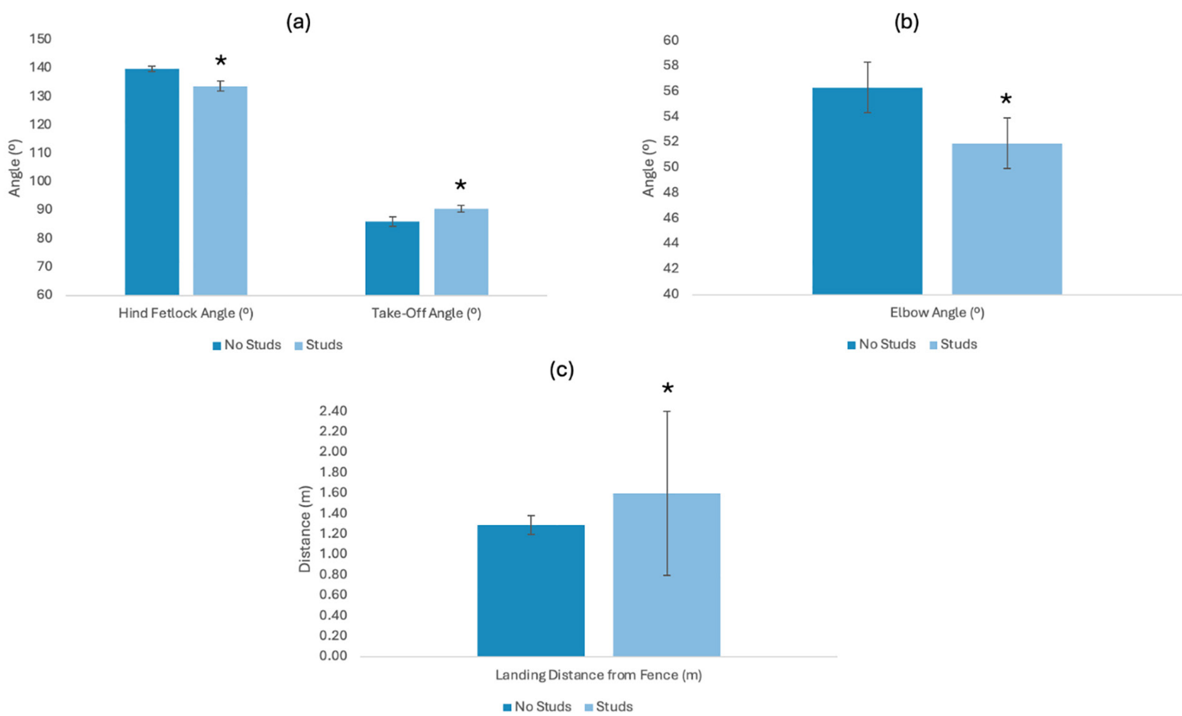

Figure 6: Jump kinematics at (a) jump take-off, (b) suspension, and (c) jump landing on an artificial surface without and with screw-in studs.

Table 2: Mean slip duration in milliseconds (ms) for each limb (mean ± SE); Leading fore (LF), Trailing fore (TF), Leading hind (LH), and Trailing hind (TH) at canter, jump take-off, and jump landing on an artificial surface without and with screw-in studs.

		Without Studs	With Studs	*P*-Value
Canter	LF	53.19 ± 3.65	55.63 ± 4.97	0.394
	TF	55.04 ± 5.10	58.10 ± 3.77	0.480
	LH	53.29 ± 5.01	44.27 ± 7.52	0.096
	TH	52.14 ± 3.51	47.14 ± 6.46	0.328
Jump Take-Off	LF	31.03 ± 1.92	31.86 ± 2.29	0.754
	TF	31.34 ± 1.38	28.59 ± 3.92	0.504
	LH	30.23 ± 1.23	27.87 ± 3.37	0.523
	TH	30.97 ± 1.33	27.87 ± 3.47	0.458
Jump Landing	LF	37.29 ± 3.03	41.71 ± 2.63	0.368
	TF	40.43 ± 2.51	41.29 ± 3.47	0.887
	LH	36.71 ± 1.67	42.00 ± 4.39	0.371
	TH	36.14 ± 0.83	40.14 ± 2.96	0.237

Table 3: Mean stance duration in milliseconds (ms) for each limb (mean ± SE); Leading fore (LF), Trailing fore (TF), Leading hind (LH), and Trailing hind (TH) at canter, jump take-off, and jump landing on an artificial surface without and with screw-in studs.

		Without Studs	With Studs	*P*-Value
Canter	LF	221.27 ± 4.89	223.04 ± 5.88	0.847
	TF	210.70 ± 8.22	214.27 ± 6.67	0.714
	LH	216.40 ± 3.75	223.03 ± 3.82	0.288
	TH	212.84 ± 8.23	213.54 ± 5.54	0.943
Jump Take-Off	LF	181.74 ± 6.39	168.31 ± 4.61	0.072
	TF	178.17 ± 13.35	191.66 ± 3.92	0.341
	LH	216.87 ± 9.49	204.17 ± 6.64	0.355
	TH	220.44 ± 9.95	202.20 ± 5.69	0.126
Jump Landing	LF	217.21 ± 4.54	202.43 ± 5.46	<0.001*
	TF	187.44 ± 5.81	181.53 ± 3.21	0.415
	LH	201.34 ± 6.38	202.90 ± 6.63	0.558
	TH	192.80 ± 7.22	185.93 ± 4.65	0.161

Certain jumping performance parameters appeared to improve with the addition of screw-in studs. These were a significantly more acute hind fetlock angle at take-off, a more acute elbow angle during suspension, and a significant increase in landing distance from the fence. Take-off, landing, and limb clearance over the obstacle play a crucial role in show jumping performance **[22]**. Recent work by Clayton *et al.* **[23]** highlighted that trunk elevation at take-off appears to be a decisive factor in achieving maximal height during suspension and the horizontal distance jumped. This is highlighted in the current work by a significant increase of 4.5° in take-off angle, resulting in a 0.31 m increase in landing distance from the fence with studs. Furthermore, this increase in take-off angle is a desirable aspect of jumping technique, with many linear scoring evaluations awarding greater distinction to this more upward take-off trajectory. Recent research has highlighted links between linear scoring evaluations and later jumping career performance **[24,25]**, with the direction of take-off being significantly associated with performance **[26]**. Due to this alteration at jump take-off, the latter stages of the jump phase appeared improved, as the suspension phase is determined at take-off **[27]**. This is a significantly more acute elbow angle of 4.41°, suggesting greater limb clearance over the fence and, as such, overall jumping performance. With limited significant alterations in hoof kinematics to explain these notable improvements in jumping performance, the authors reason that the subject horses may have felt increased confidence while jumping with the addition of screw-in studs. Confidence while jumping is a difficult parameter to quantify; however, anecdotally, it is suggested that when competitive horses feel they have greater purchase and grip on a surface, this leads to a more confident, explosive, and expressive jumping performance.

Improved jumping performance with the use of screw-in studs, combined with hoof kinematic alterations, may result in increased injury risk. Previous research has highlighted that near-maximal tendon forces are experienced at fence heights of 1.20 m **[19]**, with loads experienced by the forelimbs increasing as fence height increases **[28]**. Furthermore, Singer *et al*. **[10]** demonstrated that a restriction of foot slip by 30 mm significantly altered bone strains in the distal limb. In this study, hoof slip reductions were not significant; however, they ranged between 10.3 mm to 19.8 mm across all feet and phases. This is of some concern, considering the fence height was at 1.20 m. During competition, with increasing fence height and less deformable surfaces, these reductions may approach levels seen by Singer *et al*. **[10]**.

Comparisons made here are tenuous due to differences in experimental design between studies. However, repeatedly altering the natural shock attenuation mechanisms of the hoof while jumping may, over time, overload the soft tissues of the distal limb, leading to injury development **[29]**. This suggests that the use of screw-in heel studs may play a role in injury development; yet, much more work is needed in this area. Further research is required to fully understand the implications of studding horses for competition and to identify links between alterations in hoof and limb kinematics and mechanisms of injury. Determining the most favorable stud size, stud shape, placement, and configuration to minimize potential injury across various surface types, without conceding increased grip as a requirement for competition, would lead to the best decisions for horse welfare and career longevity in modern equestrian sport.

Table 4: Limb Kinematics at canter (mean ± SE) without and with studs.

		Without Studs	With Studs	*P*-Value
Canter	Stride Length (m)	4.06 ± 0.19	3.69 ± 0.13	0.083
	Speed (m/s)	6.45 ± 0.31	5.49 ± 0.29	0.073
	Step Length (m)	1.41 ± 0.04	1.38 ± 0.06	0.511
	Fore Fetlock Angle (°)	114.28 ± 3.34	116.93 ± 2.66	0.399
	Hind Fetlock Angle (°)	134.18 ± 1.04	137.21 ± 1.78	0.164
	Hock Angle (°)	134.62 ± 1.02	134.83 ± 1.13	0.867

Table 5: Jump Kinematics (mean ± SE) without and with studs.

		Without Studs	With Studs	*P*-Value
Take-off	Hind Fetlock Angle (°)	139.74 ± 0.92	133.75 ± 1.76	0.025*
	Distance from Fence (m)	2.17 ± 0.16	2.05 ± 0.15	0.621
	Take-off Angle (°)	86.05 ± 1.61	90.55 ± 1.08	0.035*
	Knee Angle (°)	116.17 ± 4.09	105.83 ± 3.52	0.111
	Hock Angle (°)	134.62 ± 1.02	134.83 ± 1.13	0.867
Suspension	Bascule Angle (°)	181.81 ± 1.37	182.01 ± 1.23	0.852
	Knee Angle (°)	41.74 ± 4.42	38.86 ± 3.73	0.548
	Elbow Angle (°)	56.33 ± 1.86	51.92 ± 1.90	0.045*
	Duration of Suspension (sec)	0.49 ± 0.01	0.48 ± 0.01	0.731
	Speed of Suspension (m/s)	11.44 ± 0.42	12.36 ± 0.62	0.161
	Suspension Stride Length (m)	5.59 ± 0.16	5.95 ± 0.27	0.053
Landing	Fore Fetlock Angle (°)	109.62 ± 2.19	107.03 ± 2.29	0.386
	Landing Angle (°)	63.49 ± 2.29	64.17 ± 1.61	0.655
	Distance from Fence (m)	1.29 ± 0.9	1.60 ± 0.08	0.015*

5. Limitations

The current study did not measure exact surface properties. Future work should combine both surface property measurements with the influence of traction devices. While surface properties are influential in altering kinematics, they were kept consistent during the four-day testing period. The surface was prepared using the same protocol and weather conditions remained consistent throughout the trial.

Studs chosen for the trial were based on industry experience of the authors, in the absence of scientifically informed guidelines. Both authors groomed and studded horses at FEI 5* level show jumping. Future research is needed to understand what screw-in studs industry stakeholders are using across various surface types, so that investigations may be better informed.

6. Conclusions

The findings of this study reject the null hypothesis that the use of studs would not influence limb kinematics and the hoof-surface interaction while jumping and cantering on an artificial surface. Screw-in studs significantly altered the stance duration of the leading forelimb during jump landing, while kinematics during canter appeared relatively unaffected. Certain jumping performance parameters appeared improved with the addition of screw-in studs, these being an increased take-off angle, greater limb clearance during suspension, and a greater landing distance from the fence.

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Authors' Contributions

TD – conceptualization, data collection, data analysis, and paper writing. SM – conceptualization, supervision, and paper review. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data supporting the findings of this study are available upon reasonable request from the corresponding author.

Funding

No funding was received for this research project.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Ethical Approval

Ethical approval was granted by the University of Limerick Animal Ethics Committee (ULAEC) (Reference Number: 2016_11_3_ULAEC). This study adhered to the guidelines of the Declaration of Helsinki.

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