How do the surface characteristics of three different sand-based arena surfaces change with different maintenance techniques in the UK?

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Oral presentation

Take home message

Appropriate arena surface maintenance is considered important to ensure that the surface functions correctly and to expectations. The main aim of performing maintenance is to keep an even distribution of the superficial layer of the surface across the arena to ensure the surface behaves consistently. Results indicate that different types of machines can have similar effects on certain properties, but very different effects on other properties. Care should be taken when selecting a piece of maintenance equipment based on the surface requiring maintenance and what is to be achieved by the maintenance.

Introduction

Surface maintenance has been found to alter the surface properties of various racing surfaces differently. One study determined that the more horses that exercised on a surface (woodchip and dirt) between each unit care of maintenance resulted in a more compacted, hard surface with less elastic return (Kai et al., 1999). Setterbo et al. (2013) showed that a dirt racing surface compacted and became harder at a faster rate than a synthetic surface and highlighted the need for different maintenance regimes of synthetic and dirt racing surfaces for consistent behavior. These studies indicate that different surface materials compact at different rates of usage. However, the way a surface responds to maintenance is likely to be dependent on the maintenance type and the length of the harrow tines.

To date there has been limited study on the effect of maintenance on the properties of arena surfaces used by sports horses. Northrop et al. (2013) collected data from a specially laid track and used a Clegg hammer and modified traction apparatus for testing. Results indicated that surface hardness and traction did not alter significantly on a waxed-sand with fibre (WSF) that had been harrowed or rolled. Tranquille et al. (2015) collected data from six different arenas that were ridden on daily and used the Orono Biomechanical Surface Tester (OBST) (Peterson et al., 2008) for testing. Results showed that superficial harrowing a WSF surface significantly increased the cushioning properties of the surface. Wax content of the surfaces could be an explanation for the difference in results between the two studies (Orlande et al., 2012). Different types of machines were used to carry out the harrowing in the two studies, with varying number and length of the tines, which could also have had an impact (Peterson and McIlwraith., 2008).

It is important to assess the effect of maintenance on surface types in common usage by sports horses. Waxed-sand with fibre and sand with rubber (SR) surfaces were popular choices for dressage training surfaces in the UK (Murray et al., 2010a,b) and sand with fibre (SF) was frequently used as a training surface for elite show jumpers (Egenvall et al., 2013).Wax, fibre and rubber are often added to increase shear strength, stability and decrease maintenance requirements of the surface (Hobbs et al., 2014). Rubber is added to reduce the compaction of the surface (Thomason and Peterson, 2008).

This study aimed to describe how different maintenance machines, using the study standard machine and the equipment found at each venue, affect the properties of sand-based equestrian surfaces within an arena. It was hypothesised that: 1) different maintenance machines will have a significantly different effect on the properties of sand-based equestrian surfaces and 2) rolling will significantly increase impact firmness and grip of sand-based equestrian surfaces at hoof-ground impact.

Materials and methods

The mechanical testing was carried out with the OBST. Seventy-one arenas with three different surface types were recruited for testing: SR (*n*=30), SF (*n*=20) and WSF (*n*=21). Each arena was divided equally into two regions so that two different maintenance techniques (using their own machine or the study standard machine, a Keep-A-Level machine with tines reaching a depth of 5cm and a levelling bar) could be carried out and data collected under similar weather conditions. Region A underwent the normal maintenance regime for that venue and Region B underwent harrowing with the standard machine with a set protocol. Ten different locations were tested on each region; therefore data were collected from 20 locations per arena. Data were collected on impact firmness, cushioning, responsiveness and grip value pre- and post-maintenance and exported into Matlab (Mathworks Inc., Cambridge, UK) for processing using custom written scripts. Impact firmness describes the hardness of the top layer of the surface. Cushioning describes how the surface is able to dampen and reduce the maximum force when the horse is fully weight bearing at mid-stance; an increase in this value means the peak forces experienced by the horse are higher and the cushioning properties of the surface are lower. Responsiveness describes how active, or springy, the surface feels to the horse. Grip value describes how much the horse's hoof slides at hoof-ground impact; an increase in this value means the hoof slides longer and the grip of the surface is lower (Hobbs et al., 2014).

Data were excluded when the signal displayed disturbance. Descriptive statistics were used to investigate data distribution using statistical software (Analyse-It Software Ltd, Leeds, UK). A Student's paired t-test, or a Wilcoxon-signed rank test were used as appropriate, to compare the mean values between venues with machines of a similar design, of the properties pre- and post-maintenance on the three different surfaces. A significance level of $p<0.05$ was assumed.

Results

All venues recruited with a WSF surface had combination machines (machines with height adjustable tines with one/two crumbler rollers) therefore these data were pooled together to enable comparison with the data collected from the standard machine. Both types of machines had a similar effect on the properties of a WSF surface: impact firmness increased, although not significantly; cushioning value decreased, but this was significant with the combination machine only; the responsiveness decreased, although not significantly, and grip value increased significantly with both types of machine (Table 1).

Table 1. Table summarising the mean, standard deviation (SD), percentage change and the p-value for the Student's paired t-test, or a Wilcoxon-signed rank test, comparing results for impact firmness, cushioning value, responsiveness and grip value pre-maintenance and post-maintenance with a combination machine or the standard machine on 21 arenas with a waxed sand with fibre arena surface. Significant changes are in bold. NA = not applicable; n = number of valid data points used in the analysis.

Property	**Pre/Post**	**Machine**	**Mean**	**SD**	**% Change**	**P value**
Impact firmness	Pre (n=196)		90.46	22.18	NA	NA
	Post	Combination (n=178)	92.15	26.63	↑ 1.9	0.7768
		Standard (n=194)	94.52	26.99	↑ 4.5	0.2104
Cushioning value	Pre (n=383)		12.20	1.36	NA	NA
	Post	**Combination (n=186)**	**12.04**	**1.41**	**↓ 1.3**	**0.0491**
		Standard (n=195)	12.02	1.17	↓1.5	0.2074
Responsiveness	Pre (n=375)		0.584	0.119	NA	NA
	Post	Combination (n=184)	0.564	0.204	↓ 3.6	0.0965
		Standard (n=196)	0.575	0.200	↓ 1.7	0.5754
Grip value	Pre (n=383)		0.0075	0.0016	NA	NA
	Post	**Combination (n=187)**	**0.0081**	**0.0019**	**↑ 8.5**	**<0.0001**
		Standard (n=196)	**0.0079**	**0.0015**	**↑ 5.8**	**0.0004**

There was a wide range of machine types at the SF venues recruited for the study. Data from the venue machines were pooled to compare with the study standard, however rollers were expected to change the properties differently to a harrow therefore these data were analysed separately from the other 'venue machine' data. Impact firmness increased, although not significantly, post maintenance with both the standard machine and the venue machine. The surface responsiveness variable increased with both the standard machine and the venue machine; this was only significant for the venue machine. Surface cushioning value decreased with the venue machine but increased with the standard machine. Grip value increased post maintenance with both types of machine but was only significant with the standard machine. Rolling an SF surface significantly increased impact firmness and grip value and decreased cushioning value and surface responsiveness (Table 2).

Table 2. Table summarising the mean, standard deviation (SD), percentage change and the p-value for a Student's paired t-test, or a Wilcoxon-signed rank test, comparing results for impact firmness, cushioning value, responsiveness and grip value pre-maintenance and post-maintenance (with all venue machines pooled together (n=19), a roller (n=1), or the standard machine) on 20 arenas with a sand with fibre arena surface. Significant changes are in bold. NA = not applicable; n = number of valid data points used in the analysis.

Property	**Pre/Post**	**Machine**	**Mean**	**SD**	**% Change**	**P value**
Impact firmness	Pre (n=402)		76.78	31.77	NA	NA
	Post	Venue own (n=177)	78.86	30.54	↑ 2.7	0.2993
		Roller (n=8)	**116.85**	**15.28**	**↑ 52.2**	**0.0003**
		Standard (n=47)	83.29	31.03	↑ 8.5	0.1417
Cushioning value	Pre (n=407)		10.56	2.13	NA	NA
	Post	Venue own (n=193)	10.39	2.01	↓ 1.6	0.3838
		Roller (n=8)	11.83	0.50	↑ 12.0	0.0854
		Standard (n=206)	10.68	1.99	↑ 1.1	0.8299
Responsiveness	Pre (n=401)		0.683	0.225	NA	NA
	Post	**Venue own (n=193)**	**0.730**	**0.210**	**↑ 6.8**	**0.0035**
		Roller (n=8)	0.594	0.156	↓ 13.1	0.9035
		Standard (n=205)	0.707	0.209	↑ 3.5	0.0646
Grip value	Pre (n=408)		0.0092	0.0025	NA	NA
	Post	Venue own (n=194)	0.0095	0.0027	↑ 2.8	0.4761
		Roller (n=8)	**0.0083**	**0.0007**	**↓ 10.2**	**0.0384**
		Standard (n=207)	**0.0096**	**0.0022**	**↑ 4.5**	**0.0027**

The SR venue machines included chain-harrows, 5-barred gates, commercially-available levellers (machines with no tines and a levelling plate), combination machines, and Keep-A-Level machines. There were sufficient numbers for each of the different machine types, therefore these data were analysed separately. All machines induced an increase in impact firmness; this was significant with a Keep-A-Level, a leveller and the standard machine. Cushioning value was significantly increased with a Keep-A-Level only; however a chain harrow and the standard machine caused a decrease. Surface responsiveness increased with all machine types although this was not statistically significant. Grip value increased with a combination machine, a leveller and the standard machine; all other machines caused grip value to decrease. These findings were not statistically significant (Table 3).

Table 3. Table summarising the mean, standard deviation (SD), percentage change and the p-value for a Student's paired t-test, or a Wilcoxon-signed rank test, comparing results for impact firmness, cushioning value, responsiveness and grip value pre-maintenance and post-maintenance (with a combination machine (n=8), Keep-A-Level (n=9), leveller (n=5), 5-barred gate (n=5), chain-harrow (n=3), or the standard machine) on 30 arenas with a sand with rubber arena surface. Significant changes are in bold. NA = not applicable; n = number of valid data points used in the analysis.

Property	**Pre/Post**	**Machine**	**Mean**	**SD**	**% Change**	**P value**
Impact firmness	Pre (n=552)		75.09	30.78	NA	NA
	Post	Combination (n=92)	76.90	36.23	↑ 2.4	0.9590
		Keep-A-Level (n=85)	**93.05**	**26.05**	**↑ 23.9**	**<0.0001**
		Levellers (n=27)	**92.28**	**35.11**	**↑ 22.9**	**0.0117**
		Gates (n=49)	83.52	30.81	↑ 11.2	0.1096
		Chain-harrow (n=19)	78.71	33.63	↑ 4.8	0.6549
		Standard (n=263)	**80.90**	**31.24**	**↑ 7.7**	**0.0132**
Cushioning value	Pre (n=578)		10.14	2.36	NA	NA
	Post	Combination (n=98)	9.69	2.23	↓ 4.5	0.0357
		Keep-A-Level (n=79)	**11.32**	**1.50**	**↑ 11.6**	**<0.0001**
		Levellers (n=37)	9.90	2.42	↓ 2.5	0.4532
		Gates (n=59)	10.12	1.74	↓ 0.3	0.4667
		Chain-harrow (n=19)	11.07	2.65	↑ 9.1	0.0898
		Standard (n=285)	10.25	2.12	↑ 1.0	0.7312
Responsiveness	Pre (n=478)		0.692	0.177	NA	NA
	Post	Combination (n=97)	0.743	0.279	↑ 7.4	0.1925
		Keep-A-Level (n=79)	0.698	0.113	↑ 0.9	0.1593
		Levellers (n=24)	0.733	0.221	↑ 5.9	0.5048
		Gates (n=31)	0.725	0.137	↑ 4.8	0.1802

		Chain-harrow (n=19)	0.712	0.164	↑ 2.9	0.6853
		Standard (n=265)	0.711	0.209	↑ 2.7	0.5775
Grip value	Pre (n=579)		0.0097	0.0027	NA	NA
	Post	Combination (n=107)	0.0098	0.0020	↑ 1.0	0.3274
		Keep-A-Level (n=79)	0.0095	0.0017	↓ 2.7	0.7436
		Levellers (n=39)	0.0099	0.0033	↑ 1.9	0.6283
		Gates (n=40)	0.0099	0.0022	↑ 2.2	0.3380
		Chain-harrow (n=19)	0.0093	0.0017	↓ 4.1	0.6276
		Standard (n=285)	0.0100	0.0024	↑ 2.5	0.1067

Discussion

The results support the hypotheses tested. Different types of maintenance machine can have similar effects on certain properties, but very different effects on other properties in particular on a SR surface. On a WSF and SF surface different types of machine had a similar effect on all properties. Rolling a SF surface significantly increased the impact firmness and grip of the surface but had no significant effect on the cushioning or responsiveness.

Initial assessment indicated that all venues with a WSF surface had combination machines. In contrast there appeared to be no pattern of machine type at venues with a SF or a SR surface. This could be related to the venue type, time available for arena maintenance and cost of the surface.

On a WSF surface the combination machine and the standard machine appeared to have similar effects on the properties of the surface. This could be due to the compaction of the deeper layers making the superficial layers behave more uniformly. Using other techniques, or machines with longer tines, could result in a greater ‘change’ after maintenance, if this was required by the venue.

On a SF surface the venue machine, excluding the roller, and the standard machine had similar effects on the properties of the surface. These results should be interpreted with caution as data from a number of different machine types were pooled together potentially introducing variation in the data. Rolling induced a significant increase in impact firmness and grip which is not surprising due the compaction of the superficial layer. However the results regarding the rolling should be interpreted with caution because data was collected on only one arena (albeit the mean value is substantially high).

On a SR surface all machine types caused an increase in impact firmness and responsiveness. This could be due to rubber redistribution during maintenance. Cushioning and grip value were affected differently depending on the machine type and there was no apparent pattern; the small sample sizes could be an explanation for this. The standard machine and the Keep-A-Level had different effects on the surface properties, albeit being the same machine, possibly due to the depth the tines reached which may have been different.

Limitations that should be accounted for include: arena construction, base type, type and shape of rubber pieces, usage patterns and arena surface age. There may be a manufacturer effect for the WSF surfaces because wax content can significantly alter surface properties (Orlande et al., 2012). Environmental factors have been shown to alter the properties of racing surfaces (Ratzlaff et al., 1997; Peterson et al., 2010). Adverse weather experienced during testing may have altered the surface properties of the surface of the outdoor arenas, but the effect would have been the same for both regions of the arena.

Conclusions

Results suggest that different types of maintenance machines can have similar effects on certain properties, but very different effects on other properties. This indicates that care should be taken when selecting a piece of maintenance equipment based on the surface requiring maintenance and what is to be achieved by the maintenance.

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