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Opening Forces or Failure of Commercially Available Equine Headcollars and Other Safety Devices

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ABSTRACT

A recent survey by our group indicated that headcollar (halter, USA) related incidents in which horses were injured may be common. Furthermore, 134 incidents involving horse fractures and 167 fatalities were reported. Headcollar design and materials vary markedly from traditional leather to ’safety’ headcollars and safety devices. Despite their almost universal use, there appears to be little study of how these items function or specifications for performance. The aim of the present study was to select a range of commercially available headcollars of standard design and a number of safety devices, including baler twine. The latter is widely used by equestrians to attach a horse by a headcollar to a lead rope and in turn to a fixture and perceived to increase safety. Devices were subjected to increasing load in the poll to lead-rope attachment axis, i.e. to simulate a horse pulling backwards, using a custom-made steel rig incorporating an electric 1000kg winch. The force was increased incrementally until either the headcollar or device opened or failed. The lowest mean opening force was for a safety headcollar (357±50N; n=6; mean±SD); equivalent to a load of approximately 36kg. The highest breaking force was 5798±265N for one of the eight different webbing headcollars tested (n=6). Breaking for safety devices ranged from 354±121N (n=6) for ’fine’ baler twine to 1348±307N (n=6) for a ‘heavy duty’ baler twine. Variability in opening force was lowest in two of the webbing headcollars (CV <5%) despite these having very high breaking points (>3500N). The greatest variability was found for fine baler twine (CV = 34%) and one of the commercial safety devices (CV = 38%). The range of opening forces and the variability in opening forces for standard headcollars, safety headcollars and safety devices is a cause for concern and may give horse owners/handlers a false sense of security of safety, and actually predispose horses and handlers to an increased risk of injury.

KEYWORDS: horse; restraint; safety; force; tack; injury

INTRODUCTION

Headcollars or halters are pieces of tack that are fitted to a horse's head to allow control of the horse. Headcollars are primarily used for husbandry procedures such as tying horses up, keeping them in one place by a handler, for example for foot care or veterinary examination, or leading horses from the ground. A recent survey of almost 5615 equestrians reported that 88% used a headcollar on their horse's multiple times on a daily basis (Marlin, Williams & Pickles, In Press). Almost one third of respondents had experienced a horse being injured associated with the wearing of a headcollar, including 167 fatalities. In 15% of the reported headcollar incidents, a person was also injured (Marlin, Williams & Pickles, In Press). Injury due to falls or being thrown from horses has been the most commonly reported injury in riders whilst for riders unmounted or non-riders/handlers, the most common cause of injury was reported to be kicks [1], but no reference was made to headcollar related injuries to people.

The majority of headcollar-related injuries to horses in the survey by Marlin, Williams & Pickles (In Press) occurred whilst they were 'tied-up' (70%). The precise circumstances of the injuries were not investigated in the former study, but possible examples include a horse pulling back, the structure to which the horse was secured collapsing, the horse slipping whilst tied, the headcollar getting caught on a physical object or a horse getting a leg over the lead rope used to tie the horse up. Clearly, the force at which a headcollar, lead rope, clip or fastener breaks or releases the horse could have a significant impact on the type and severity of injury sustained in such incidents.

To date there does not appear to have been any attempt to characterise how different headcollars behave when subjected to high forces. A 500kg horse pulling back at 2-3g when tied-up could result in forces in excess of 10,000N. Some materials have a very high breaking point and could lead to injury due to high pressures under the headcollar generated by the horse. Severe consequences of headcollar-related incidents have been reported in the veterinary literature, including fracture of the atlas (first cervical vertebra; the connection between the head and the rest of the skeleton)[2], fracture of the paracondylar process of the occiput (where the atlas connects to the skull)[3] and atlantoaxial subluxation (a misalignment of the 1st and 2nd cervical vertebrae) [4]. These accidents often involve strangulation type events when the headcollar becomes caught on an external fixture such as stable fixtures and fittings[3]. However, the description of the headcollars involved and the nature of the injuries are generally vague or unrecorded

A number of patents exist for safety headcollars or halters. For example, a 1984 US patent (US4502265A) for a "Breakaway safety halter" refers to a design "….which can release or separate from each other in response to excessive longitudinal forces, such as forces in the neighbourhood of

30 pounds or so" (133N). No justification for this value was presented in the patent. By contrast a more recent US patent (US20060185331A1) for a "Continuous duty equine halter" specifies an opening force of "…in the range of 150 to 250 pounds of force", equivalent to 667-1108N, although again without clear justification for the setting of the opening force.

A variety of different types of headcollar materials are commonly used in horses including leather and synthetic materials such as nylon webbing, nylon rope and plastics. Headcollars are also available in a standard design, which are not intended to open under force, and 'safety' headcollars which are designed to open under force, although the opening force is rarely, if ever, stated. Marlin, Williams and Pickles (In Press) reported that in 67% (webbing headcollar related) to 80% (lead rope related) of headcollar incidents, the headcollar/lead-rope was reported to have behaved as expected, i.e. if it was a safety device it is presumed to have opened and a non-safety headcollar would have remained attached and intact. This calls into question whether current headcollar specifications are appropriate. In addition to standard and safety headcollars, there are a variety of safety devices commercially available which are designed to be attached between the headcollar and lead rope, or between the lead rope and the point of fixation.

The aim of the present study was to test the force required to break, or release in the case of a safety headcollar or device, a range of commercially available standard and safety headcollars, and safety devices, including baler twine. In addition, the breaking force of three different strengths of baler twine (synthetic twine designed for binding bales of hay, straw, or similar material) was also investigated as, anecdotally, this is commonly believed to reduce the risk of injury and was reported to be used by 40% of equestrians (Marlin, Williams & Pickles, In Press).

<u>**MATERIALS & METHODS**</u>

Commercially available products or materials for testing were purchased either online or direct from manufacturers without specifying that these were for a research project. Products and materials to be tested were chosen to represent the types of headcollars and safety devices commonly being used by horse owners. These are specified in Table 1.

Table 1. Products or materials tested.

Model	Manufacturer	Size	Type	Material
Baler Twine (Fine)	Agritel Ltd	NA	Safety Device	Nylon
Baler Twine (Medium)	Agritel Ltd	NA	Safety Device	Nylon
Baler Twine (Heavy Duty)	Agritel Ltd	NA	Safety Device	Nylon
Bungee Breakaway Trailer Tie	Shires Equestrian Products	NA	Safety Device	Webbing/Elastic#
Cottage Craft 83	Harry Hall International Ltd	Full	Standard HC	Webbing/Fleece
Equi-Ping	Safety Release Ltd	NA	Safety Device	Plastic
FieldSafe	Horseware Products Ltd	Cob	Safety HC	Webbing
Hy Fieldsafe	Hy Equestrian	Cob	Safety HC	Webbing
Hy Soft Webbing	Hy Equestrian	Cob	Standard HC	Webbing
HyClass Leather	Hy Equestrian	Cob	Standard HC	Leather
KM Elite Webbing	KM Elite Products	Cob M	Standard HC	Webbing
Leather Foal Slip	Shires Equestrian Products	Foal	Standard HC	Leather
Libbys Field Safe	Libbys International	Full	Safety HC	Webbing
Protechmasta IR Ergonomic	Harry Hall	Cob	Safety HC	Webbing
Ready To Ride	John Whitaker International Ltd	Cob	Standard HC	Leather
Stellar (Position A)*	Equilibrium Products Ltd	Cob	Safety HC	PVC
Stellar (Position B)*	Equilibrium Products Ltd	Cob	Safety HC	PVC
Topaz	Shires Equestrian Products	Cob	Standard HC	Webbing
Vogue	Le Mieux, Horse Health Wessex Ltd	Cob	Standard HC	Webbing
Wonder Wish Adjustable Rope Halter	Wonder Wish Pet	One size	Standard HC	Nylon

HC = headcollar
*These positions and their effect are explained in detail on the manufacturer's website. In position A the headcollar opens at 50-60kg. In position B it opens at 80-90kg.
A combination of webbing and elasticated materials.

Manufacturer's addresses: Agritel Packaging Supplies, Agritel Ltd, Gledrid Industrial Park, Wrexham, LL14 5DG, UK; Shires Equestrian Products, Leominster, Herefordshire, HR6 0QF, UK; Harry Hall International Ltd, Park View Mills, Bradford, BD6 3QA, UK; Safety Release Ltd, Brickfields Stud, Newmarket, Suffolk, CB8 7JH, UK; Horseware Products Ltd, Finnabair Business Park, Dundalk, Co Louth, Ireland; Hy Equestrian, Battle, Hayward & Bower Ltd, Allenby Road Industrial Estate, Lincoln, LN3 4NP, UK; KM Elite Products, Crawfold Business Park, Petworth, West Sussex, GU28 9JT, UK; Libbys International, Alderholt, Fordingbridge, Hampshire, SP6 3AX, UK; John Whitaker International Ltd, Smallbridge Business Park, Rochdale, Lancs, OL16 2SH, UK; Equilibrium Products Ltd, Unit 2, Acorn Farm Business Centre, Leighton Buzzard, Beds, LU7 0LB, UK; Le Mieux, Horse Health Wessex Ltd, Greenwood, Woodington Rd, Romsey, Hants, SO51 6DQ, UK; Wonder Wish Pet.

TESTING RIG

A frame was constructed of welded box steel sections (Figure 1). The overall dimensions of the frame were 60cm x 60cm x 210cm (width x depth x height). The upright and base sections were

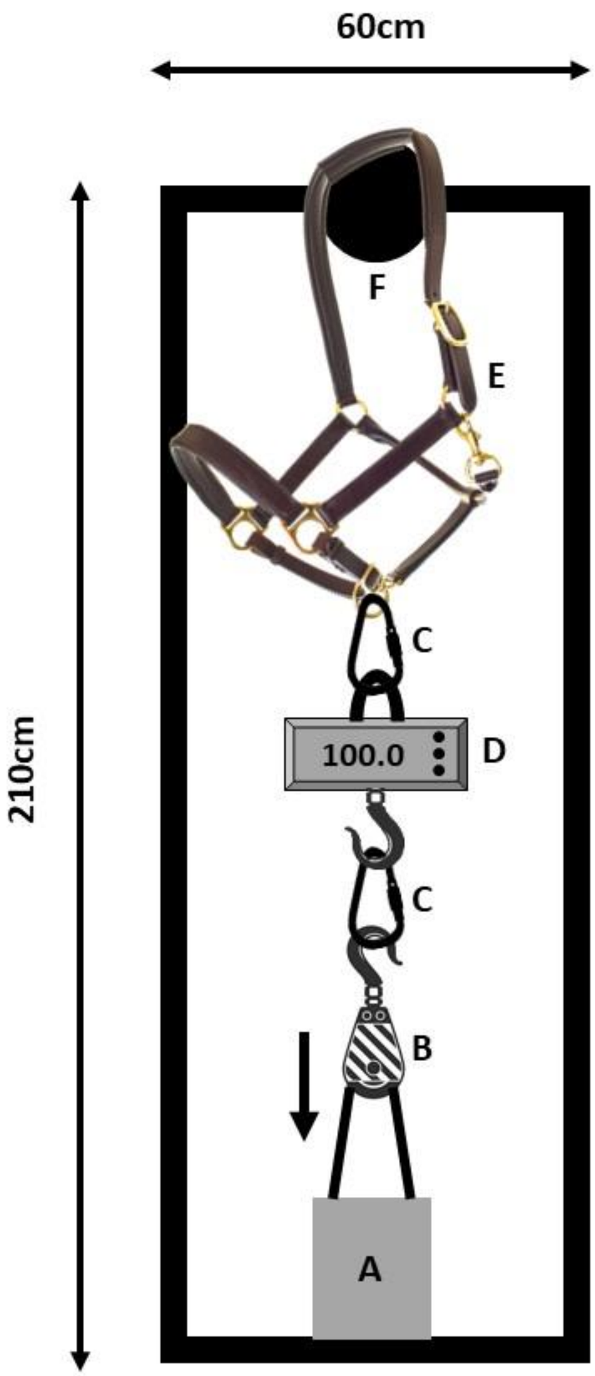

Figure 1. Testing setup. A = winch; B = pulley; C = carabiner; D = crane scale; E = headcollar/product under test; F = 15cm x 3mm steel tube.

constructed from 50mm x 50mm x 3mm steel box lengths. The top section was constructed from 90mm x 5omm x 3mm sections. A section of 50mm x 5mm x 3mm steel was fixed across the base and a 150mm diameter round steel tube (3mm thick), to approximate the width of a horse's poll, was fixed parallel to this across the top. This allowed medium sized headcollars to hang 'naturally' such that the poll ends were in line with the cheek pieces. Two sides of the frame had 3mm polycarbonate sheets attached with bolts to the frame to protect the operator from projectiles due to headcollar failure under load. An electric hoist with a maximum rating of 1000kg when used in double cable mode and a nominal output of 1600W was attached to the bottom box section (240VEHA1000, Warrior Winches, Wigan, WN6 0XQ, UK). The winch hook was attached to the bottom of a battery-operated crane scale with a maximum rating of 1000kg (Model OCS-S1, Huanyu Group Zhejiang High Tech Co. Ltd, Wenzhou Bridge Industrial Zone, Zhejiang, China) by a 14cm x 1.2cm diameter galvanised steel carabiner hook rated at 510kg (WK WLL DIN 5299 510kg J28, Kleinsorge, 57439 Attendorn, Germany). The headpiece of the headcollar to be tested was passed over the top of the 15cm steel tube. The top of the crane scale was connected to the ring of the headcollar (where a lead rope would normally be attached) by a second steel carabiner clip. Elastic bungee ropes with a rating of 40kg (Master Lock Bungi Cords, Master Lock Europe SAS, A92 400 Courbevoie, France) were used to stabilise the crane scale so that on failure of a headcollar the crane scale would not be damaged. For testing the safety devices or baler twine that would not fit over the steel tube, identical carabiner hooks were used to connect both the crane scale and overhead steel tube.

TESTING PROTOCOL

The test articles were attached to the top round steel tube and the top of the crane scale using a steel carabiner hook. The scale was then zeroed. For headcollars with size adjustment, these were set to the mid-range of adjustment or the smaller size in the case of an even number of holes (e.g. if there were 4 holes, then the 2nd from the top was used). If keepers were present (usually a rubber or leather loop to hold excess ends of headpieces in place where the headcollar is adjustable) these were always used. Force was applied in pulses by briefly activating the winch using the remote-control unit. After each application of force, the scale was allowed to stabilise (1-2s) and the reading in kg noted. The process was repeated until the product being tested either failed or opened in the case of safety products. The process was repeated 6 times for each product. For non-safety headcollars a new product was used each time. The safety devices, all of which were designed to be used repeatedly, were examined visually by eye and under a magnifier and if undamaged, testing was repeated on the same unit.

STATISTICS

Crane scale readings in kg were converted to Newtons by multiplying by the force of gravity i.e. 9.807 m.s^{2}. The existence of overall differences in opening or failure point (force) between products was evaluated with a one-way ANOVA followed by Tukeys HSD test to determine which means were significantly different (Real Statistics Release 7.5.2 with Microsoft Excel 2019 MSO 64-Bit). Separate tests were run for the headcollars and the safety products/devices. Coefficient of variation (%CV) was calculated as SD/mean x 100. Data are presented as mean±SD and significance was set at $P<0.05$.

RESULTS

An example of the 1st and 6th forcepulse curves obtained for one of the safety headcollars tested is shown in Figure 2. The mean opening force for the standard and safety headcollars are shown in Figure 3. The mean opening force ranged from 357N for the Hy Fieldsafe headcollar to 5798N for the Hy Soft Webbing Headcollar. Safety headcollars opened at the lower end of the force range whilst the standard headcollars were at the higher breaking range. The mean opening force for the two commercial non-headcollar safety devices and the three strengths of baler twine are shown in Figure 4. The mean opening force ranged from 354N for fine baler twine to 1348N for heavy duty baler twine. The consistency of the different headcollars and safety devices is indicated by the coefficient of variation for the 6 tests, which are shown in Table 2. Two of the webbing headcollars, which had a coefficient of variation equal to or less than 5%, also had the 1st and 4th highest for mean opening force. The most variable items tested were fine baler twine (CV 34%) and the Bungee Breakaway Trailer Tie (CV 38%), both of which would be perceived as safety devices.

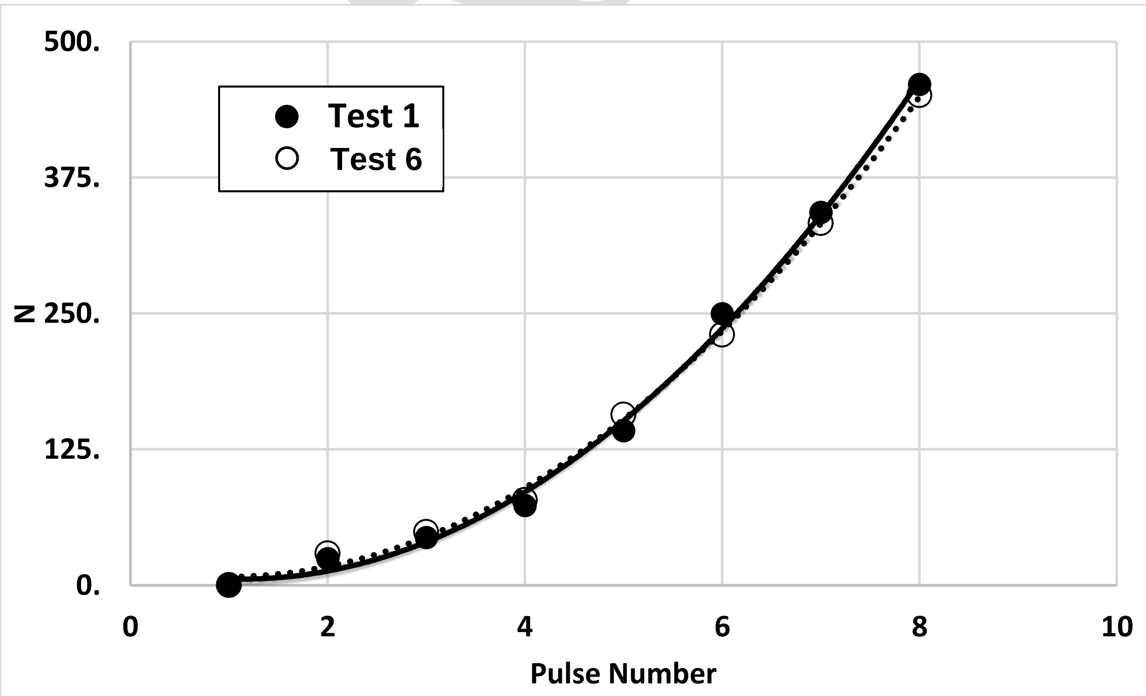

Figure 2. First and sixth tests on an Equilibrium Stellar Headcollar with the popper in position A (top position and keeper in place). The solid line and dotted lines represent 2° polynomial fits thorough all points for Test 1 ($y = 9.71x^2 – 21.90x +18.11$; $R^2 = 0.997$) and Test 6 ($y = 8.95x^2 - 17.53x + 16.54$; $R^2 = 0.998$), respectively

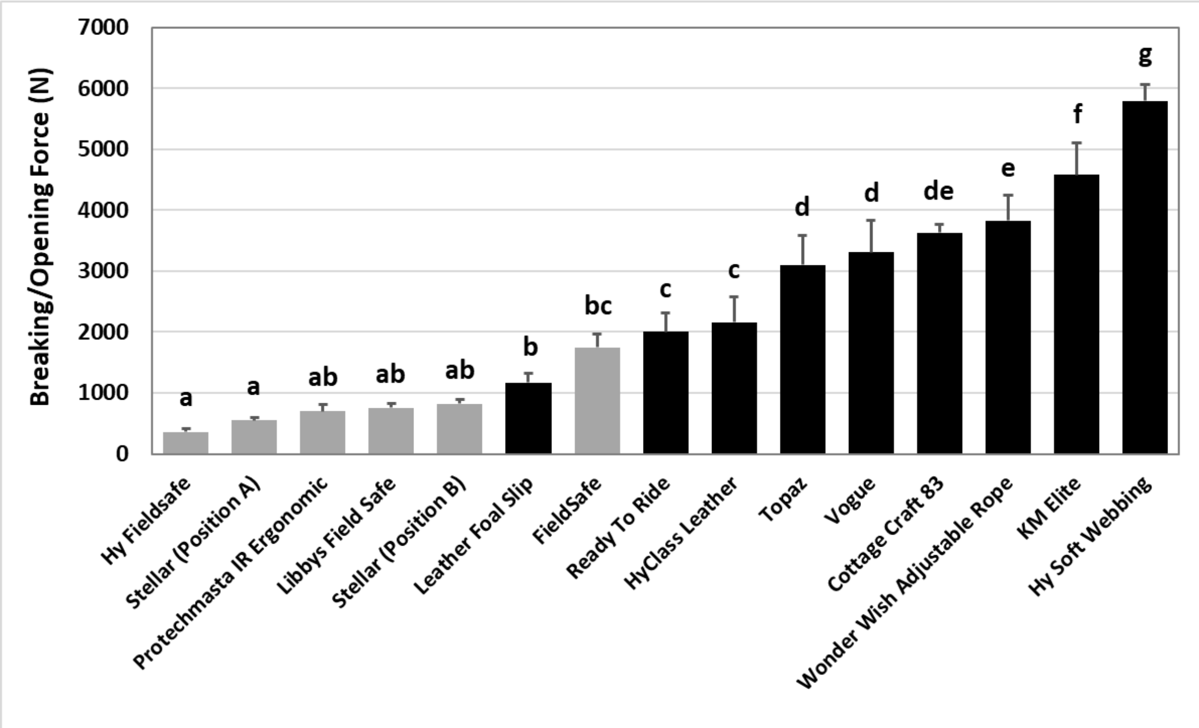

Figure 3. Opening or breaking force (N) for standard headcollars (black bars) and headcollars marketed as 'safety' headcollars (grey bars). Data are presented as mean±SD (n=6). ANOVA $P<0.0001$. Columns with different letters differ by at least $P<0.05$ (Tukeys HSD).

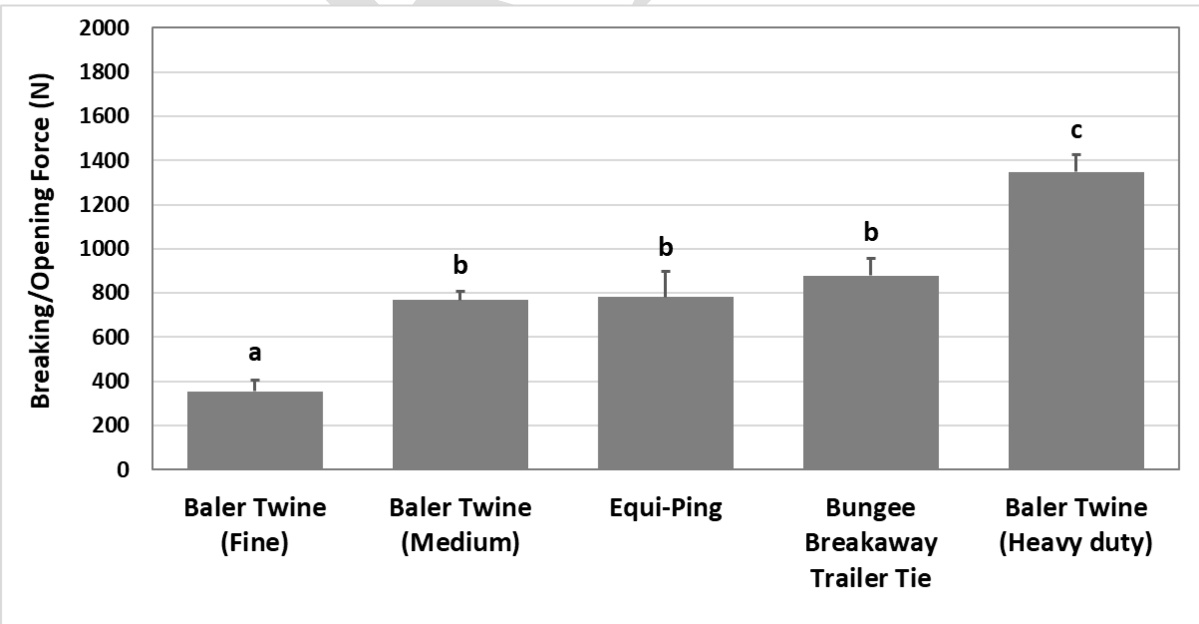

Figure 4. Opening or breaking force (N) for fine, medium and heavy grade baler twine and two commercially available safety devices. Data are presented as mean±SD (n=6). ANOVA = P<0.0001. Columns with different letters differ by at least P<0.05 (Tukeys HSD).

Table 2. Percentage coefficient of variation, minimum and maximum opening force and range in force (max – min) from series of 6 tests for each product.

Product	%CV	Minimum Opening Force (N)	Maximum Opening Force (N)	Range (N)
Cottage Craft 83	4	3481	3736	255
Hy Soft Webbing	5	5296	6031	736
Stellar (Position A)	8	510	608	98
Baler Twin (Medium)	9	667	863	196
Stellar (Position B)	9	736	937	201
Libbys Field Safe	10	657	848	191
Wonder Wish Adjustable Rope	11	3334	4413	1079
KM Elite	12	3825	5100	1275
FieldSafe	12	1373	2010	637
Leather Foal Slip	13	961	1383	422
Hy Fieldsafe	14	304	441	137
Ready To Ride	16	1667	2285	618
Vogue	16	2795	4021	1226
Topaz	16	2462	3678	1216
Protechmasta IR Ergonomic	16	525	834	309
HyClass Leather	19	1863	2452	588
Baler Twine (Heavy duty)	23	1059	1912	853
Equi-Ping	24	574	1108	534
Baler Twine (Fine)	34	181	500	319
Bungee Breakaway Trailer Tie	38	432	1295	863

All of the commercial safety devices tested were designed to be reset after opening and used again. This included FieldSafe, Hy Fieldsafe, Libbys Field Safe, Protechmasta Infrared Ergonomic, Stellar (Position A), Stellar (Position B), Equi-Ping and Bungee Breakaway Trailer Tie. There was no significant difference in mean opening force across all devices between the 1^{st} (854±530N), 2^{nd} (854±425N), 3^{rd} (775±319N), 4^{th} (778±463N), 5^{th} (805±439N) and 6^{th} tests (873±430N)(ANOVA F =0.075; P=1.0).

DISCUSSION

Limitations of the present study: the headcollars and safety devices were only tested by pulling in one plane, equivalent to a pull at 180° to the horse’s poll. However, when horses are tied-up and pull backwards this would most likely represent the direction of force application. The safety headcollars tested were also all designed to open when force was applied in this direction. However, baler twine loops, the Equi-Ping and Bungee Breakaway Trailer Tie would all be able to release in response to loading at different angles to the attachment between the device and headcollar. The method of testing applied small pulsatile loads to the headcollars and devices tested. The opening or breaking force may be different for continuous incremental application of force or rapid application of force, as in a drop test, compared with the pulsed application used. Finally, some devices tested produced high coefficients of variation. As other devices produced low coefficients of variation and as all devices were tested in the same way, it would be reasonable to conclude that the variability was in the device/equipment tested as opposed to the test procedure.

One of the remarkable features of these results is the range of breaking/opening forces of the devices and headcollars tested from as low as ~350 up to close to 6000N. A force of 6000N equates to a load of 611kg. Thus, a 500kg horse could potentially be suspended by a headcollar of this strength, provided the lead rope was of a similar strength. Using the same testing setup as reported here, we have measured lead rope failure in five difference commercial products of between 1470 and 4700N. Similarly, there is likely to be an increased risk of injury to the handler if they become entwined in a headcollar/lead rope, when a horse pulls back and exerts a high force if the breaking force is high. Experimental fracture loads in the human forearm are reported to be between 707 – 5821 N, averaging 3180 N [5,6] suggesting the breaking forces reported here could be extremely dangerous and contribute to significant damage to human soft tissue and bone as a result of the headcollar and/or safety device not breaking. Therefore, it could be recommended that headcollars with high opening/breaking forces are not left on unsupervised horses e.g. at pasture, when travelling, or when tied-up. Such headcollars may also present a risk of injury to handlers. In addition, it could also be recommended that such headcollars, if used to restrain horses, are not used without a secondary safety device of some kind. There may however be circumstances in which a headcollar with a very high breaking force would be preferable, for example if leading horses in potentially dangerous environments, such as along roads or when loading/unloading at ports and airports.

Anecdotally, there is a widespread perception that leather headcollars are 'safer' than synthetic, nylon or webbing headcollars as they would break at a lower force. For the two models of standard (non-safety) leather headcollars tested, these indeed both broke at lower forces than the majority of webbing headcollars tested. This observation is also consistent with the fact that leather headcollars were reported to have a lower injury rate compared with synthetic or webbing headcollars (Marlin, Williams & Pickles, In Press).

Headcollar-related injuries could be expected to fall into several categories, including pressure-induced lesions of superficial anatomical structures, traumatic injuries to deeper structures, injuries to the neck distal to the attachment of the headcollar and other injuries potentially as a result of horses falling. The true incidence of such injuries is unknown as they are rarely reported and are often suspected rather than observed. Force-related tissue damage can occur over prominent bony areas with little overlying tissue; as such the head is vulnerable. If normal capillary pressure is exceeded, surrounding and underlying tissues become anoxic. If this pressure is sustained for a critical duration, cell death occurs resulting in tissue necrosis. The most common cause of pressure-related headcollar injury is probably paresis of the buccal branch of the facial nerve which can occur under general anaesthesia if the headcollar cheek piece of the dependent side is not sufficiently padded. The facial nerve is particularly at-risk during surgeries involving the head or eye, when surgical manipulations may subject the head to extra weight or pressure [7]. Facial nerve paralysis in a horse has also been reported following 'rope recovery' from general anaesthesia which suggests the rope recovery system (i.e. headcollar with attached rope) may have resulted in an increased pressure on the head [8].

When force is focussed on a known area we discuss the implications for tissue damage in terms of pressure per unit area i.e. Pressure (Pa) = Force (N) / Area (m^2). Tissue damage as a result of pressure is due to a combination of the absolute pressure and the duration of application of the pressure. In people, pressure ulcers (sores) are typically the result of damage caused to the skin and underlying tissue by long-term contact due to pressure, shear, friction and moisture. Depending on the orientation of the patient, mean surface pressure on different parts of the body in human subjects ranged from 0 to 24kPa [9]. Using canine models, the threshold for pressures leading to pressure ulcers has been proposed to be only 4.3kPa [10,11]. However more recent studies have suggested thresholds of around 9kPa [12] or even 32kPa [13,14]. But these are forces which lead to ulcers over prolonged periods of time and it is unlikely that a horse would have high pressure applied by the headpiece of a headcollar for more than a matter of minutes. In horses, Nykios et al. [15] proposed pressure thresholds of 11kPa for mean pressure and 31kPa for peak pressure for pain or tissue damage on the horses back under the saddle area. In a preliminary study of the pressure on the poll under a synthetic headcollar headpiece in a horse being led at walk and trot, peak pressures of 50kPa at walk and 60kPa at trot were recorded (Godoy & Marlin, unpublished observations). For a headpiece of 3cm width and assuming half of the circumference was in contact with the 15cm diameter steel tube (2 x Pi x r / 2 = 23.6cm), the area of contact would be 23.6cm x 3cm, = 70.8cm^2. At a force of 2000N (the lowest breaking force of a conventional headcollar, this would represent an average pressure of 28.2 N/cm^2 x 10 = 282kPa. For the highest breaking force this would represent an average pressure of 818 kPa.

Conclusion

The force at which safety headcollars and safety devices opened and conventional headcollars failed showed a considerable range and some products or devices showed a high variation in test to test. However, all safety devices and ‘baler twines’ opened at a lower mean forces than all headcollars failed, with the exception of the foal slip tested. . These findings are generally consistent with a recent survey of horse owners (Marlin, Williams & Pickles, In Press) concerning headcollar use and headcollar related incidents and injuries. At present there do not appear to be any industry standards for headcollar or headcollar safety device standards and it is proposed that manufacturers, welfare bodies and equestrian stakeholders give this issue serious consideration as a priority..

<u>Conflict of Interest Statement</u>

This study was commissioned and funded by Equilibrium Products Ltd. Equilibrium Products Ltd specified, purchased and supplied the products/materials to be tested with the exception of the baler twine (Agritel Packaging Supplies Ltd). The testing rig and testing protocol was built and designed by one of the authors (DM). Equilibrium Products Ltd were shown a final copy of the manuscript but had no involvement in the analysis, writing or presentation of results or in the final conclusions presented.

<u>Acknowledgments</u>

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