Kinematic analysis of the influence of three different guide dog harnesses on the movement of the spine

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Pressure distribution under three different types of harnesses used for guide dogs

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ABSTRACT

The aim of this study was to evaluate the pressure distribution under three different types of harnesses used for guide dogs (designated H1, H2 and H3). The dogs ($n = 8$) led a trainer through a course including a range of exercises (straight line, curve left, curve right, upstairs and downstairs). All dogs were clinically sound and showed no sign of lameness. The pressures beneath the harnesses were determined by sensor strips and related to the gait. In all harnesses, the highest pressures were found in the right sternal region (H1 2.02 ± 0.6 N/cm^2; H2 1.76 ± 0.4 N/cm^2; H3 1.14 ± 0.5 N/cm^2). In all other regions, the pressures were in the range of 0–1.32 N/cm^2. The right and left sternal regions were almost constantly loaded. Contrary to previous assumptions, the back regions had minimal loading. This investigation demonstrated that there were significant differences among the harnesses.

Introduction

Guide dogs are highly specialised working dogs that increase safety and quality of life for blind people (Calabró-Folchert, 1999). Communication between the guide dog and the blind person is facilitated by a harness with a handle through which the blind person has to interpret the movement of the guide dog. Depending on the length of the handle, which is fixed to the harness, varying forces are applied to the dog. As a result of these forces, the harnesses exert pressure on the trunks of the guide dogs. Where animals are used for work, animal welfare is an issue. Harnesses are used in sled dogs, but their mechanical effects on the dogs have not been investigated.

Saddle and tack are well studied in horses (Kotschwar et al., 2010; von Peinen et al., 2010; Belock et al., 2012; van Beek et al., 2012) and therefore can be used as a model for other species. Clayton et al. (2011) showed that a force of up to 30 N is exerted via side reins to the horse's bridle. Preuschoft et al. (1999) found forces of 50–80 N in dressage horses. The mass of the head–neck segment in horses is comparable to the body mass of large dogs. Since horses are walked on the bit, there should be continuous tension on the rein, which exerts pressure on the bit (Fédération Equestre Internationale, 2009). This is similar to the handle (fixed on the harness) of guide dogs. The blind person should always keep a certain tension to be able to continuously communicate with the dog. Since guide dogs usually walk on the left side of the person to be guided, an asymmetric tension force is expected, which acts on the dog's trunk. It is assumed that this force will change during daily exercises (e.g. walking straight, indicating obstacles or barriers, dodging these obstacles or barriers, indicating the first and the last steps of stairs, and climbing stairs).

Coppinger et al. (1998) found that assistant dogs were able to pull a wheelchair when exerting a force of 29.3 N. Pulling forces acting on sled dogs are 5.6–26.7 N. Taking into account that the daily working period of a guide dog is several hours, it is necessary to identify this load and to establish whether it is harmful to the dogs. Knowledge of the forces acting across the harness to the dog during the daily interaction of humans and dogs will help development of better harnesses and preventive physiotherapeutic exercises (Coppinger et al., 1998).

The information gained will also help extend the working lives of the dogs. Maintaining the health of these animals for as long as possible is of importance, not only because of the high costs (the training of a good guide dog amounts to approximately €25,000[1]) but also because of the close relationship to its owner. Therefore, reducing the load the harness exerts on the dogs by as much as possible is potentially important (Coppinger et al., 1998).

To the authors' knowledge there have been no studies of pressure values under the harnesses of guide dogs. This raises the question as to whether the currently used harnesses and handles affect the performance and health of guide dogs because of the varying

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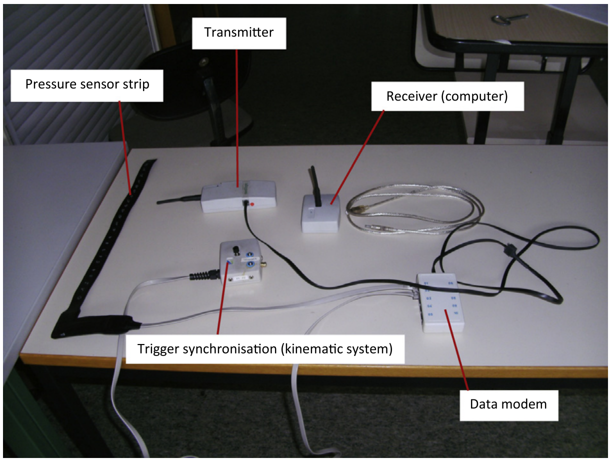

Fig. 1. Pressure measurement system consisting of the sensor strips, the data modem, transmitter, trigger for synchronisation with the kinematic system and the receiver connected to the computer.

pressures they exert. The first aim of this study was to record force and pressure between the harness and trunk, in order to determine the magnitude of these variables. The second aim of this study was to determine whether there are differences between three different harnesses and whether different exercises affect measured force and pressure.

Materials and methods

This project was approved by the Institutional Ethics Committee of the University of Veterinary Medicine Vienna (approval number 14/06/97/2006; date of approval 3 July 2006).

Dogs

The measurements were carried out using eight guide dogs, which were led by the same trainer through a course designed to simulate the activities undertaken during the normal daily working life of a guide dog. All dogs were clinically sound and showed no signs of lameness.

Harnesses

All harnesses were made of leather (Fig. 1). In the first harness, the mobility of the frame was restricted by loops. The second harness used was padded in the area covering the spine. The third harness used had a rigid connection with the frame.

Equipment and measurement procedures

The pressure exerted from the harness to the dog was determined by sensor strips ($n = 23$; T&T Medilogic Medizintechnik; sample rate 60 Hz; 0.1–4 N/cm^2, length of the sensor strips 40 cm; sensor size 2 cm $\times$ 1.5 cm) attached to the harnesses (Fig. 2). The pressure sensors were placed under the harnesses. Each harness consisted of a chest and a trunk strap. Within each strap, certain regions were distinguished ('chest strap front left and right', 'chest strap shoulder left and right', 'trunk strap back left and right', 'trunk strap chest left and right' and 'trunk strap sternum left and right'; Fig. 2). Sensor strips and harnesses were individually adapted to each guide dog to achieve continuous coverage of the harness. The area on the left received the same number of sensors as the symmetrical area on the right. The overlap of the sensors at the connection of chest strap and trunk strap was excluded from analysis. Each trunk strap on the left and right sternum was covered with five sensors. The sensors were numbered for easy identification (Fig. 3).

Kinematic system

The time course of the pressure was cut into motion cycles via a marker on the left forelimb of the guide dog using a kinematic measurement system (Motion Analysis Corporation; sample rate 120 Hz). A reflecting marker (1 cm in diameter) was placed on the distal aspect of the fifth metacarpal bone of the left fore limb. The system was calibrated with a calibration frame of known dimensions for each session. Data were analysed using motion analysis software. Prior to the data acquisition, the dogs were given time to become accustomed to the experimental environment.

Measurements

To minimise the influence of different dog handlers, all dogs used in this study were led by the same person. The harnesses and the exercises were chosen randomly. The dogs passed the course five times under all testing conditions for each of the three harnesses, resulting in at least five motion cycles for each exercise. Each dog had to walk each course including the following exercises: straight line, curve left, curve right, upstairs, and downstairs. Straight line was chosen as the reference exercise. A minimum of five motion cycles were analysed.

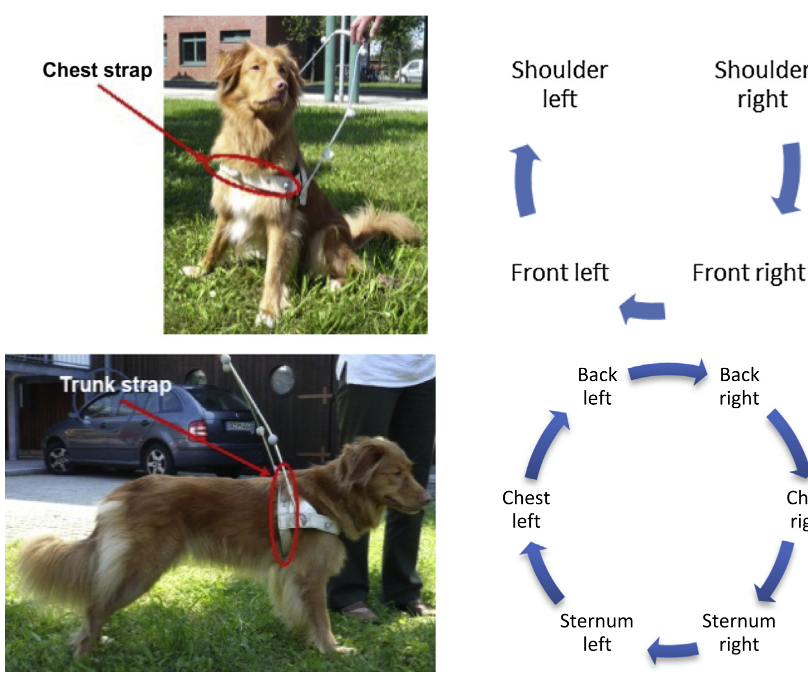

Fig. 2. Regions of the harness: the regions of each of the chest and trunk straps were split in the following manner: 'chest strap front left and right', 'chest strap shoulder left and right', 'trunk strap back left and right', 'trunk strap chest left and right' and 'trunk strap sternum left and right'.

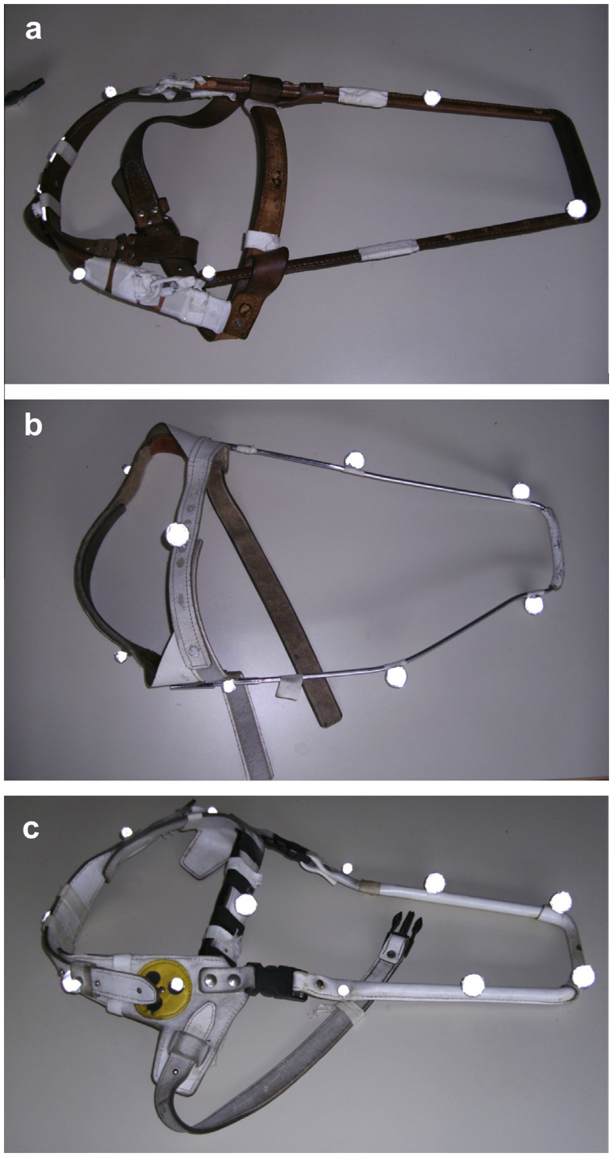

Fig. 3. Harnesses used: (a) Harness 1 (H1). (b) Harness 2 (H2). (c) Harness 3 (H3).

Signal processing

With the help of the kinematic data of the reference extremity, the synchronous force and pressure data were cut into motion cycles. The maximum pressure (N/cm^2) of each motion cycle was determined and the mean ± standard deviation (SD) for each dog, each harness, each exercise and each region were calculated. A crossover design where all dogs underwent all exercises and conditions was used, and therefore the independent variables were the harnesses and the exercises. All harnesses and exercises were compared to each other. The data were tested for normal distribution with the Kolmogorov Smirnov test. To show differences, a generalised linear model (analysis of variance) for repeated measurements was used.

Results

All data were normally distributed. In all harnesses, the highest forces and pressures were found on 'sternum right'. In the reference exercise, the largest force and pressure values measured at 'sternum right' (force 30.3 ± 9.2 N; pressure 2.02 ± 0.6 N/cm^2) were recorded for the first harness, H1). The forces and pressures were smaller for harnesses H2 and H3 (Tables 2 and 3; Figs. 4 and 5). In all other regions, the forces and pressures were smaller (Table 1; Figs. 4 and 5). It is noteworthy that the regions 'sternum right' and 'sternum left' were almost constantly loaded. The different harnesses had a significant influence on the force and the pressure values, whereas the influence of the exercises was not significant (Tables 2 and 3).

Discussion

This study investigated the load exerted from three different types of harness to 10 different regions on the canine trunk. The highest loads were measured on the trunk straps in the region sternum right (underneath). Contrary to previous assumptions, the back regions were not heavily loaded, probably due to the lifting of the handle. This load was also nearly constant at the same level throughout all exercises, but differed between the harnesses (Tables 1 and 2). This may result from the trainer (blind person) walking on the right side of the dog and trying to keep a constant tension on the harness via the handle. This force vector points from the region 'trunk strap sternum right' up to the left side of the guide dog (into the direction of the trainer's arm). This effect is comparable to that seen in the reins of horses ridden on the bit (Preuschoft et al., 1999; Clayton et al., 2011). In horses, the measured loads (30 N) were similar (Clayton et al., 2011). Preuschoft et al. (1999) found considerably higher forces of 50–80 N in the reins.

We can conclude that a minimum force of about 30 N is necessary for dog handlers (riders) to stay in contact with the animals. The head–neck segment of a horse has a mass of 50 kg (Buchner et al., 1997). Only large dogs have such a comparable mass. The dogs in our study had a mean mass of 30.4 ± 3.3 kg. This is only 60% of the mass of the head–neck segment in horses. Therefore, the load exerted on the trunk of guide dogs was higher in relation to their body mass than horses.

The maximum force found in our study was surprisingly high (30.3 N) compared to dogs pulling a wheelchair (29.3 N) or sledge (26.7 N) (Coppinger et al., 1998).

Anatomical studies will be necessary to show if those asymmetrical forces (torques) will have an effect on the musculoskeletal systems similar to the effects of asymmetric muscles.

von Peinen et al. (2010) reported that the maximal pressure under the saddle differed in horses with clinical signs of an ill-fitting saddle in all gaits (walk, trot and canter) compared to a sound control group. In walk, horses with dry spots under the saddle showed a maximum pressure of 30.6 kPa (3.06 N/cm^2), horses with acute

Table 1
Specifications of guide dogs used in this experiment.

Dog	Age (years)	Sex	Breed	Shoulder height (cm)	Chest measurement (cm)	Body mass (kg)
1	5	FN	German shepherd	63	80	32
2	1.7	MN	Golden retriever	67	77	33
3	2	FN	Labrador retriever	56	73	26
4	0.8	F	Flat coated retriever cross	69	80	31
5	3	MN	Labrador retriever	63	88	36
6	7	FN	Labrador retriever cross	60	75	28
7	2.5	FN	Labrador retriever	58	72	27
8	2	FN	Labrador retriever	57	72	30

F, female intact; MN, male neutered; FN, female neutered.

Table 2
Comparison of different exercises and harnesses (mean maximum values ± standard deviation of the right sternal region).

Exercise	Straight	Left curve	Right curve	Stairs up	Stairs down
H1					
Force (N)	30.3 ± 9.2	28.8 ± 9.0	27.6 ± 7.5	28.4 ± 6.5	27.3 ± 7.4
Pressure (N/cm^2)	2.02 ± 0.61	1.92 ± 0.60	1.84 ± 0.50	1.89 ± 0.43	1.82 ± 0.49
H2					
Force (N)	27.4 ± 5.0	26.2 ± 3.1	26.9 ± 3.2	26.0 ± 4.1	25.6 ± 4.5
Pressure (N/cm^2)	1.83 ± 0.33	1.74 ± 0.21	1.80 ± 0.21	1.73 ± 0.27	1.70 ± 0.30
H3					
Force (N)	17.1 ± 7.3	16.6 ± 7.5	16.9 ± 6.9	17.9 ± 7.2	20.3 ± 6.8
Pressure (N/cm^2)	1.14 ± 0.49	1.11 ± 0.50	1.13 ± 0.46	1.19 ± 0.48	1.35 ± 0.45

H1, harness 1; H2, harness 2; H3, harness 3.
Significant differences: See Table 3.

Table 3
Significant differences of the maximum pressure values between the different harnesses in the sternal region.

	Straight maximum pressure	Left curve maximum pressure	Right curve maximum pressure	Stairs up maximum pressure	Stairs down maximum pressure occurrence
H1	H3 < H1 $P = 0.013$	H3 < H1 $P = 0.016$	H3 < H1 $P = 0.035$	H3 < H1 $P = 0.026$	
H2	H3 < H2 $P = 0.028$		H3 < H2 $P = 0.013$		H1 earlier than H2 $P = 0.020$
H3					H1 earlier than H3 $P = 0.042$

H1, harness 1; H2, harness 2; H3, harness 3.
Statistically significant if $P < 0.05$.

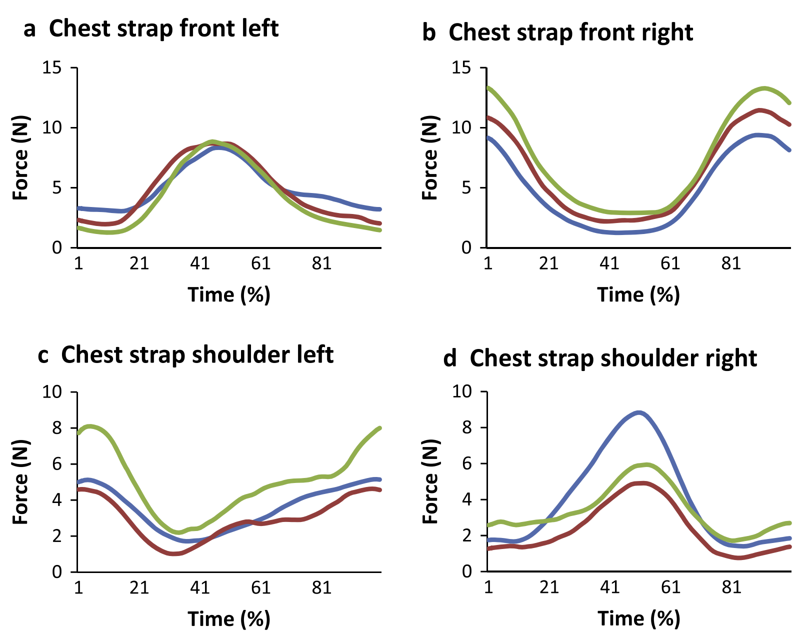

Fig. 4. Force curves of all regions of the chest strap during the straight walk exercise. (a) Chest strap left. (b) Chest strap right. (c) Chest strap shoulder left. (d) Chest strap shoulder right. Blue, harness 1; red, harness 2; green, harness 3.

clinical signs of ill-fitting saddles 38.9 kPa (3.89 N/cm^2) and a sound control group 13.4 kPa (1.34 N/cm^2). These values are comparable to those measured under the harnesses of the guide dogs. The coat (hair) of the saddle region in horses is always kept very short. The dogs used in our investigation (retriever, German shepherd) had considerably longer hair than horses have in the saddle region. The longer hair of the fur may increase the sliding effect of the harness and thus may reduce occurrence and/or number of high pressure points. Only the vertical components of the force to the sensors could be measured; therefore, we cannot make any conclusion in respect to the shear forces (Clayton et al., 2013).

This study showed that the maximum pressure (force) under H2 and H3 at sternum right is lower than that in horses with dry spots under the saddle and in horses with acute clinical signs, but higher than that in the healthy control group of horses (von Peinen et al., 2010). Only the maximum pressure values of H3

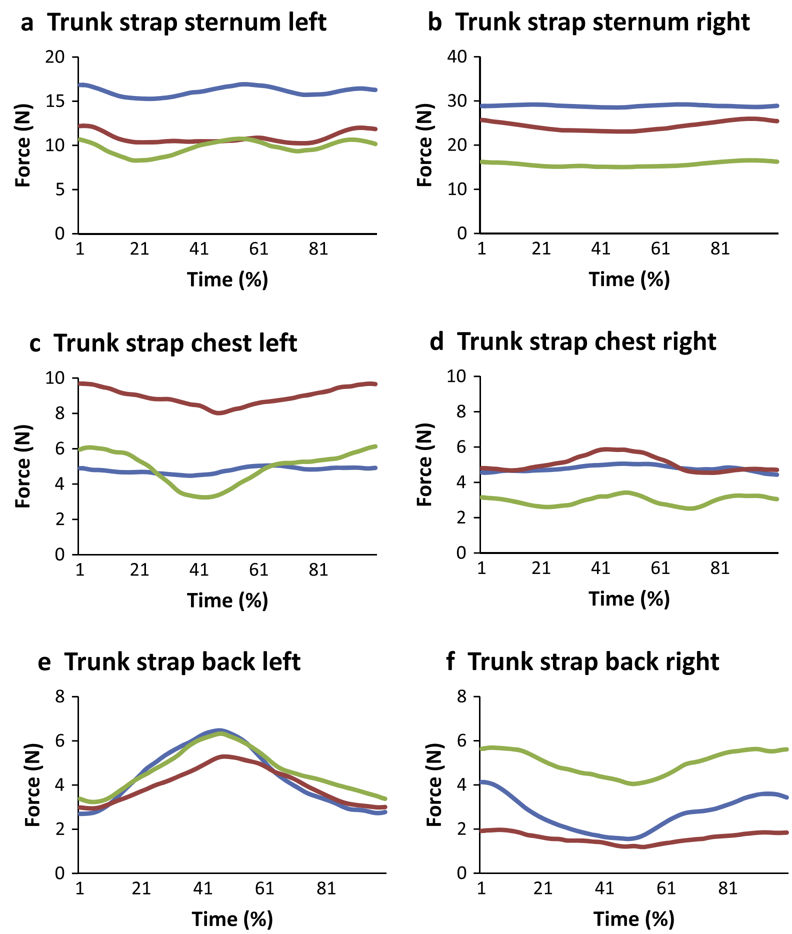

Fig. 5. Force curves of all regions of the trunk strap during the exercise straight walk. (a) Trunk strap sternum left. (b) Trunk strap sternum right. (c) Trunk strap chest left. (d) Trunk strap chest right. (e) Trunk strap back left. (f) Trunk strap back right. Blue, harness 1; red, harness 2; green, harness 3.

are below the control group, and the 'stairs down' reading is slightly higher. As far as we know, no studies are available investigating the influence of pressure to the skin of dogs. However, rats developed skin ulcers over bony prominences at a pressure of 100 mmHg (1.33 N/cm^2) (Nola and Vistnes, 1980).

Nevertheless, more studies including a greater number of dogs are necessary to determine the clinical significance of our findings. Furthermore, future studies should clarify whether orthopaedic disorders, such as muscle spasms and diseases of the spine, are related to the choice of harness.

Since coordination of movement between guide dogs and blind people will vary according to individual differences in both handler and dog, it will also be of great importance to investigate the individual interactions of different teams. As far as we know from equestrian sports, both partners influence the resulting pressure distribution and their dynamic coordination plays a particularly important role (Peham et al., 2001; Lagarde et al., 2005). Another aspect worth focussing on is the effect guiding a dog has on the body posture of the blind person.

Conclusions

The forces measured under harnesses in guide dogs were greatest under the trunk strap at 'sternum right' and 'sternum left'. There was a measurable difference between the pressures exerted by three different types of harness. The maximum forces and pressures imposed by the different exercises were not significantly different from those measured when walking in a straight line. This work highlights the importance of the correct selection and adaptation of the harness to the dog and to the blind handler. There are differences among harnesses which are likely to affect the interaction between dog and its handler. A suitable harness will reduce load on the guide dogs.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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