Canine collars: an investigation of collar type and the forces applied to a simulated neck model

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ABSTRACT

Background
Dog collars have the potential to cause harm when the dog pulls on the lead. This study aimed to determine the effects of collar type and force applied using the lead, on the pressure on a simulated neck model.
Methods
Seven collars and a slip lead were tested on a canine neck model. This consisted of a plastic cylinder ‘neck’, with a pressure sensor beneath the collar. A range of forces were applied to the lead representing different interactions: firm pull (40N), strong pull (70N), and jerk (mean force 141N). Contact area of the collar and pressure on the neck were recorded.
Results
Collars exerted a pressure of between 83kPa and 832kPa on the model neck. There was a significant effect of collar type ($F(7)=25.69$, $p<0.001$) and force applied ($F(2)=42.60$, $p<0.001$) on the pressure exerted on the neck. Collar type ($\chi(7)=64.94$, $p<0.001$), but not force applied ($\chi(2)=3.20$, $p=0.202$), affected the contact area that the pressure was exerted over.
Conclusion
Variation in the pressures exerted on the neck may have implications on comfort and the potential to cause injury. No single collar tested provided a pressure considered low enough to mitigate the risk of injury when pulling on the lead.

INTRODUCTION

The collar provides a means to identify a dog or demonstrate ownership. It is also frequently used to provide a connection between handler and dog as an aid to influence the animal’s behaviour in some way. To facilitate control, enable restraint, or to elicit a desired movement [1,2]. In the United Kingdom, legislation outlines the obligations of dog owners’ responsibilities pertaining to identification and control, and the use of a collar and lead are imbedded within this legislation [3].

A variety of collars are commercially available, made with different materials and offering an array of styles to dog owners. Human technical apparel and sportswear are frequently supported by research and development with the aim to optimise performance and comfort [4]. The processes behind dog collar design is less clear. Where collars have been created with function in mind, these have been designed (and marketed) with the intention to aid handling and assist training and restraint; whilst sports collars, alongside other active dog equipment, are constructed of sports materials (e.g. neoprene lining and breathable fabric). These differences in material have been shown to have an impact on the pressure felt on the dog’s neck, even at low forces [5].

Concern has been raised regarding the use of collars as a restraint and control device. Studies have highlighted the negative aspects of collars which include incidence of acute musculoskeletal injuries [6] and increased intraocular pressure [7]. However, they did not monitor specific pressure on the neck itself. Collar use on neck pressure has been studied with a relatively low force (2-4N) applied to the lead, akin to a looser contact between dog and handler via the lead [5]. Even at low forces, the pressure on the neck had the potential to cause damage if applied consistently over time. In humans, tourniquets used to actively restrict or stop arterial bleeds are used at a pressure of 250mmHg on the arm and 300mmHg on the thigh (33.3 and 40.0kPa respectively), with higher pressures associated with higher probability of further injury [8,9]. In humans, a tight necktie has been found to cause transient increases in intraocular pressure [10], and this was also found in dogs on a lead but not a harness [7], where data suggests that there is a detrimental effect on cerebral vasculature, possibly through constriction of the jugular vein. Collar pressure was also higher than those observed in equine nosebands which ranged from 200 to 400mmHg (27 to 53kPa) [11]. It has been suggested that peak saddle pressures of >4.67kPa cause damage through lack of tissue perfusion and pressures >30kPa under a saddle are associated with back pain [12]. Equine research found inappropriate equipment impacted directly upon horse welfare, compromising movement, exerting excessive and inappropriate pressure, and compromising musculoskeletal health [13,14]. As a result, studies have investigated optimising the fit of saddles, girths, bridles, nosebands, and bits by evaluating the impact of design on pressure points [15,16]. Guide dog harnesses have been assessed using pressure sensors to determine the effect of the harness [17] and their impact on movement postulated to cause long term physical damage resulting from restricted spinal movement and pressure distribution of the harness on the back, chest and neck regions [17,18]. Recognition that an evidence-based approach is needed to assess the accoutrements used for animal husbandry has been applied to other species but is limited in dogs.

In addition to the impact of the type of collar, the interactions between a handler and dog through the lead will vary and influence how forces are transmitted. When owners were questioned about their training methods, jerking the lead was a corrective training method listed as a tactic employed by some owners [19,20]. Lead jerks may also occur when dogs on extendable leads abruptly come to a stop, or when a dog lunges on a lead. This rapid application of force is in contrast to the not unfamiliar sight of dogs pulling on the lead, which can result in coughing or choking. An indication of incidence of dogs pulling on the lead is offered by the findings in a study investigating owners' perceptions of behaviour problems, where 8 out of 17 owners identified pulling on the lead to be a problem [21]. Whilst the impact of walking on a collar has been explored in terms of neck pressure [5] the effect of higher forces consistent with pulling on the lead or a lead 'jerk' have not been explored, despite having a higher injury risk.

This study sought to explore the collar pressures dogs may be exposed to and how this varies with different constructions of collar, and the influence of the force exerted by handler. The aim was to determine the effect of collar type on the pressure exerted on a simulated neck model at different forces associated with walking and pulling on a lead. For ethical and welfare reasons associated with testing on a live animal, an inanimate model of the neck was used for testing. This enabled a range of more extreme interactions to be tested and provided a consistent surface on which the applied forces could be evaluated.

MATERIALS AND METHODS

Collar types

Seven commercially available collars, and a slip lead were selected to provide a representative sample of the range of designs and materials used for general purpose collars considered to be used for routine dog walking (Figure 1). Collars were measured according to height (width of the collar when sat against the dog's neck) (1.5-3.8cm) and thickness (when laid out on a surface, the distance from the flat surface to the top of the collar) (0.2-0.6cm), or in the case of the rolled collar and slip lead, diameter (1.0-1.1cm). Materials used were predominantly leather and nylon with variation in construction and with or without neoprene padding. Collars were all of a similar circumference to fit the 31cm tube with 2 fingers comfortably between the collar and tube (to reflect the standard collar fit on a dog), with the collar on approximately the middle hole of the collar on the middle of the sliding adjuster for non-buckled collars.

Collar Name	Image	Dimensions	Material
Padded webbing collar		Height: 3.1cm Thickness: 0.6cm	Nylon webbing with light neoprene padding Wainwrights collar https://www.petsathome.com/shop/en/pets/merch-groups/lp-wainwrights-dog-acc
Rolled collar		Diameter: 1.1cm	Nylon webbing twisted rope 3 peaks collar https://www.petsathome.com/shop/en/pets/3-peaks-dog?ddkey=https:en/pets/searchterm
Padded sports collar		Height: 3.8cm Thickness: 0.4cm	Nylon webbing with thick neoprene padding Non Stop polar collar https://www.non-stopdogwear.com/product/polar-collar/
Lurcher collar		Height: 2.8cm to 6.2cm (at widest point) Thickness: 0.4cm	Leather https://www.pampeano.co.uk/dog-accessories/collar/plain-brown-lurcher-dog-collar
Leather and thread collar		Height: 2.7cm Thickness: 0.5cm	Leather with thread overlay https://www.pampeano.co.uk/dog-accessories/collar/leather-dog-collar-navidad
Flat webbing collar		Height: 1.5cm Thickness: 0.2cm	Nylon webbing https://www.petsathome.com/shop/en/pets/dog-collars/pets-at-home-spot-dog-collar-medium-pink
Rope slip lead		Diameter: 1cm	Nylon single braided rope https://www.gundog-solutions.co.uk/product/rope-slip-lead
Check chain		Height: 0.9cm Thickness: 0.4cm	Metal https://www.thepetexpress.co.uk/dog-collars/heritage-extra-heavy-check-chain/

Figure 1: Details of the collar types tested. Collars were measured according to height (width of the collar when sat against the dog's neck) (1.5-3.8cm) and thickness (when laid out on a surface, the distance from the flat surface to the top of the collar) (0.2-0.6cm), or in the case of the rolled collar and slip lead, diameter (1.0-1.1cm).

Experimental canine neck model

A model of a canine neck was created using a length of plastic PVC piping, measuring 31cm circumference (a similar circumference to the neck of a medium/large dog) and 0.25cm thick, securely attached in a fixed position to a material test machine (Figure 2). The pipe was sufficiently robust to maintain shape and avoid deforming under the forces exerted. For consistency between tests, collars were positioned at a consistent point on the neck model. A strip pressure sensor (sensor area 203.2 mm x 76.2 mm) (Model: Tekscan 9801 Prosthetic Sensor with Tekscan EVO2 Handle. Manufacturer: Tekscan Inc., Massachusetts, USA) was calibrated using calibration dead-weight applied over a measured area. The pressure sensor was positioned to wrap around the sides and front of the neck model (Figure 2). To enable the handler to apply consistent tensile forces, a tension load cell (Model: RDPE Load Cell - RLT0050kg. Manufacturer: RDP Electronics Ltd., Wolverhampton, UK) with a 500N capacity, was attached between the lead and collar. Potential contact area was determined based on the dimensions of the individual collar. Area and pressure are standard outputs for the Tekscan sensor.

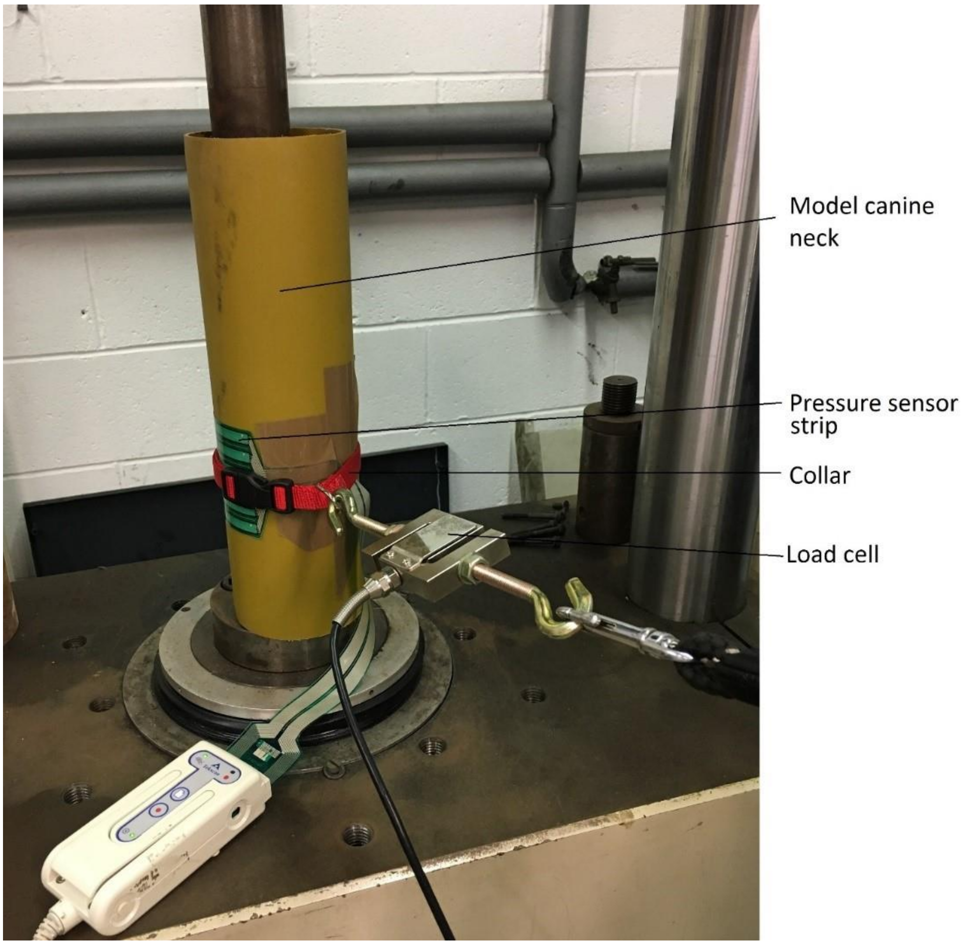

Figure 2: Experimental model of a canine neck

Simulating potential lead interactions

For each collar type, three magnitudes of force (40N, 70N and a lead jerk ~141N) were applied by the handler to simulate three possible scenarios of interaction with a medium/large dog (Table 1). The intention of these three force values was to explore a range of possible forces that may be applied to a lead by a handler. For each test, every effort was made to maintain a constant angle of applied force, perpendicular to the collar. Measurements were taken of pressure across the contact surface on the neck and contact area for each collar on the model neck, at each of the three forces. For the 40N and 70N forces, pressure sensor recordings were taken for 5s. For the lead jerk, an even 40N force was maintained, and the lead jerk (mean force 141N, range 131N-155N) applied during the 5s testing period. For consistency, the same researcher was designated the role of 'dog handler' and applied tension on the lead for all tests. Each force and collar combination was tested 3 separate times.

Table 1: Description of lead pull test scenarios

Scenario	***Description***	***Force***

A dog pulling lightly on the lead	A light consistent pull on the lead was maintained.	Tension force applied 40N
A dog pulling strongly on the lead	A strong consistent pull on the lead was maintained.	Tension force applied 70N
A sharp jerk on the lead	A quick sharp pull on the lead.	The mean tension force applied across all jerk tests was 141N (range: 131N–155N)

Zones of the collar

The length of the collar was divided into 3 equal zones for analysis (side 1, middle, side 2) (Figure 3). The 'side' of collar was determined by the collars position on the neck model and was designated as side 1 and 2, this was kept consistent throughout the study. The middle of the collar is the zone opposite where the lead was attached. The collars assessed in this study did not have a specific orientation that they must be fitted on the neck, and therefore it was not appropriate to analyse the difference between collars on a single side. This division was used to determine whether different areas of the collar were subjected to different pressures as the force applied varied.

Data analysis

Data were analysed using SPSS 23.0 (SPSS Inc., Chicago, IL). Data were tested for normality using a Shapiro–Wilk test. Pressure was found to be normally distributed and was therefore analysed using a one-way ANOVA. A Tukey post-hoc test was applied to determine differences between collar types. Area was found to not be normally distributed, data were analysed using a Kruskal-Wallis test in order to determine the effects of collar type and force applied on i) the pressure exerted on the neck, and ii) the contact area with the neck. Bonferroni corrected Dunn post-hoc tests were applied to determine differences between the collar types and force applied. Significance was set at $P < 0.05$.

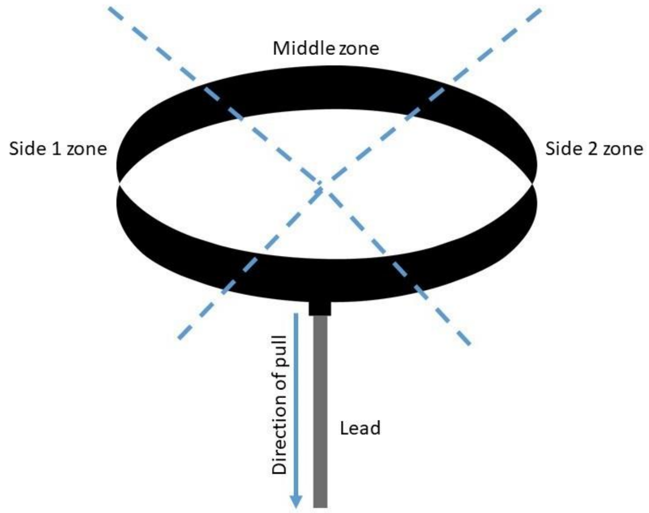

Figure 3. Zones of the collar

The study was approved by the Nottingham Trent University's School of Animal, Rural and Environmental Science's Ethics Committee (ARE619) June 2017.

RESULTS

Collar type: overall pressure

The pressure exerted on the model neck ranged from 83kPa at 40N to 832kPa at 70N force. The padded webbing, padded sports collar, and lurcher collar exerting the lowest pressure (105kPa, 125kPa, 83kPa respectively) on the neck model at 40N force, through to the rolled collar exerting the highest pressure (509kPa). As the force applied through the lead was increased, the padded webbing collar, rope slip lead and lurcher collar exerted the lowest pressure (182kPa, 160kPa and 160kPa respectively). When a lead jerk was applied to the collar, the slip lead exerted the lowest force (182kPa) and the rolled collar the highest pressure on the neck model (814kPa). The overall pressure on the neck model when the force was applied differed between the seven collars and slip lead ($F(7)=25.69$, $p<0.001$), and increased with the increasing force applied from 40N, 70N and lead jerk ($F(2)=42.40$, $p<0.001$) (Figure 4). Post-hoc tests revealed that for collar type, differences were observed between the rolled collar and all other collar types ($p<0.001$); between leather and thread and lurcher ($p<0.05$), padded webbing ($p<0.05$) and rope slip lead ($p<0.05$); and between flat webbing and rope slip lead ($p<0.05$). Force differences were seen between 40N and lead jerk ($p<0.001$) and between 70N and lead jerk ($p=0.05$). No differences were observed between 40N and 70N.

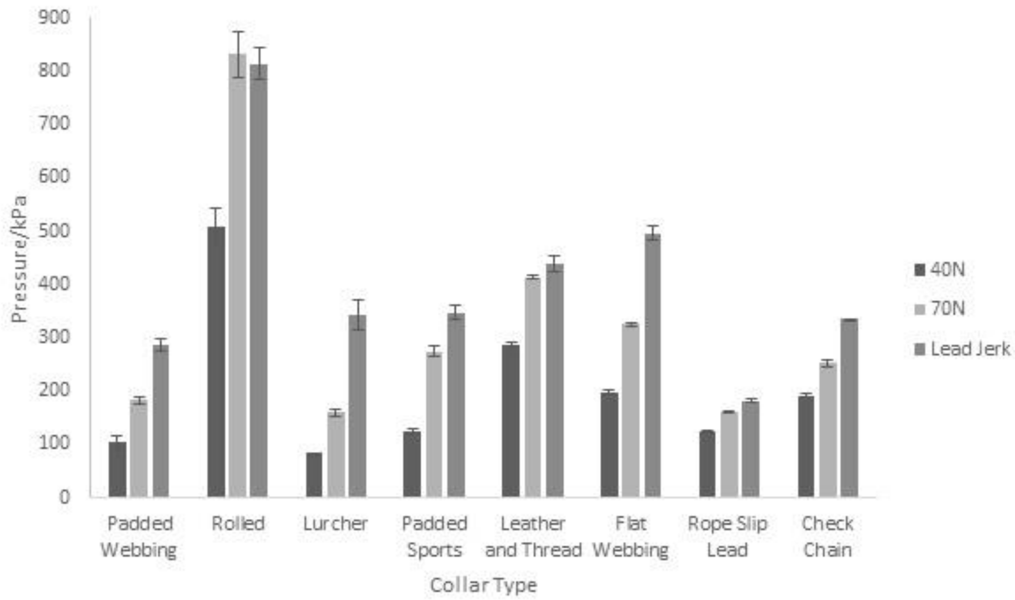

Figure 4: Mean pressure exerted across the neck by each of the collars at different forces. Error bars indication standard error of the mean (SEM). Three repeats were recorded per treatment. Differences were observed between the rolled collar and all other collar types ($p<0.001$); between leather and thread and lurcher ($p<0.05$), padded webbing ($p<0.05$) and rope slip lead ($p<0.05$); and between flat webbing and rope slip lead ($p<0.05$).

Collar type: pressure zones

The way in which the pressure was distributed between the sides of the collar and the middle varied both between collars and force applied (Figure 4). At 40N, the pressure was either evenly distributed across the three zones (padded webbing, check chain, leather and thread, padded sports), or with respect to the middle of the collar, increased pressure on both sides (rolled), or was higher on one side (lurcher, rope slip lead), or lower on one side (flat webbing). As the force applied to the collar increased, this distribution of pressure around the circumference of the collar altered, with the evenness in pressure distribution across the zones reduced. The rolled collar, in addition to showing the highest pressure, went from a higher level of pressure exerted at the sides at 40N, to a one-sided pressure at 70N, to a higher level of pressure in the middle at the lead jerk. The padded webbing collar went from a relatively even pressure distribution at 40N, to a higher pressure on one side in the middle at 70N and lead jerk (since the padding did not reach the entire circumference of the collar). The lurcher collar went from a one-sided pressure at 40N, to higher and even sided pressure with lower pressure maintained in the middle at 70N, whilst the leather and thread collar moved from the lowest pressure in middle zone at 40N to the highest pressure in the middle zone at lead jerk force. The other collars remained relatively consistent in their pressure distribution over the three areas, although distribution generally became more pronounced with increased force applied (Figure 5).

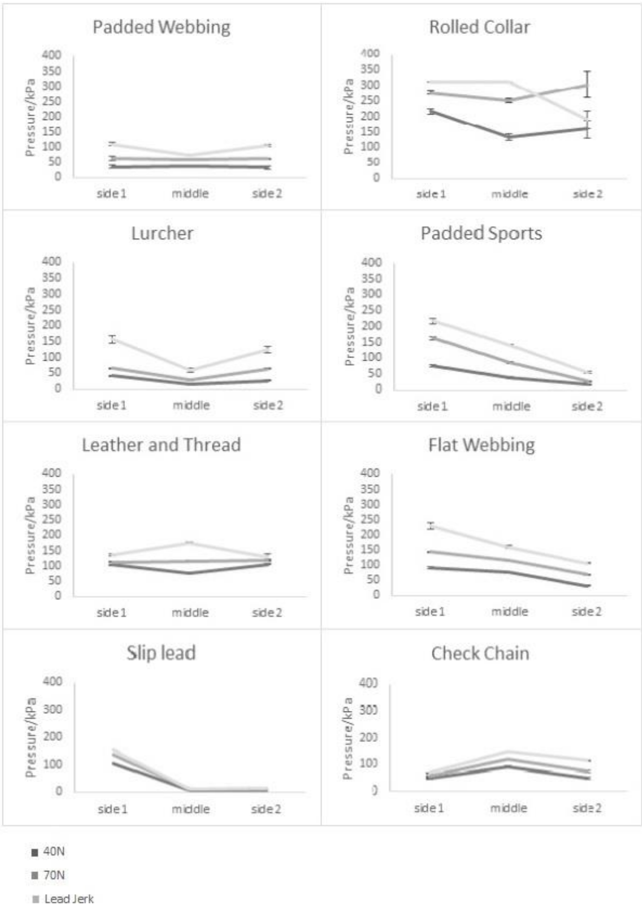

Figure 5. Pressure exerted on the neck according to collar type, with three different forces applied. Error bars indication standard error of the mean (SEM). Three repeats were recorded per treatment.

Collar type: area

The slip lead and check chain covering the smallest overall area when all three forces were applied (23.6-31.7cm^2 and 26.3-30.1cm^2 respectively). The collar covering the largest area was the lurcher collar when all three forces were applied (67.1cm^2, 82.3 cm^2, 90.3cm^2). The overall area over which the pressure was exerted on the neck varied significantly between the seven collars and slip lead ($\chi(7)=64.94$, $p<0.001$). Differences were observed, via post hoc tests, between the rope slip lead and leather and thread ($p<0.05$), flat webbing ($p<0.01$), padded webbing ($p<0.001$), padded sports ($p<0.001$) and lurcher ($p<0.001$); rolled collar and padded webbing ($p<0.01$), padded sports ($p<0.01$) and lurcher ($p<0.001$); check chain and padded sports ($p<0.05$); check chain and lurcher ($p<0.001$); and leather and thread and lurcher ($p<0.05$). For all collars, there was no significant effect of force applied on the contact area of the collar as the force increased from 40N to 70N force and lead jerk ($\chi(2)=3.20$, $p=0.202$) (Figure 6).

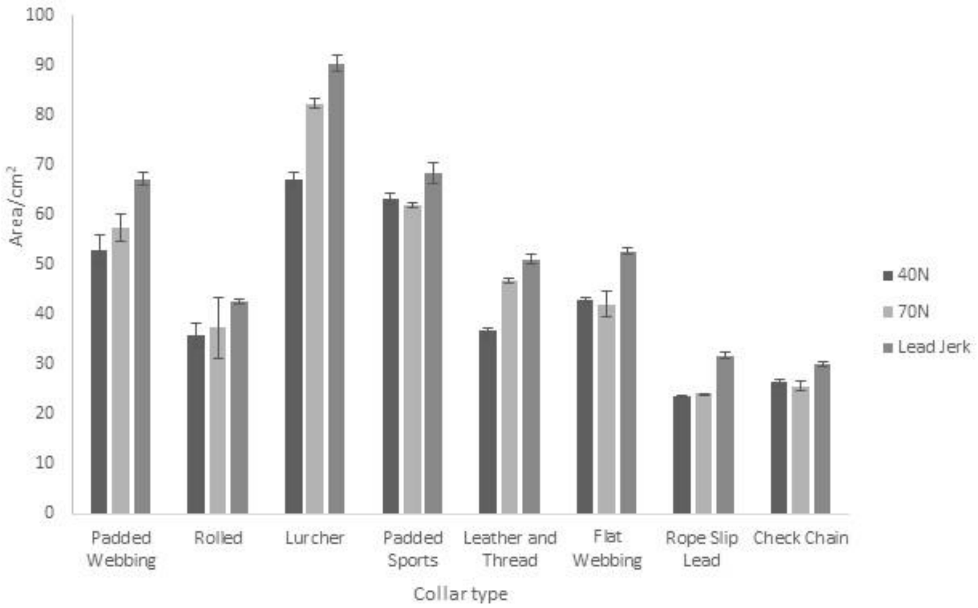

Figure 6: Mean area over which pressure is exerted across the neck by each of the collars at different forces. Error bars indication standard error of the mean (SEM). Three repeats were recorded per treatment. Differences were observed between the rope slip lead and leather and thread ($p<0.05$), flat webbing ($p<0.01$), padded webbing ($p<0.001$), padded sports ($p<0.001$) and lurcher ($p<0.001$); rolled collar and padded webbing ($p<0.01$), padded sports ($p<0.01$) and lurcher ($p<0.001$); check chain and padded sports ($p<0.05$); check chain and lurcher ($p<0.001$); and leather and thread and lurcher ($p<0.05$).

DISCUSSION

Dog collars are utilised by handlers for everyday restraint and control of their dog. However, their potential impact on the welfare of the dog has not been studied in detail. This study investigated the application of a range of forces transmitted through the lead that represented different lead interactions, and measured the resultant pressures exerted on a canine neck model by different types of dog collar.

Collar pressure findings

Collar Pressure

The pressures recorded indicated that all the collar types tested have the potential to cause injury. The pressures measured revealed that amongst a range of commercially available collars of different construction, with different forces transmitted through the lead there was significant variation in pressures underneath the collar, ranging from 83kPa (lurcher collar at

40N) to 832kPa (rolled collar at jerk) (Figure 4). Despite this variability in collar pressures occurring, even the pressure at the lower end of recordings the pressure was much higher than values known to cause tissue damage and tissue death in humans at a pressure of 4.3kPa [22]. In humans, high pressure has been shown to have a variety of detrimental physical effects including increased intraocular pressure and vascular obstruction (over 33.3kPa) [8,9,10]. The type of the collar therefore is not important if even those transmitting the lowest pressure risk, at a minimum, pain if not injury when a low force is applied through the lead.

The risk of injury is arguably high with collars as a result of increasing or transient pressure consistent with a lead jerk or the cumulative effect of constantly pulling on the lead. However, whether the impact is more damaging as an acute response (jerk) or a cumulative effect (consistent pulling) over time requires further investigation.

Collar area

The contact area between the collars and the rigid neck model was constant throughout testing. Therefore, for each collar type there was little effect on contact area with increasing lead interaction force. However, the area of the collar in contact with the neck influenced the pressures recorded. A smaller contact area, minimises pressure distribution and concentrates the force on a smaller area, this is more likely to have a higher risk of injury. The lurcher collar provides a much larger area for the distribution of force compared to the rope slip lead and check chain (Figure 6). Both the check chain and rope slip lead appeared to exhibit a 'locking mechanism' when the lead was pulled perpendicular to the collar, which would not occur if the lead was pulled to one side. Although those collars exhibiting the lowest pressure (force per unit area) (Figure 4), conversely have some of the smallest contact area (check chain and slip lead). The position of the collar lies over a region where anatomical structures are responsible for directing the food, fluids and air that enter the mouth down the correct passageway, i.e. food to the oesophagus, air to the trachea [23]. Anecdotally, it is not uncommon to observe dogs pulling on the lead which appears to contribute to breathing distress and/or intermittent coughing, the potential for pathoanatomy in this situation requires further investigation.

Collar zones

The distribution of pressure across the neck altered according to collar type which may also affect the risk of injury. The way in which the collar reacted when the lead was pulled differs between collars, with higher levels of pressure exerted on the middle of the neck, compared to the sides (creating a nutcracker effect), could ultimately affect the structure at risk of injury. This was particularly evident in the case of the check chain, and the leather and thread collar (lead jerk only) (Figure 5). Placing more pressure in the region of the larynx would potentially place pressure on and damage the thyroid gland, an endocrine gland that functions to control metabolism [23]. Whether this position predisposes the gland (or its associated nerves and vasculature) to risk of injury from collar pressure is unknown. However, thyroid lesions have been observed in humans involved in motor vehicle collisions and attributed to seat belt trauma [24]. Blood vessels and nerves may be compressed which could compromise the structures they are supplying, with major nerves running through the collar region (e.g. the vagus nerve). The lurcher collar consistently put pressure on the sides of the neck compared to the middle, taking the emphasis of pressure away from those areas more likely to be at risk of damage. Conversely, as the force on the rolled collar increased from 40N to a jerk, the pressure on the middle of the neck began to exceed that of the sides (Figure 5). At present, it is unknown how an uneven pressure on the sides of the neck might affect the dog, such as occurs with the rope slip lead. However, dogs manhandled with check chains and prong collars have shown laryngeal, oesophageal, thyroidal, tracheal damage [25] and calcinosis circumscripta-like lesions may develop as a result of muscle trauma [26].

Limitations
The canine neck model used in this study was a solid plastic, cylindrical structure, it is therefore unable to replicate neck conformation (including individual and breed variation), nor can it simulate the biological response of tissues, or the interaction between the handler and dog; however it did create a consistent and replicable test situation for each collar type. In this study, the handler pulled the lead level with the collar, in reality the dog is likely to be on the ground and the lead angle more acute. In addition, pulling a lagging dog forwards or sideways will change how forces are applied. Whilst only one of each type of collar type was tested, it was assumed that the consistency in material and manufacturing process would minimise any differences in their response to forces applied. The range of forces applied through the lead interactions provided typical scenarios and some context of the magnitude of the forces applied. This in turn highlights the high level of pressure exerted through the collar and potential injury risk.

Conclusion
Collars may be a suitable method of displaying identity tags and a means of restraint for dogs that consistently walk on a loose lead. However, where dogs pull on the lead or the lead is jerked, this study suggests there is a risk of injury to the neck for all collar types and styles tested, even where collars are padded or wide fitting. No single collar tested provides a pressure considered low enough to mitigate the risk of injury when pulling on the lead.

Future studies should investigate real world scenarios to better understand the nature of lead interactions and the pressures exerted on the neck.

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