



Pressure and force on the canine neck when exercised using a collar and leash



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ARTICLE INFO

Keywords:

Canine
Collar
Force
Kinetics
Leash
Pressure
Restraint

ABSTRACT

The aim of this study was to assess the pressure and force applied to the canine neck at walk when using collars of different material.

Three different collars of equal size but different construction were used. A double-layer polyester and nylon weave (DN), a single layer nylon weave (SN), and a single layer canvas (SC). Eight dogs wore all three types of collar and were led in a randomized order through a course containing straight, clockwise and counterclockwise sections. Force and pressure were measured and recorded using a Tekscan® F-Scan In-shoe system and analyzed using SPSS statistical software.

Peak force and contact pressure were significantly higher under DN collar when compared with the others ($p < 0.0005$ and $p = 0.001$, respectively). Whilst differences in mean force were not observed between collars, there were significant differences depending on the direction of travel of the dog ($p < 0.0005$), being highest in a counter-clockwise direction, and lowest in a straight line. Peak contact pressure was not significantly different in any condition.

Results suggest that collar construction material will alter contact pressures and peak force exerted on the neck, and that a double layer nylon weave collar with ethylene-vinyl acetate cushioning has a higher contact pressure than either a single layer nylon or canvas construction, which may be contrary to an owners expectations when purchasing a collar. Furthermore, forces will vary depending on the direction of travel in relation to the handler.

Introduction

There are approximately 8.5 million dogs domestic dogs in the UK (PFMA, 2017). The code of practice for the welfare of dogs, based on the animal welfare act (UK Gov, 2006), states that regular exercise is vital for the physical and mental wellbeing of a dog (DEFRA, 2018). The Control of Dogs Order 1992 states that every dog in a public place must wear a collar with the name and address of the owner inscribed (UK Government, 1992), and legislation is now in place requiring all dogs to be restrained by a leash when being walked on public land (UK Government, 2015). There are a variety of restraints that allow this, most commonly; head collars, neck collars or harnesses (Grainger, Wills & Montrose, 2016).

Canine welfare comes into question when selecting the type and size of collar chosen for an animal, as well as how it is used. Due to the natural instinct of the dog to pull against the pressure exerted from a neck restraint (Ogburn, Crouse, Martin & Houpt, 1998) inappropriate choice and use can have welfare consequences for the animal with the

potential to cause nerve damage or temporary upper airway obstruction (AVSAB, 2007a, 2007b). Pressure exerted on the neck may also aggravate certain conditions of the eyes or be detrimental to certain breeds such as brachiocephalic breeds. The higher the collar sits on the neck, the greater the risk of damage (AVSAB, 2007a, 2007b).

Collars are now manufactured in a diverse range of materials, with the most popular being; nylon, leather and metal. (Barrington, 2017). Each material has different properties and will therefore alter the force and pressure exerted on the neck. Extensive research has been carried out on pressure under tack of the horse, primarily saddles (Clayton, O'Connor & Kaiser, 2014), but also nosebands (Casey, McGreevy, O'Muiris & Doherty, 2013), however, no specific research has been carried out on pressure under the collar, or the influence of the material.

The aim of the research project was to assess contact pressure, peak pressure, force and peak force, under three different collars in an attempt to determine whether the material it is comprised of affects these measurements, this could lead to reducing the negative effects collars

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<https://doi.org/10.1016/j.vas.2019.100082>

Received 5 September 2019; Received in revised form 12 October 2019; Accepted 23 October 2019

Available online 24 October 2019

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Table 1
Specifications of the dogs used in trial.

Dog	Age	Sex	Breed	Weight (kg)	Neck circumference (cm)
1	7	MN	Australian Labradoodle	13.2	35
2	3	FN	Hovawart	33	50
3	2	MN	Standard Poodle	25	44
4	11	FN	Hovawart	26.5	40
5	5	MN	German wire-haired pointer	31	38
6	7	FN	Cane Corso × rottweiler	40	51
7	4	MN	Russian Black Terrier	55	58
8	12	MN	Labrador × border collie	28	48

can have on the neck and making it a more suitable restraint to use. Further objectives of the study were to determine pressure and force variations beneath the three collars, as well as to assess the effect of direction on the force and pressure measurements, with a view to making recommendations for the most appropriate material for pet owners to select when choosing a collar for their pet.

Materials and methods

A research proposal was submitted and subsequently approved by Writtle University College, ethics approval reference 98350516/2017.

Dogs

Eight healthy dogs of varying breeds were included in the study as shown in Table 1. Mean age was 6.5 ± 3.38 ranging from two to 12 years, mean weight was 31.4 ± 11.40 kilograms (kg) ranging from 13.2 kg to 55 kg and mean neck circumference was 45.5 ± 7.17 centimeters (cm) ranging from 35 cm to 58 cm. All dogs were clinically sound and showed no signs of lameness. Prior to enrolment of the trial the dogs were acclimatized to both the environment and handler, and any dog that was felt could not walk correctly to the side of the handler was excluded and replaced with a different dog until eight suitable candidates for the trial were found.

Collars

Three collars, each 20 mm in width and 650 mm in length, from the same manufacturer (Great and Small) (G&S, UK) were used for the trial. Components of each collar were a plastic buckle to resize, a metal ring to attach the leash, and a plastic and metal side release clasp as shown in Fig. 1. The specifications of each collar were:

- > DN – A double-layer polyester and nylon weave, with a cushioning of 70% nylon and 30% EVA, with a thickness of 5 mm on the single strip, and 12 mm at the doubled over sections. Has a convex design,

so is thicker in the center where the padding occurs, and thinner on the outside where the stitching occurs.

- > SN – A single layer nylon weave, with a thickness of 2 mm on the single strip, and 4 mm on the doubled over sections. This collar is a flat design, the same thickness over the entirety of the collar.
- > SC – A single layer canvas with a thickness of 3 mm on the single strip, and 7 mm on the doubled over sections. Has a concave design, is thicker on the outer sides of the collar where the stitching occurs and is thinner in the center.

Each collar was fitted by the same person and tightened to ensure that two fingers could be placed comfortably between the collar and neck, according to the safety guidelines set out by the American Kennel Club (AKC, 2019).

Equipment

Neck pressure from the collar was determined using a commercially available pressure measuring device (F-Scan In-Shoe Analysis Sensor, Tekscan, USA) placed ventrally between the collar and the neck of the dog and attached to a Versatek cuff and wireless recording unit via the extended tab. The system consisted of one sensor, with an overall size of 327.2×65 mm, and a sensing area of 304.8×65 mm. The sensor contained 3.9 sensors per cm^2 , with a maximal sample rate at 100 Hz on the wireless system. The equipment was calibrated with a 5 kg weight prior to data collection.

To ensure no additional weight would be placed on the dog the wireless unit was taped to the lead, with the handler holding the lead below the unit. The sensor was placed at the back of the head, to ensure that it did not impede the dogs neck movement.

Measurements

To minimize the influence of different dog handlers, all dogs used in this trial were led by the same person. The collars and the exercises (straight line, clockwise and anticlockwise) were chosen randomly. Before starting the exercise, the dog stood still with the handler by its left forelimb and the leash was held to allow minimal contact. The leash length was kept the same for each dog and for all three collars. Throughout the exercises the handler remained on the left-hand side of the dog at all times and aimed to keep a constant tension on the leash by using a tension gauge (TeleRein, TeleRein C IT New Zealand). Tension on leash was kept between two and four Newtons (N). The same handler remained adjacent to the forelimb of the dog and led each dog around three segments of the course in the following order; clockwise circle, anticlockwise circle and straight with the latter being used as a reference exercise. Collars were chosen randomly, and each exercise was carried out three times for each of the collars.

Data collection and analysis

Using the Tekscan® F-scan research foot v. 6.85 software, peak



Fig. 1. The three collars used for the trial (from left to right); Collar 1 - double-layer nylon and polyester weaved design (DN). Collar 2 - single-layer nylon weave design (SN) and Collar 3 - single layer canvas design (SC).

pressure, peak contact pressure, peak force and force recordings were collected. Data was recorded in Newtons (N) for force, and Newtons per centimetre square (N/cm^2) for pressure readings and plotted against time. A newton is a unit of force. It is equal to the force that would give a mass of one kilogram an acceleration of one meter per second per second.

The mean values per collar and direction were taken from each recording containing at least 800 data points. Mean peak force, force, contact pressure and peak contact pressure were taken to remove any outliers caused by a change in behavior of the dog, and standard deviations were calculated.

Statistical analysis

Tabulated data were imported into SPSS v. 24 (IBM Corporation, Armonk, New York, USA) for analysis. Data were tested for normality using a Shapiro–Wilk test and all variables were found to be normally distributed. Data was analyzed with two-way repeated measures ANOVA in order to determine interactions between the collar, direction and each of the variables measured. Significance was set at $P < 0.05$.

Results

Mean contact pressure

Analysis of the studentized residuals showed that the data was mostly normally distributed. Mauchly's sphericity test has shown that sphericity was not violated for the two-way interaction ($p > 0.05$). Data are mean \pm standard deviation, unless otherwise stated. There was no statistically significant difference between collar material and direction regarding contact pressure at $p = 0.390$. An example of data collected can be seen in Fig. 2.

The main effect of direction showed no significant difference in contact pressure at $p = 0.19$ with the main effect of the collar showing a significant difference in contact pressure at $p = 0.001$.

Post hoc analysis with a Bonferroni adjustment revealed that there was a decrease of contact pressure from $5.1342 \pm 0.4132 \text{ N}/\text{cm}^2$ with collar DN to $4.2824 \pm 0.5491 \text{ N}/\text{cm}^2$ with collar SN, a statistically significant decrease of $0.8518 \text{ N}/\text{cm}^2$ (95% CI, 0.3128 to $1.3908 \text{ N}/\text{cm}^2$), $p = 0.007$. Further to this, there was a decrease of contact pressure from collar DN to $4.3360 \pm 0.5153 \text{ N}/\text{cm}^2$ with collar SC, a statistically significant decrease of $0.7982 \text{ N}/\text{cm}^2$ (95% CI, 0.3217 to $1.2747 \text{ N}/\text{cm}^2$), $p = 0.005$. A decrease was also shown between collar SN and collar SC, with a contact pressure of $4.3360 \pm 0.5153 \text{ N}/\text{cm}^2$, however, this was not statistically significant different, $p = 0.626$ as shown in Fig. 3.

Peak contact pressure

Analysis of the studentized residuals to determine the effect of different collars on peak contact pressure showed that the data was mostly normally distributed. Sphericity was met for the two-way interaction ($p > 0.05$). There was no statistically significant difference between the collar material and direction on peak contact pressure $p = 0.223$.

The main effect of the collar showed no significant difference in peak pressure at $p = 0.349$. There was no significant difference between direction and peak pressure values $p = 0.435$ as shown in Fig. 4.

Force

A two-way repeated measures ANOVA was run to determine the effect of different collars over mean force. Analysis of the studentized residuals showed that there was normality, as assessed by the Shapiro–Wilk test of normality and no outliers, as assessed by no studentized residuals greater than ± 3 standard deviations. Sphericity was met for the interaction term, as assessed by Mauchly's test of sphericity

($p > 0.05$). There was no statistically significant two-way interaction between the collar and direction on force, ($p = 0.034$). Therefore, main effects for the two within-subjects factors were run. There was also no significant difference in the effect of different collars on force ($p = 0.235$). However, there is a significant statistical difference in the effect of the direction ($p < 0.005$).

Results showed a decrease of force when moving straight ($147.228 \pm 35.467 \text{ N}$) compared with moving in a clockwise circle ($164.419 \pm 37.140 \text{ N}$), which is a difference of 17.190 N (95% CI, 5.278 to 29.099 N), $p = 0.011$.

A statistically significant difference of force is also shown between moving straight and in a counter-clockwise direction ($196.405 \pm 41.900 \text{ N}$), a difference of 49.177 N (95% CI, 22.223 to 76.131 N), $p = 0.004$. When comparing clockwise and counter-clockwise circles, there is a statistically significant difference of 31.987 N (95% CI, 8.317 to 55.661 N), $p = 0.015$ as can be seen in Fig. 5.

Peak force

Lastly a two-way repeated measures ANOVA was conducted to determine the effects of different collars and direction on peak force. There were no outliers and the data was normally distributed at each time point, as assessed by boxplot and Shapiro–Wilk test ($p > 0.05$), respectively. The assumption of sphericity was met, as assessed by Mauchly's test of sphericity ($p > 0.05$). There was no statistically significant two-way interaction between direction and collars ($p = 0.057$). For the simple main effects, a Bonferroni adjustment was applied. There was a statistically significant simple main effect of collars on peak pressure ($p < 0.0005$) and also on the simple main effect of direction ($p = 0.037$). Data are mean \pm standard deviation unless otherwise stated. All simple pairwise comparisons were run between the collars and directions. There was a statistically significant mean difference between: the DN and SN collars and between DN and SC collars. DN collar has shown a higher peak force than the other two collars in all three directions. On a straight line it has shown the highest peak force, being 11.737 N or 250% and 11.162 N or 212% higher than SN and SC, respectively ($p = 0.021$). Likewise, on clockwise and counterclockwise direction DN has still shown higher pressure than the other collars analyzed ($p = 0.043$ and $p = 0.046$, respectively) (Fig. 6).

There was a statistically significant simple main effect of directions on peak pressure ($p = 0.033$), but only for the DN collar. On the clockwise and counterclockwise directions, DN has shown a lower peak force than on a straight line ($p = 0.028$). The collars SN and SC have not shown significant differences between them or in the different directions.

Discussion

Both pressure and force remained fairly constant throughout each exercise when the dog was moving well, however, if the dog became distracted, started pulling or jumped, the load varied greatly. Research has shown that dogs are more unruly and disobedient when being led on a neck collar rather than a head collar (Ogburn et al., 1998).

The average overall peak force was 30.2 N , similar to the maximal force value found in a study measuring pressure under harnesses in guide dogs, albeit pressure from a harness is exerted at the sternum as opposed to the neck (Peham, Limbeck, Galla & Bockstahler, 2013). Other values were recorded by Coppinger, Coppinger and Skillings (1998) for dogs when pulling a wheelchair or sled as 29.3 N and 26.7 N , respectively. The absolute maximal force in this study was approximately 73 N which was experienced during pulling and accelerating.

Similar loads have been observed in horses ridden on the bit (Clayton, Larson, Kaiser & Lavagnino, 2011). The mean weight dogs studied was $31.4 \pm 12.20 \text{ kg}$ equating to approximately 60% of the

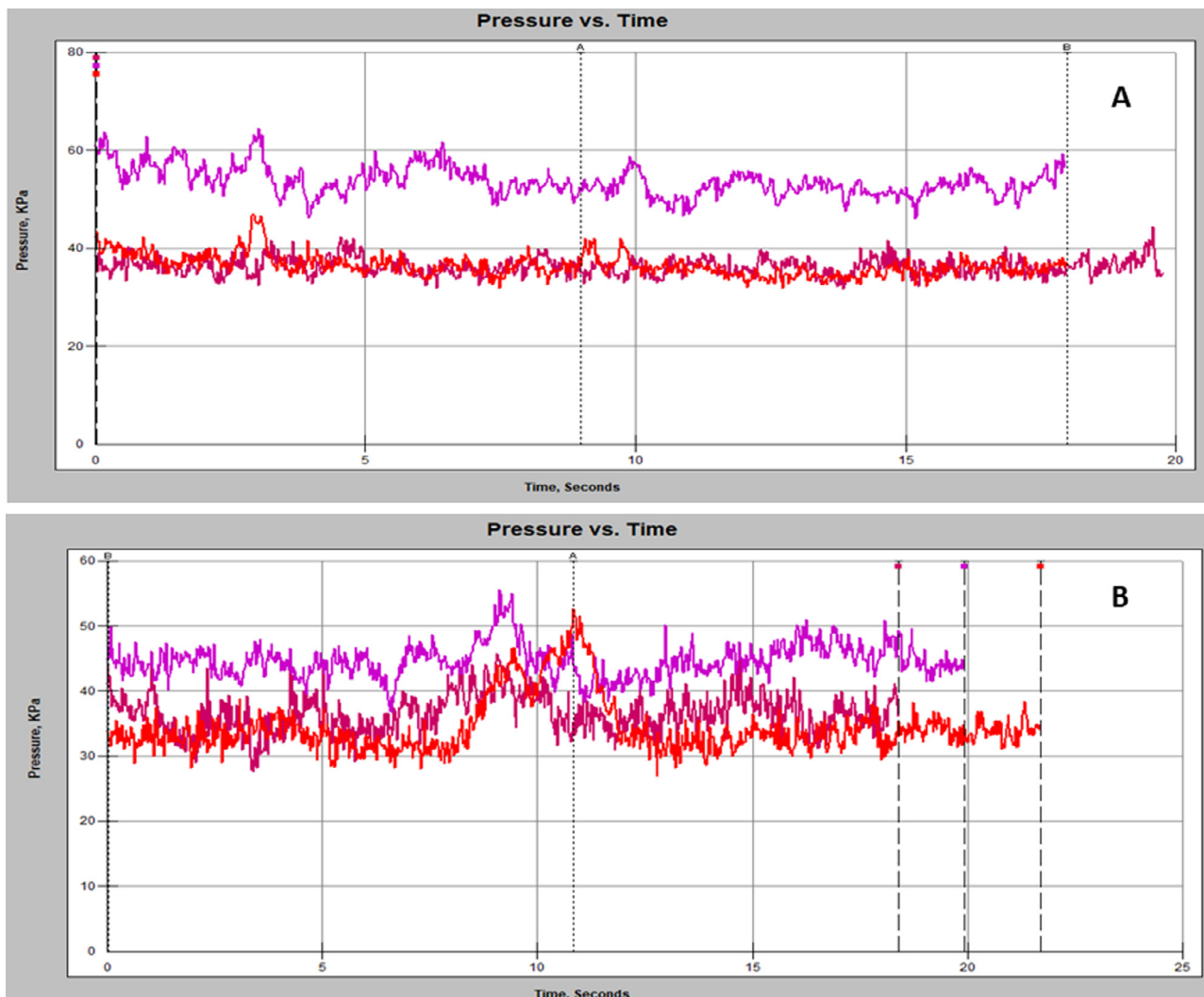


Fig. 2. Graphs showing the pressure when walking the same dog in a clockwise circle (A) and in a straight line (B). Pink line represents collar DN, red is collar SN and purple is collar SC.

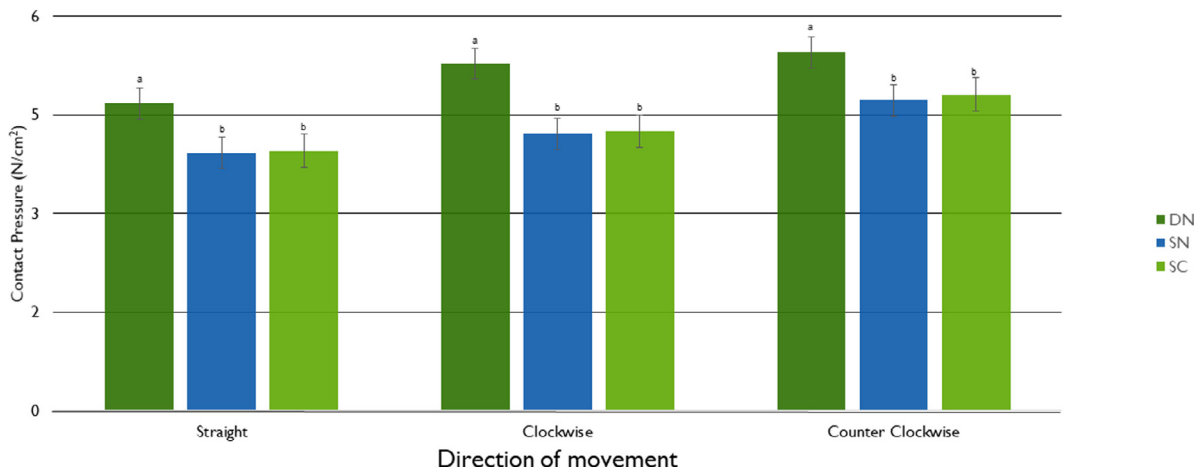


Fig. 3. Mean contact pressure readings for all three collars in each direction. The error bars indicate standard error of the mean (SEM). DN = A reflective teal double-layer nylon and polyester weaved design. SN = A single-layer nylon weave design. SC = A single layer canvas design. Different letters indicate significant differences between collars ($p < 0.05$).

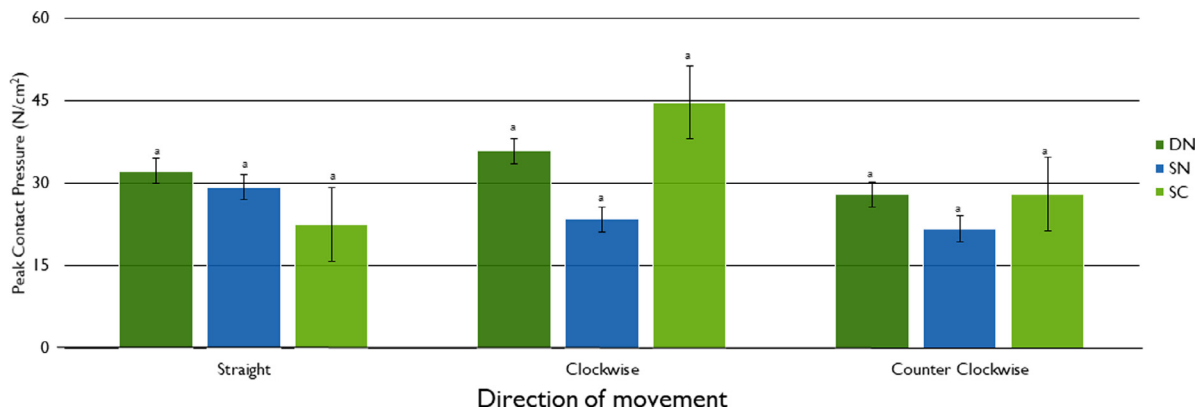


Fig. 4. Mean peak pressure readings for all three collars in each direction. The error bars indicate standard error of the mean (SEM) DN = A double-layer nylon and polyester weaved design. SN = A single-layer nylon weave design. SC = A single layer canvas design. Different letters indicate significant differences between collars ($p < 0.05$).

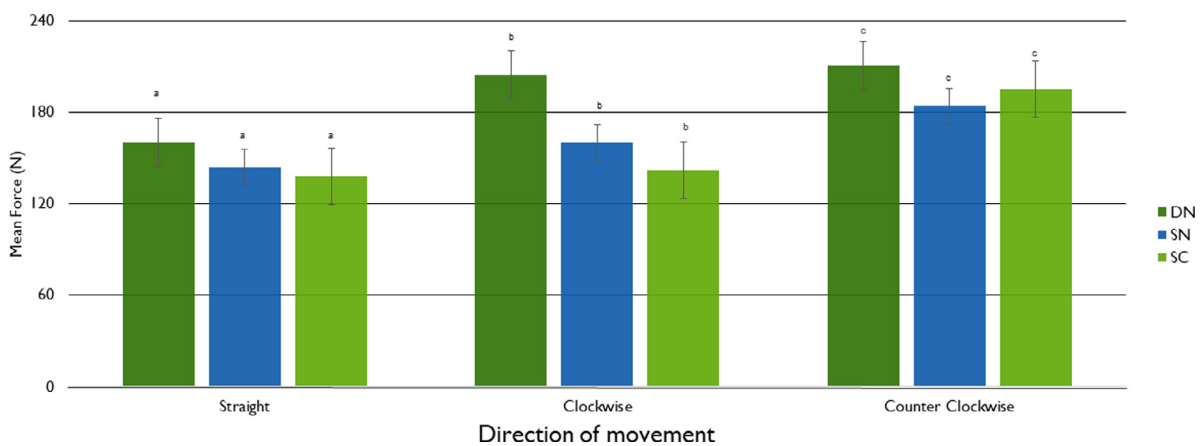


Fig. 5. Mean force readings for all three collars in each direction. The error bars indicate standard error of the mean (SEM). DN = A nylon and polyester weaved design. SN = A single-layer nylon weave design. SC = A single layer canvas design. Different letters indicate significant differences between collars ($p < 0.05$).

estimated mass of the head-neck segment of a horse (50Kg) (Buchner, Savelberg, Schamhardt & Barneveld, 1997). Load is therefore much higher on the dog in relation to their body mass.

Pulling or tugging from the dog or handler onto a narrow collar can

cause major trauma to the neck, with research suggesting that just over 2 g of weight can suppress a nerve's function by up to 50% (Kaufman, 2007). This is particularly relevant when discussing pressure on the neck as the cervical and accessory spinal nerves run under the

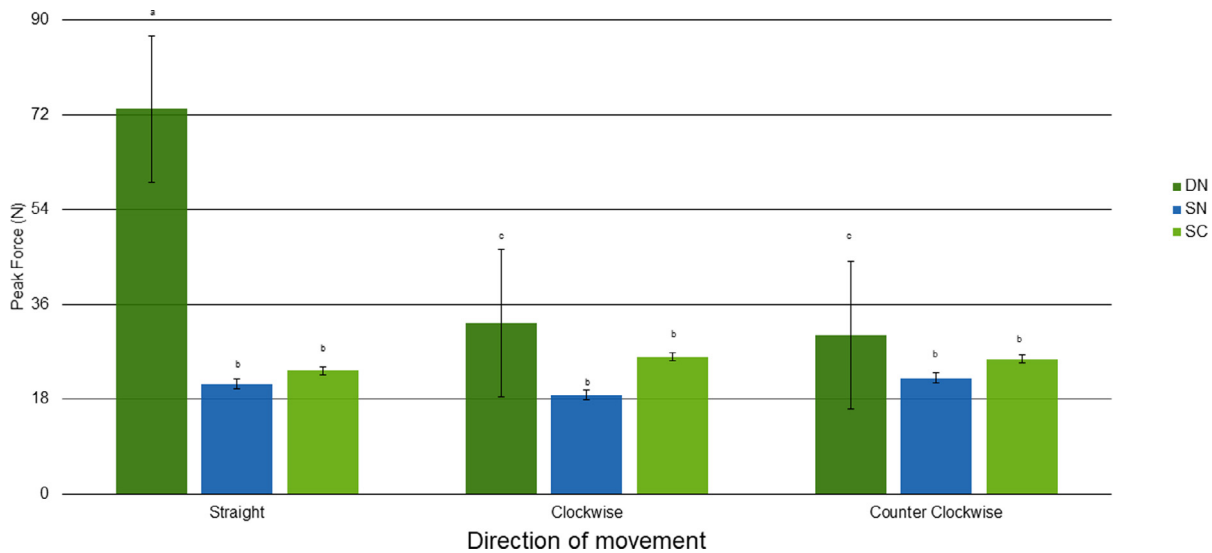


Fig. 6. Mean peak force readings for all three collars in each direction. The error bars indicate standard error of the mean (SEM). DN = A double-layer nylon and polyester weaved design. SN = A single-layer nylon weave design. SC = A single layer canvas design. Different letters indicate significant differences between collars ($p < 0.05$).

collar (Goody, 2013). Head collars, in comparison to the neck collar, are designed to put pressure on the back of the neck, as a straight-line force is exerted, and minimal pressure on the neck and nose strap (Ogburn et al., 1998). The resultant effect is for the dog pull back on the head collar, rather than forwards when pulling against the neck restraint, significantly reducing the pressure exerted on these nerves.

Pressure measurements observed were significantly higher than those seen in previous research, with contact pressure reaching 4.58 N/cm², and the maximal peak contact pressure 44.61 N/cm² reflecting the smaller area that a collar occupies when compared with a harness. It is interesting to note that despite the cushioning material on collar DN it presented the highest peak force and contact pressure. This is explained by the fact that the cushioning material is not present around the whole collar and therefore creates a reduced contact area, effectively concentrating pressure and force into a smaller area. Contact pressures observed are greater than those experienced by horses exhibiting clinical signs of ill-fitting saddles, at 3.89 N/cm² (Von Peinen, Wiestner, Von Rechenberh & Weishaupt, 2010). These may include focal swelling, thoracolumbar pain and ruffling of the hair (Dyson, Carson & Fisher, 2015), similar to symptoms seen in dogs that have experienced collar misuse.

To the author's current knowledge, there is no research investigating the effect of pressure on the skin of a dog, although research on pressure sores has been carried out in other species such as humans and horses. A small amount of pressure can cause injury to an area, particularly those that are poorly protected by thin layers of soft tissue, when applied over a sufficiently long period of time (Clayton, Kaiser & Nauwelaerts, 2010). This is particularly relevant when discussing the collar on a dog, which will rarely be removed.

As far as we know, there is no research available which considers the influence of pressure to the skin of dogs, but in humans deterioration and death of tissue occurs when pressure on the skin exceeds capillary pressure, estimated at approximately 0.43 N/cm² (Landis, 1930). It is noteworthy that mean skin thickness in dogs ranges from 0.5 to 5 mm and is thinner ventrally where collar pressure would be applied during exercise. It may be reasonable to assume that if the maximum pressure observed in this study was maintained over a sufficient period of time, even it has been shown to be sufficient to cause ischaemic necrosis in pigs (Daniel, Priest & Wheatley., 1982), albeit research has indicated that capillary closure pressure varies considerably between species and individuals within a population (Bennet, Kavner, Lee, Trainor & Lewis, 1981; Ek, Gustavsson & Lewis., 1987; Peirce, Skalak & Rodeheaver., 2000). This leads to reduced blood flow and prevents oxygen and nutrients reaching the tissue whilst allowing waste products to accumulate (Clayton et al., 2010). Peak pressures seen within this research project are significantly higher, which merits further investigation. This is particularly relevant to dogs that are prone to pulling on the lead. Furthermore, there is an inverse relationship between pressure and its duration of application in dogs which may influence the development of pressure sores (Kosiak, 1959). A small amount of pressure therefore being exerted over a prolonged period may result in an injury similar to one created by higher pressures applied over for a shorter period (Clayton, 2010).

All of the dogs used during this study had a long coat length when compared to the trimmed area of a horse under the saddle area. This may increase the sliding of the collar, which may create pressure points (Peham et al., 2013), however, no research has been carried out to assess this further.

There was a significant difference between direction of movement and force under each collar, with counterclockwise (away from the handler) showing the highest force, and straight the lowest force. Research shows that a dog will pull away from direct pressure caused by a handler pulling on a restraint (Ogburn et al., 1998). When the handler was to the outside of the dog, they were able to influence direction with their body movement, meaning less force was required on the restraint.

Conclusion

This study suggests that not only material and design/profile of dog collars, but also the direction of exercise, affect the amount of pressure and forces applied to the dog neck. DN collar has shown the highest contact pressure amongst the three studied collars. Likewise, the peak force was higher with DN collar when compared with the other two collars, noticeably at straight line, showing a poor distribution of the forces applied to the neck with this specific collar. Mean force was significantly higher when performing circles when compared with walking on straight line. And counterclockwise circle has elicited a higher pressure than clockwise circle, showing the effect of the handler position on the mean force. The peak force, contact and mean pressures imposed by the different directions were not significantly different. This work highlights the importance of the correct selection of the collar to the dog, a suitable collar should reduce load on the dogs neck. In comparison with collars without padding, the presence of cushioning was not effective in reducing total force and localized pressure on the neck and seems to cause concentration of pressure in specific points.

Ethics

The material in the manuscript has been acquired according to modern ethical standards and has been approved by the Animal Welfare and Ethics Committee of Writtle University College. The approval number is 98350516/2017. 2. A written informed consent was obtained from the owners of the participants of the study was obtained.

Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

Special thanks to Josh Ingleton of Tekscan for use of equipment, as well as to all the owners of dogs who gave their time to make this study possible.

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