The effect of recumbency and hindlimb position on the lumbosacral interlaminar distance in dogs: a cadaveric computed tomography study

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Abstract

Objective To examine the effect of sternal or lateral recumbency, with or without cranial extension of the hindlimbs, on the distance between the dorsal lumbosacral laminae in dogs.

Study design Blinded, randomised, crossover, experimental study.

Animals A total of 19 canine cadavers.

Methods Computed tomography of the lumbosacral junction was performed in four positions: sternal and right lateral recumbency, with hindlimbs extended cranially or not. Order of positioning was randomised. The lumbosacral interlaminar (LSI) distance, defined as the distance between the dorsal laminae of the seventh lumbar vertebra (caudal margin) and sacrum (cranial margin), was measured for each position by two independent assessors who were unaware of positioning. Mean distances in each position were compared using a paired t-test, corrected for multiple comparisons.

Results For $n = 19$ cadavers [6 female, median (range) age 9 (0.3 – 16) years, 20.4 (1.0 – 34.0) kg], cranial extension of the hindlimbs increased the LSI distance, compared to control, in both sternal (9.2 ± 2.2 mm *versus* 3.1 ± 1.3 mm, $p < 0.001$) and right lateral recumbency (8.2 ± 1.9 mm *versus* 4.9 ± 1.5 mm, $p < 0.001$). With the hindlimbs extended cranially, sternal recumbency increased LSI distance when compared to right lateral recumbency ($p < 0.001$).

Conclusions and clinical relevance Cranial extension of the hindlimbs in both sternal and lateral recumbency increases the LSI distance to an extent that is both statistically significant and of potential clinical relevance. Although ease of epidural access or injection was not assessed, the small (1 mm) difference in LSI distance between cranial hindlimb extension in sternal *versus* right lateral recumbency is unlikely to be of clinical relevance. Conversely, cranial extension of the hindlimbs in either sternal or lateral recumbency would be expected to facilitate epidural injection.

Keywords anatomy, canine, epidural, extradural, regional anaesthesia.

Introduction

The lumbosacral space is a commonly used site for epidural administration of analgesic and anaesthetic drugs in dogs (Jones 2001; Campoy 2004). Lumbosacral injection may be performed in sternal or lateral recumbency (Heath 1992; Jones 2001; Campoy 2004). Anecdotally, sternal recumbency appears to be more commonly utilised, for reasons of operator convenience and ease of animal positioning. However, individual preference or animal-specific factors, including degenerative joint disease or hindlimb fracture, may lead to lateral recumbency being selected for the procedure (Heath 1986).

Studies describing lumbosacral injection in dogs, irrespective of recumbency, frequently state that the hindlimbs were pulled forwards, as part of their description of animal positioning (Iff & Moens 2010; Adami et al. 2013; Liotta et al. 2015; Kawalilak et al. 2015; Ertelt et al. 2016; Liotta et al. 2016; Viscasillas et al. 2016; Martinez-Taboada & Redondo 2017). Cranial extension of the hindlimbs has been recommended since the early descriptions of lumbosacral injection in dogs (Bradley et al. 1980). This recommendation is based on the assumption that such positioning produces flexion of the vertebral column, including at the lumbosacral junction (Wetmore & Glowaski 2000; Jones 2001; Campoy 2004). Lumbosacral flexion widens the distance between the dorsal laminae of the lumbosacral vertebrae [hereinafter referred to as the lumbosacral interlaminar (LSI) distance] and may therefore facilitate injection or catheter placement.

In humans, lumbar epidural injection is usually performed between the third and fifth lumbar vertebrae (Boon et al. 2004). A number of positioning techniques, including hip flexion, have been shown to increase the interspinous distance (Fisher et al. 2001; Sandoval et al. 2004; Jones et al. 2013; Dimaculangan et al. 2016). In dogs, the idea that a similar effect could be achieved at the lumbosacral junction through cranial positioning of the hindlimbs has been challenged (Valverde 2008). Instead, it was suggested, based on experience with cadavers, that cranial positioning of the hindlimbs might enhance landmark palpation rather than increasing the LSI distance per se (Valverde 2008). It was subsequently demonstrated that cranial positioning of the hindlimbs, at least in sternal recumbency, can increase the LSI distance (Di Concetto et al. 2012). However, the effect of hindlimb positioning in lateral recumbency was not assessed, and as a result it was also not possible to compare the LSI distance in sternal *versus* lateral recumbency.

We therefore designed a study to compare the effect of hindlimb positioning on the LSI distance in both sternal and lateral recumbency. We hypothesised that cranial extension of the hindlimbs would increase the LSI distance in both sternal and lateral recumbency. Additionally, we hypothesised that cranial extension of the hindlimbs in sternal recumbency would result in a greater LSI distance than cranial extension of the hindlimbs in lateral recumbency.

Materials and methods

Dogs

A blinded, crossover, experimental study was performed on canine cadavers. Ethical approval was granted by the University of Edinburgh Veterinary Ethical Review Committee (VERC# 02/10). Canines of any size and age euthanized for causes unrelated to the present study and donated to the hospital by their owners were included in the study. Dogs with a clinical history, or radiological evidence (on computed tomography scan review by a radiologist (M.L., T.L.), of lumbosacral or pelvic abnormality, including fracture, hemivertebrae, transitional vertebrae, intervertebral disc disease, severe degenerative joint disease or spondylosis deformans, were excluded. Weight, sex, age and reason for euthanasia were recorded.

Procedures

The four positions into which each cadaver was placed are illustrated in Figure 1. These comprised sternal recumbency with hindlimbs extended caudally (control) or cranially, and right lateral recumbency with hindlimbs lying neutrally (control) or extended cranially. The order in which each case was placed into each of the four positions was randomised independently, firstly by randomly selecting the initial recumbency and then, for each recumbency, randomly selecting the initial hindlimb position (www.randomizer.org). Positioning was always performed by the same two investigators (M.L., T.L.). Foam wedges and sandbags were used to align each dog correctly within the gantry, keeping the pelvis and spine parallel to the table, as previously described (Puggioni et al. 2006), and maintaining the hindlimbs in the desired position.

For each of the four positions, a multi-detector computed tomography exam of the lumbosacral junction was performed in helical mode, at 100 kV and 100-150 mAs, with a 1 mm slice thickness, spiral pitch factor of 0.8, rotation time of 1 second, and matrix size 512x512 (Somatom 64; Siemens, Germany). The entire lumbar spine and sacrum were included in the sequences to rule out lumbosacral abnormality and to allow measurements to be made at the correct intervertebral space. Images were acquired within 24 hours of euthanasia; cadavers were stored at 4°C until scanning.

The distance between the dorsal laminae of the seventh lumbar vertebra (caudal margin) and sacrum (cranial margin), referred to as the LSI distance (Fig. 2), was measured in each position, at the level of the midline, by two independent assessors (A.P., M.L.), each making one measurement in each position. The assessors viewed images containing only the lumbar spine and lumbosacral junction, and were therefore unaware of recumbency or hindlimb position at the time of measurement. Multiplanar reconstruction and measurement were performed using certified medical software (Osirix PRO; Aycan, Germany). Images were reconstructed at a 0.1 mm increment. A bone reconstruction algorithm (I70h, WW735, WW4096) was used to detect lumbosacral abnormality, and to measure the LSI distance and the mid-body height of the fifth lumbar vertebra (L5) (Fig. 2). A soft tissue reconstruction algorithm (I40s, WL45, WW360) was used to detect any additional lumbosacral abnormalities.

Statistical analysis

Sample size calculations based on pilot data suggested that a minimum of 15 cases would be required to detect a change in distance of ≥ 50% (Type I error rate 0.05, Type II error rate 0.2). We therefore aimed to include 20 dogs in the study population to ensure adequate power. For each position, the mean of the measurements recorded by the two independent assessors was calculated and used in the subsequent analysis.

Data were assessed graphically for normality prior to analysis. Data are presented as mean ± standard deviation (SD) unless otherwise stated. Mean LSI distance in each position was compared using a paired t-test, corrected for multiple comparisons using a Bonferroni correction. The relationship between LSI distance and mid-body height of L5 or body weight was assessed using Pearson correlation analysis. Positive or negative values of r between 0.30 and 0.49, 0.50 and 0.69, and 0.70 and 1, were considered to represent weak, moderate or strong correlations, respectively. Inter-assessor reliability was examined by calculation of the intraclass correlation coefficient, using a two-way mixed, single measure, absolute agreement model.

Values of $p \leq 0.05$ were considered significant. Data were analysed using Excel for Mac (version 15.38; Microsoft, WA, USA), Prism 7 for Mac OS X (version 7.0c; GraphPad Software Inc, CA, USA), and SPSS Statistics (version 23.0.0.3; IBM, NY, USA).

Results

Nineteen cadavers were included in the final analysis. One cadaver was excluded prior to analysis because of the presence of pelvic fractures and sacroiliac luxation. Summary descriptive data for the study population are shown in Table 1. Data for individual cases are provided in Table S1.

Analysis of LSI distances in sternal recumbency confirmed that hindlimb position significantly alters LSI distance (Fig. 3a). Cranial extension of the hindlimbs increased LSI distance compared to caudal extension (9.2 ± 2.2 mm *versus* 3.1 ± 1.3 mm, $p < 0.001$). Thus, between the two extremes of hindlimb position in sternal recumbency, there was almost a three-fold difference in LSI distance.

The LSI distance was then assessed in right lateral recumbency, comparing hindlimbs positioned neutrally or extended cranially. Again, cranial extension of the hindlimbs significantly increased the mean LSI distance compared to neutral positioning (8.2 ± 1.9 mm *versus* 4.9 ± 1.5 mm, $p < 0.001$) (Fig. 3b). On average, cranial extension of the hindlimbs in lateral recumbency increased the LSI distance by 67% compared to control.

Having confirmed that cranial extension of the hindlimbs increases the LSI distance in both sternal and lateral recumbency, we next examined whether one recumbency was superior. With the hindlimbs extended cranially, sternal recumbency resulted in only a 1 mm (12%) increase in mean LSI distance when compared to right lateral recumbency (9.2 ± 2.2 mm *versus* 8.2 ± 1.9 mm, $p < 0.001$) (Fig. 3c).

The mid-body height of L5 was measured at the same time as LSI distance to assess the effect of size on LSI distance. Body weight was also recorded for 16 dogs. Both L5 mid-body height and body weight showed only weak correlation with LSI distance in right lateral recumbency with neutral hindlimb position (Fig. 4a, c); L5 height: r = 0.49, 95% C.I. 0.04-0.77, $p = 0.04$; body weight: r = 0.34, 95% C.I. -0.19-0.71, $p = 0.20$. A moderate correlation was observed with cranial hindlimb extension (Fig. 4b, d); L5 height: r = 0.54, 95% C.I. 0.11-0.80, $p = 0.02$; body weight: r = 0.60, 95% C.I. 0.14-0.84, $p = 0.01$.

Inter-assessor reliability was examined by calculation of an intraclass correlation coefficient from all 76 measurements (19 dogs in four positions) made by each of the two assessors. This gave a value of 0.89 (95% C.I. 0.82-0.94), suggesting excellent agreement between the two assessors.

Discussion

The findings of this canine cadaveric study support the primary hypothesis that cranial extension of the hindlimbs increases the LSI distance in both sternal and lateral recumbency. The results also confirm and extend those of a previous, clinical study (Di Concetto et al. 2012), which demonstrated that cranial extension of the hindlimbs increased the LSI distance in sternal recumbency, but did not examine the effect of hindlimb position in lateral recumbency.

The earlier study by Di Concetto et al. (2012) suggested that cranial extension of the hindlimbs in sternal recumbency increases the LSI distance by 83% on average. Our study found a similar effect (67% average increase) of cranial extension of the hindlimbs in right lateral recumbency. The magnitude of effect of hindlimb position that we measured in sternal recumbency cannot be compared directly to this previous study, nor translated directly into a clinical setting, because we elected to use caudal extension of the hindlimbs as our control position in sternal recumbency. Similarly, comparison of the relative effect of changing hindlimb position in sternal *versus* lateral recumbency in this study is of no value because of the difference in control positions. The effect on the LSI distance of changing hindlimb position in sternal recumbency was intentionally not expressed as a percentage to minimise the risk of the misperception that hindlimb position had a greater effect on LSI distance in sternal recumbency than in lateral recumbency.

In lateral recumbency, cranial hindlimb extension was compared to a clinically relevant, neutral, control position. Conversely, although caudal extension of the hindlimbs in sternal recumbency would not be used clinically, it was selected for two reasons. Firstly, it has previously been suggested that cranial extension of the hindlimbs does not increase the size of the LSI space in cadavers (Valverde 2008). Therefore, we wanted to test the limits of hindlimb excursion in our cadaveric study to maximise the validity of a negative finding had we been unable to detect an effect. Secondly, positioning the hindlimbs in a neutral, flexed position in sternal recumbency can lead to the presence of photon starvation artefact on computed tomography images (Schwarz & Saunders 2011), which could have affected the accuracy with which we were able to measure LSI distance, through decreasing the signal to noise ratio. To optimise measurement accuracy, the reconstruction increment was minimized to 0.1 mm to maximize the longitudinal resolution, considering the pitch factor of 0.8 (Brink et al.

1994). Any potential bias was assumed to be consistent across positions and homogeneously spread between observers.

When comparing LSI distance with cranial extension of the hindlimbs in sternal *versus* lateral recumbency, we found only a small, albeit statistically significant, difference. Although this enabled us to accept our secondary hypothesis, that cranial extension of the hindlimbs in sternal recumbency would result in a greater LSI distance than cranial extension of the hindlimbs in lateral recumbency, the clinical significance of an average increase in LSI distance of 1 mm (or 12%) is likely to be minimal. A similar finding (average increase of 3%), albeit using a different measurement methodology and plain film radiography, was obtained in a canine cadaveric study that compared cranial extension of the hindlimbs in sternal or lateral recumbency and its effect on the mid-laminar distance between the fifth and sixth lumbar vertebrae (Puggioni et al. 2006).

In human medicine, epidural and spinal injection for neuraxial anaesthesia is commonly performed between lumbar vertebrae, rather than at the lumbosacral junction (Boon et al. 2004). Patients are routinely advised to arch their back in order to widen the interlaminar space and facilitate needle placement. Hip flexion has also been shown to widen the interspinous space between multiple lumbar vertebrae (Fisher et al. 2001). Whereas the average percentage increase in the interspinous space width was relatively slight in this human study, ranging from 7% to 21%, our study demonstrates that cranial extension of the hindlimbs in dogs in right lateral recumbency is able to increase the LSI distance by an average of 67%.

The effect of canine size on LSI distance was assessed by examining its association with body weight or the mid-body height of L5. A positive linear relationship was anticipated and, to an extent, observed. The lack of a strong correlation between either of the metrics of canine size and LSI distance suggests that other factors influence individual variation in LSI distance. These might include breed, body condition and age. It is interesting that the strength of correlation improved when the hindlimbs were extended cranially. This suggests that the manner in which the hindlimbs lie in a neutral, unstressed position may itself be a source of variation in LSI distance and that cranial extension of the hindlimbs reduces this variation.

The cadaveric nature of our study is an obvious limitation. However, one would expect that alive, anaesthetised dogs should be no harder to position. Indeed, with adequate muscle relaxation, the effect of cranial extension of the hindlimbs on LSI distance might even be slightly greater, an inference supported by the findings of Di Concetto et al. (2012). Unintentional variation in positioning of the hindlimbs, spine or pelvis could have affected individual measurements. However, positioning was always performed by the same two, experienced investigators. Further, an advantage of computed tomography over traditional radiography is that, following multiplanar reconstruction, measurement of the LSI distance was always made at the mid-sagittal plane. The excellent agreement between assessors in this study supports the validity of our approach and findings. However, intra-assessor variability was not assessed. While only right lateral recumbency was assessed in our study, we would not anticipate that the effect of hindlimb position on LSI distance would be any different in left lateral recumbency. Although comprising only a limited number of dogs, the wide range of ages, weights and breeds included (Table S1) means that our findings are likely to be applicable to the majority of canines.

Importantly, the finding of an increased LSI distance with cranial extension of the hindlimbs in both sternal and lateral recumbency does not necessarily mean that lumbosacral injection is easier or more likely to be successful in these positions. This is a long-standing assumption within both the veterinary and human literature, but one that should ideally be confirmed with a prospective, randomised, blinded clinical trial. Concealing hindlimb position from the person performing epidural injection could pose a challenge, but should be surmountable. Failure rates of 7% and 16% have been reported for epidural injection in dogs (Heath 1986; Troncy et al. 2002). Although reasonably low, this still suggests that epidural injection is unsuccessful in around one in ten dogs, so simple modifications that may facilitate successful injection are worthy of investigation.

A lack of clear superiority of sternal over lateral recumbency supports the conclusion that either is an appropriate position in which to perform lumbosacral injection. It is important to note that foam wedges and sandbags were used to align each dog correctly within the gantry, so as to keep the pelvis and spine parallel to the table as previously described (Puggioni et al. 2006). This is not always performed in a clinical setting and could itself alter the ease of epidural access, irrespective of position or recumbency. In general, the choice of recumbency should be determined based on patient-specific factors and operator preference (Bradley et al. 1980; Naganobu & Hagio 2007; Martinez-Taboada & Redondo 2017). In addition to anatomical or medical considerations that may make lateral recumbency preferable, lightly sedated or conscious dogs may be more easily restrained and positioned on their side. As such, although sternal recumbency is preferred by many, it is important that veterinary anaesthetists are trained in, and capable of, performing lumbosacral injection in both sternal and lateral recumbency.

In summary, this canine cadaveric study shows that cranial extension of the hindlimbs in both sternal and lateral recumbency increases the distance between the dorsal lumbosacral laminae to an extent that is both statistically significant and of potential clinical relevance. Our findings support the longstanding recommendation that the hindlimbs are pulled forward when positioning for lumbosacral injection. The small difference in LSI distance found between cranial extension of the hindlimbs in sternal *versus* lateral recumbency, although statistically significant, is of questionable clinical relevance. Therefore, neither recumbency appears to offer inherently superior access to the lumbosacral epidural space when the hindlimbs are cranially extended.

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Figure Legends

Figure 1 Computed tomography of the lumbosacral junction was performed in four positions. Dogs were placed in sternal recumbency (a,b) with hindlimbs extended caudally (a) or cranially (b). Each dog was also placed in right lateral recumbency (c,d) with hindlimbs in a neutral position (c) or extended cranially (d).

Figure 2 The effect of recumbency and hindlimb position on lumbosacral interlaminar (LSI) distance. Sagittal reconstructions with bone window of computed tomography images were produced in four different positions for each dog: sternal recumbency with hindlimbs extended caudally (a) or cranially (b); right lateral recumbency with hindlimbs in a neutral position (c) or extended cranially (d). White arrows indicate the lumbosacral junction. The lines identified by * and † indicate the sites at which the LSI distance and the L5 mid-body height, respectively, were measured. All images are from the same dog. L5, fifth lumbar vertebra; L7, seventh lumbar vertebra; S, sacrum.

Figure 3 The effect of cranial extension of the hindlimbs and recumbency on lumbosacral interlaminar (LSI) distance. In sternal (a) or right lateral (b) recumbency, cranial extension of the hindlimbs significantly increases the LSI distance versus control (caudal hindlimb extension (a) and neutral hindlimb position (b)). Comparing cranial extension of the hindlimbs in sternal versus right lateral recumbency (c) reveals a small, but statistically significant, difference in LSI distance.

Figure 4 Correlation between L5 mid-body height or body weight and lumbosacral interlaminar (LSI) distance. L5 mid-body height (a,b) and body weight (c,d) correlate only weakly with LSI distance when hindlimbs are in a neutral position (a,c) (as in Fig. 1c) and moderately when hindlimbs are extended cranially (b,d) (as in Fig. 1d).

Table 1 Summary descriptive data for 19 dogs comprising the study population

Signalment	**Median (range) or number**
Age (years)	9 (0.3 - 16)
Sex	female 6 (5 neutered) male 13 (9 neutered)
Weight (kg)	20.4 (1.0 - 34.0)*

*Weight was recorded for 16/19 dogs.

Figure 1

Figure 1. Computed tomography of the lumbosacral junction was performed in four positions. Dogs were placed in sternal recumbency (a,b) with hindlimbs extended caudally (a) or cranially (b). Each dog was also placed in right lateral recumbency (c,d) with hindlimbs in a neutral position (c) or extended cranially (d).

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Figure 2

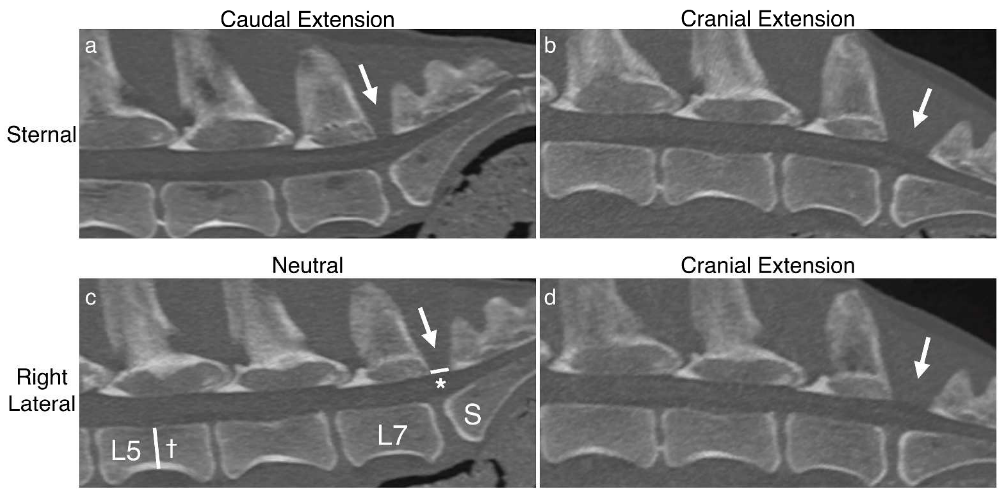

Figure 2. The effect of recumbency and hindlimb position on lumbosacral interlaminar (LSI) distance. Sagittal reconstructions with bone window of computed tomography images were produced in four different positions for each dog: sternal recumbency with hindlimbs extended caudally (a) or cranially (b); right lateral recumbency with hindlimbs in a neutral position (c) or extended cranially (d). White arrows indicate the lumbosacral junction. The lines identified by * and † indicate the sites at which the LSI distance and the L5 mid-body height, respectively, were measured. All images are from the same dog. L5, fifth lumbar vertebra; L7, seventh lumbar vertebra; S, sacrum.

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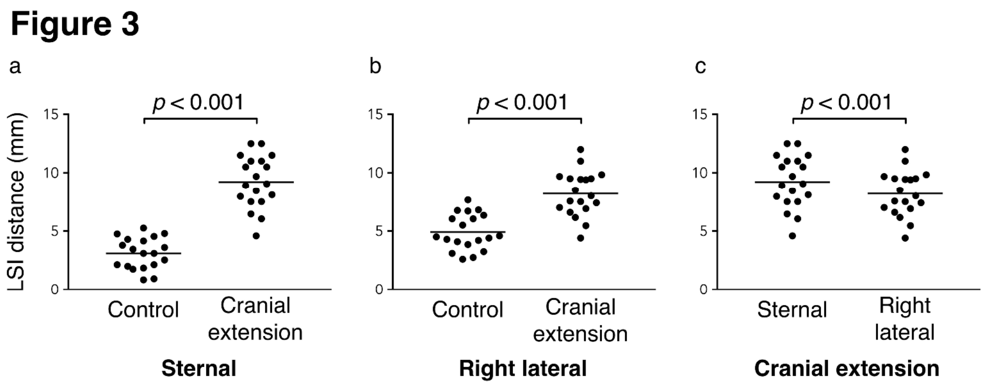

Figure 3. The effect of cranial extension of the hindlimbs and recumbency on lumbosacral interlaminar (LSI) distance. In sternal (a) or right lateral (b) recumbency, cranial extension of the hindlimbs significantly increases the LSI distance versus control (caudal hindlimb extension (a) and neutral hindlimb position (b)). Comparing cranial extension of the hindlimbs in sternal versus right lateral recumbency (c) reveals a small, but statistically significant, difference in LSI distance.

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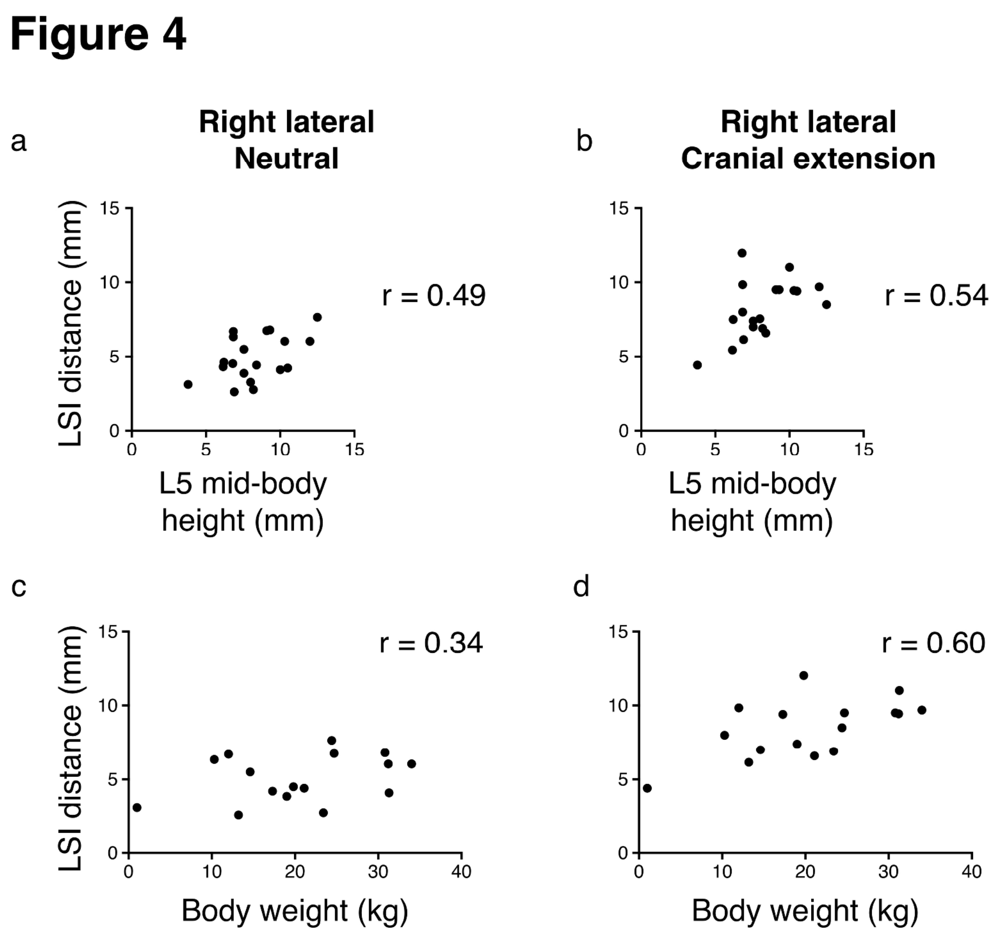

Figure 4. Correlation between L5 mid-body height or body weight and lumbosacral interlaminar (LSI) distance. L5 mid-body height (a,b) and body weight (c,d) correlate only weakly with LSI distance when hindlimbs are in a neutral position (a,c) (as in Fig. 1c) and moderately when hindlimbs are extended cranially (b,d) (as in Fig. 1d).

1150x1121mm (72 x 72 DPI)