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Urinary posture and motor laterality in dogs (*Canis lupus familiaris*) at two shelters

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ABSTRACT

Motor laterality is the preference shown for using one limb or lateral half of the body over the other. In domestic dogs, most laterality studies have examined forelimb preferences during staged tasks. We focused instead on hindlimb preferences during urination when males use the raised-leg posture and females the squat-raise. We observed individual dogs during walks at two shelters (Tompkins County SPCA and Cortland Community SPCA) and recorded posture used for each urination and hindlimb raised, if any. First, we examined whether raising a hindlimb during urination varied with sex, age class, or reproductive status (females, anestrous intact or spayed; males, intact or neutered). Second, for dogs that raised a hindlimb during urination, we determined whether a population bias existed. Finally, for dogs with at least 10 urinations in which a hindlimb was raised, we examined whether a significant hindlimb preference existed. For some analyses, we had sufficient dogs at only one shelter. We found that males were more likely than females to raise a hindlimb during urination ($P < 0.0001$ at each shelter), and that propensity to raise a hindlimb was unaffected by reproductive status ($P = 0.82$, Cortland). Seniors were more likely than adults, which, in turn, were more likely than juveniles, to raise a hindlimb during urination ($P < 0.0001$, Tompkins). We found no evidence of a population bias with respect to hindlimb raised at either shelter (% of hindlimb raises involving the right hindlimb: 53%, Tompkins; 43%, Cortland). Of the dogs that met the criterion for at least 10 urinations with a raised hindlimb, most were ambilateral (83%, Tompkins; 90%, Cortland). Our study confirms and extends for shelter dogs the effects of sex and age on urinary postures previously reported for dogs living under other conditions; to our knowledge, the increased likelihood of raising a hindlimb during urination that characterized seniors (males, 91%; females, 25%) when compared to adults (males, 73%; females, 6%) has not been reported previously. Lack of a population bias with respect to hindlimb raised is consistent with findings of most motor laterality studies in dogs. However, our finding that most dogs were ambilateral differs from results obtained from studies using staged forelimb tasks. Assessing motor laterality for a natural hindlimb behavior in dogs during walks has both advantages and disadvantages, which include ease of observation during a positive experience for the dog and the challenge of obtaining sufficient scores for each dog.

1. Introduction

Motor laterality is preferential use of motor structures on one lateral side of the body over structures on the other side for a specific behavioral task (Corballis, 2009). It is usually quantified in two ways. The first is population laterality, which is the overall preference across all individuals in a population for one side or the other. The second is laterality strength, which is a measure of consistency within individuals. The more consistently an individual uses one side or the other, the higher the laterality strength.

Population biases with respect to motor laterality have been found in some mammals, but not others. The most well known example is handedness in humans, who are approximately 93% right-handed (Hécaen and de Ajuriaguerra, 1964; Warren, 1980). A right hand bias also occurs in captive chimpanzees for the tube task and manual gestures, but not for simple reaching (*Pan troglodytes*; Hopkins et al., 2013). Laterality shifts toward the left hand in gorillas (*Gorilla gorilla*) and baboons (*Papio papio*) when the task involves sliding a panel; no population biases occur in simple reaching tasks (Fagot and Vauclair, 1988a,b). Certain breeds of horses (*Equus ferus caballus*) show a left foreleg preference during grazing whereas

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other breeds show no preference (McGreevy and Thomson, 2006). In some mammals, laterality with respect to use of front paws differs between sexes. In Virginia opossums (*Didelphis virginiana*) and sugar gliders (*Petaurus breviceps*), males favor the right paw and females favor the left during feeding and when supporting the body in a tripedal stance (Giljov et al., 2013). In contrast, in domestic cats (*Felis catus*), males favor the left paw and females the right when retrieving food from a jar, reaching for a toy in the air, and reaching for a toy moving along the ground (Wells and Millsopp, 2009). Finally, one consistency across several studies is a correlation between laterality strength and complexity of behavior: the more complex the behavior, the more likely it is to be strongly lateralized (Boesch, 1991; Fagot and Vauclair, 1991; Hunt et al., 2006; Wells and Millsopp, 2009). This is known as the manipulation complexity hypothesis.

Domestic dogs (*Canis lupus familiaris*) have become increasingly popular subjects in studies of laterality due to their availability and ease of observation, and because measures of laterality may indicate suitability for complex tasks such as seeing-eye work and police dog training (Tompkins et al., 2012a,b). Canine laterality has been assessed for several different motor tasks, including tail wagging (Quaranta et al., 2007), head turning (Siniscalchi et al., 2008), and front foot first used when walking (Tompkins et al., 2010a). Most commonly, laterality has been measured for paw preference during non-walking activities. Almost all of these studies have focused on forelimb behaviors, such as the paw used to remove a piece of adhesive tape from the nose (Batt et al., 2008; Batt et al., 2009; Quaranta et al., 2004), hold either a rawhide chew (Poyser et al., 2006) or Kong toy (Batt et al., 2008; Batt et al., 2009; Branson and Rogers, 2006; Tompkins et al., 2010a), and the paw given when asked to shake hands (Wells, 2003). Some studies report no overall population bias (McGreevy et al., 2010; Poyser et al., 2006) but others found population lateralization in opposite directions for males and females, with male dogs predominantly left-pawed and female dogs predominantly right-pawed (Quaranta et al., 2004; Wells, 2003). Wells (2003) found that strength of paw preference was higher when dogs were asked to give-a-paw than when they were presented with a food retrieval task that entailed complex manipulation. These findings for dogs do not support the manipulation complexity hypothesis, but previous training by owners could have influenced the give-a-paw behavior (Wells, 2003).

Two studies examined laterality of a hindlimb behavior, specifically the hindlimb raised during urination. Berg (1944) studied five male dogs during the first 9 months of life, and found that one male exclusively used the right hindlimb, three used the right hindlimb from 61 to 70% of the time, and one used the left hindlimb 58% of the time. As part of a study of paw laterality and fear responses, Branson (2006) opportunistically recorded the hindlimb raised during urination in a sample of 16 dogs, and reported that three dogs (one male and two females) showed a left-hindlimb preference, with the remainder showing no preference. These two studies differed dramatically in approach: whereas Berg (1944) recorded hindlimb raised for a small number of dogs, each with many raised-leg urinations (from 120 to 247), Branson (2006) studied a larger number of dogs, but only nine had 20 or more urinations involving a raised hindlimb and the remaining seven had fewer than five such urinations.

In our study, we explored the hindlimb raised during urination in a large sample of dogs at two animal shelters. We first determined the effects of sex, age class (juvenile, adult, or senior), and reproductive status (females, anestrous intact or spayed; males, intact or neutered) on the probability of a dog raising a hindlimb while urinating. Urinary postures used by adult dogs can change in response to stressful situations (Berg, 1944; Martins and Valle, 1948), and shelter environments are known to be challenging for dogs (Hennessy et al., 2001; Hiby et al., 2006). Thus, our first analysis allowed us to examine whether shelter dogs exhibit urinary behavior that is similar to that reported for dogs living under other conditions (e.g., in private homes, laboratory colonies, or free-ranging). Next, we calculated overall population laterality at each shelter. Finally, for individual dogs that met the criterion of at least 10 urinations involving a raised hindlimb, we determined whether a hindlimb preference existed and strength of laterality; we repeated these analyses for individual dogs with at least 20 urinations involving a raised hindlimb. Based on results from previous studies with dogs (Beach, 1974; Cafazzo et al., 2012; Ranson and Beach, 1985; Sprague and Anisko, 1973), we predicted that males would be more likely than females, and older dogs (adults and seniors) more likely than juveniles, to raise a hindlimb during urination. Our study is the first to systematically examine urinary postures used by male and female dogs in the senior age class. We predicted that urinary postures of intact males and neutered males would be similar based on Beach's (1974) findings that castration of juvenile or adult dogs has no effect on urinary posture. Similarly, we expected no difference in the postures used by anestrous intact females and spayed females based on results reported by Martins and Valle (1948). Most previous studies of motor laterality in dogs have found no population bias but a majority of dogs exhibiting a side preference (i.e., most dogs were right or left preferent and not ambilateral, which is the term used for absence of a preference; see review by Tompkins et al., 2010b), so we predicted the same for raising a hindlimb during urination.

2. Material and methods

2.1. Dogs and housing

We walked dogs at two shelters, the Tompkins County SPCA (hereafter called the Tompkins shelter; $n = 175$ dogs) in Ithaca, NY, USA and the Cortland Community SPCA (hereafter called the Cortland shelter; $n = 102$ dogs) in Cortland, NY, USA. Most dogs at both locations were mixed-breed males and females that were either picked up as strays or surrendered by owners. Shortly after intake at each shelter, dogs received a physical examination. An orthopedic examination was included in this initial examination on a case-by-case basis (e.g., for elderly dogs and for any dogs exhibiting a limp). The following procedures also were performed: administration of vaccinations; heartworm test; flea control; fecal exam and deworming; and any additional diagnostic tests deemed necessary (e.g., complete blood count/chemistry profile). Dogs were microchipped, if scanning revealed no previous microchip, and intact dogs were scheduled for spaying or neutering. Shelter staff (members of the Behavior Program) performed behavior evaluations, which included the following tests: cage presentation; sociability; teeth exam; handling; arousal; food bowl; possession; stranger; and dog-to-dog (Bollen and Horowitz, 2008; Sternberg, 2006). At the time of their walk(s), all dogs were available for adoption, having received veterinary care and undergone behavioral evaluation. We excluded from analyses dogs that did not urinate during the walk; this left us with final counts of 170 dogs at the Tompkins shelter and 94 dogs at the Cortland shelter. Our sample included intact and spayed or neutered dogs that were at least 4 months old, which is the earliest age at which male dogs raise a hindlimb during urination (Beach, 1974). Some females raise a hindlimb before 6 months of age (Ranson and Beach, 1985). Table 1 includes details of all dogs from each shelter included in analyses.

At the Tompkins shelter, dogs were housed individually in one of thirteen cubicles, which ranged in size from 5.2 m^2 to 7.3 m^2, and had large Plexi-glass windows along one or two of their walls. Each cubicle contained a raised bed, blankets and toys, and a water bowl. At the Cortland shelter, dogs were housed in three different rooms.

Table 1
Numbers of dogs analyzed by sex and reproductive condition at each shelter, and basic descriptive information (median and range) for age, body mass, height at withers, and time spent at shelter.

	Tompkins County SPCA	Cortland Community SPCA
Total number of dogs analyzed (n)	170	94
Neutered males (n)	104	34
Intact males (n)	8	21
Spayed females (n)	51	20
Intact females (n)	7	19
Age (years)	2.0 (0.3–14.0)	1.5 (0.5–13.0)
Body mass (kg)	22.2 (2.0–50.0)	21.3 (4.1–49.0)
Height at withers (cm)	50.8 (20.3–76.2)	50.8 (22.9–71.1)
Time at shelter (days)[a]	19 (4–97)	9 (1–34)

[a] Time spent at shelter before first walk

The first room contained 10 small cages along one wall. The second room contained four runs, separated by brick wall dividers; each run had a chain-link door. The third room contained seven cages, ranging in size from 2.3 m^2 to 4.5 m^2, with chain-link doors and chain-link fences dividing the cages from one another. Dogs were most often housed in the third room; cages in the first room were reserved for very small dogs and those in the second room for small to medium sized dogs. Each cage contained a raised bed, toys, and a water bowl.

2.2. Experimental procedures

We followed routine walking procedures used at each shelter. At the Tompkins shelter, we connected a harness (either a PetSafe Easy Walk Harness, Radio Systems Corporation, Knoxville, TN, USA or a Zack & Zoey Nylon Pet Harness, Pet Any Way LLC, model US2395 14 99) to a 5 m retractable leash (Flexi North America, LLC, Charlotte, NC, USA) and walked each dog to a large nearby field (16.6 ha; 42°28′20″N, 76°26′22″W). The substrate of the field was mostly grass, although there were some smaller sections of dirt and leaf litter. At the Cortland shelter, we connected a 1.8 m cloth lead (Weiss Walkie, Dr. Emily Weiss, Wichita, KS, USA) to a metal ring on the collar and brought each dog to a grassy area outside the shelter (0.3 ha; 42°34′55″N, 76°13′01″W). This area was surrounded on one side by a gravel parking lot and on the other side by a road. At both shelters, most collars were simple buckle collars, with the remainder being martingale collars (collars were donated, so various brands were used). We observed each dog for 20 min at the Tompkins shelter and 10 min at the Cortland shelter. We used different observation times to accommodate differences in the areas available for walking the dogs. During the observation period, the dog was allowed to walk freely around the area. No attempt was made at any point during the observation period to restrain the dog in a "heel" position along either side of the walker; dogs at both shelters typically walked ahead of the walker, as far as the leads would allow. Walking routes were randomized to ensure that neither side of the dog nor side of the walker was favored by a particular path or environmental stimulus. One person walked the dog while the other collected behavioral data, took a photograph for identification, and measured height at withers (in cm). Data were typically collected using a check sheet, but were occasionally recorded verbally using the voice memo app on an iPhone 5 (model ME306LL/A, Apple Inc., Cupertino, CA, USA) and later transferred to a check sheet. Most dogs were walked once; however, 4 of the 102 dogs from the Cortland shelter were walked two or three times and 43 of the 175 dogs from the Tompkins shelter were walked between two and eight times, with each walk occurring on a different day. For logistical reasons (distance from campus) our visits to the Tompkins shelter were more frequent (two or three times a week) than our visits to the Cortland shelter (once a week). This scheduling difference, along with adoptions at each shelter during our study, resulted in different numbers of walks for dogs. All walks occurred between 12:00 and 17:00 h.

During each walk, we recorded the posture used by the dog for each urination. We classified urinary postures for females as squat and squat-raise, and for males as lean-forward or raised-leg (and occasionally squat), based on previous descriptions (e.g., Sprague and Anisko, 1973; Wirant and McGuire, 2004). At the end of the walk we collected the following background data for each dog from shelter cage cards and veterinary records: name, identification number, intake date, sex, age, body mass (in kg), and reproductive status (intact; spayed or neutered). Based on assessments by shelter personnel, who monitored physical signs and behavioral changes, intact females were not in proestrus or estrus at the time of our data collection. All data were collected between February 16, 2013 and September 5, 2014, and all procedures were carried out under protocol 2012-0150, which was approved by Cornell University's Institutional Animal Care and Use Committee.

2.3. Statistical analyses

We assigned age classes (juvenile, adult, or senior) using height at withers and age, employing a system similar to that described by Řezáč et al. (2011). This system takes into account that puberty usually occurs earlier in smaller dogs than larger dogs (Pineda, 2003), and uses size classes based on breed standards set forth by the Fédération Cynologique Internationale (FCI). For reference, puberty typically occurs between 6 and 9 months of age for male dogs (spermatozoa in ejaculate) and between 9 and 16 months for female dogs (first overt heat displayed; Pineda, 2003). We classified juveniles as any small dog (<30 cm) younger than 9 months, any medium dog (30–50 cm) younger than 12 months, or any large dog (>50 cm) younger than 16 months. Adults were classified as any dog between the maximum juvenile age (based on height at withers) and up to, but not including, 8 years. Seniors were classified as any dog 8 years or older. We used intake date to calculate the number of days each dog had been at the shelter on the day of its walk (= time at shelter). Dog behaviors unrelated to urination (e.g., time spent resting or barking in cages) vary as a function of time spent at a shelter (Wells et al., 2002), so we wanted to examine the potential influence that time at shelter might have on urinary behavior as well.

We analyzed data from each shelter separately due to differences in the areas available for walking and resulting differences in observation times. First, we examined factors that might influence propensity to raise a hindlimb during urination (n = 170 dogs at the Tompkins shelter; n = 94 dogs at the Cortland shelter). We performed this analysis using a Generalized Linear Mixed Model with a binomial distribution and a logit link function (proc GLIMMIX) in SAS version 9.3 (SAS Institute, 2001). The sampling unit for the analysis was a single urination of a single dog on a single walk. The model for the Cortland shelter included the following fixed factors:

sex, age class, reproductive status, and time at shelter. Only nine dogs (two males and seven females) fell into the senior age class from the Cortland shelter, so all senior dogs were removed and the model was run with juvenile and adult dogs only. We found a difference in likelihood of raising a hindlimb between adults and seniors at the Tompkins shelter (see Section 3.1), so we chose not to pool adults and seniors at the Cortland shelter. The Cortland model included dog as a random effect but excluded walk within dog due to the small number of dogs that were walked multiple times ($n = 4$ dogs). Finally, we examined a sex by reproductive status interaction at the Cortland shelter; this interaction was not significant, so we dropped it from the final model. The model for the Tompkins shelter contained the same fixed factors as the Cortland shelter with the exception of reproductive status. Sample sizes of intact males ($n = 8$) and intact females ($n = 7$) were too small at the Tompkins shelter to include reproductive status in the analysis, so we considered intact and gonadectomized dogs of each sex together. We pooled dogs of different reproductive status at the Tompkins shelter because previous findings (Beach, 1974; Martins and Valle, 1948) and our data from the Cortland shelter (see Section 3.1) indicated that reproductive status did not influence likelihood of raising a hindlimb in dogs. Dog and walk within dog were random factors in the model for the Tompkins shelter. We examined the sex by age interaction at the Tompkins shelter using adult and senior dogs; we had to exclude juvenile dogs from this analysis because none of the juvenile females raised a hindlimb during urination. The interaction was not significant, so we dropped it from the final model. We used *t*-tests to compare least squares means, and employed the Bonferroni correction for multiple comparisons when appropriate. In addition to examining age as a categorical variable in our Generalized Linear Mixed Models, we further explored the relationship between age and likelihood of raising a hindlimb by plotting for each dog the percent of urinations that involved a raised hindlimb against age as a continuous variable. We combined data from the two shelters (age-related patterns were similar at the two shelters, with age as a categorical variable; see Section 3.1) and examined general patterns in males and females separately. These data with age as a continuous variable were not subjected to statistical analyses; the plots were simply meant to provide a visual display of the data and to aid with interpretation.

Next, we determined the overall population laterality for each shelter using two different methods. First, because multiple urinations were observed during each walk, and some dogs were repeatedly measured over multiple walks, we used a Generalized Linear Mixed Model with a binomial distribution and a logit link function (proc GLIMMIX) to model the ratio of raising the right hindlimb versus raising the left hindlimb. All dogs that raised a hindlimb at least once during their walks were included in the analysis ($n = 92$ dogs at the Tompkins shelter; $n = 50$ dogs at the Cortland shelter). The model for the Tompkins shelter included dog and walk within dog as random effects. The model for the Cortland shelter included dog as the only random effect.

Our second method of assessing population laterality is more commonly used in studies of laterality in dogs (e.g., Batt et al., 2009; McGreevy et al., 2010; Poyser et al., 2006). We calculated a laterality index for each dog with more than 10 urinations involving a raised hindlimb. We chose 10 as the minimum number in order to ensure accuracy of the normal approximation (i.e., dogs with one or a few urinations could bias the distribution; Brožek and Tiede, 1952). Laterality indices were calculated using the following equation from Tompkins et al. (2012a), which we modified for hindlimb raises: ((Number of right hindlimb raises − Number of left hindlimb raises)/(Number of right hindlimb raises + Number of left hindlimb raises)) × 100. Negative values for the laterality index indicate a left side preference, while positive values indicate a right side preference. A Shapiro–Wilk test was used to determine whether the distributions were significantly different from normal, which would indicate a population bias. We used Excel (Microsoft, 2010) and SPSS (SPSS Inc., 1999) for these analyses.

We determined laterality strengths, which are the absolute values of the laterality indices, from the same group of dogs with more than 10 urinations involving a raised hindlimb. Laterality strength does not depend on which side is used; the important factor is how consistently dogs use one side or the other. The response value is on a scale from 0 to 100, with zero meaning that a dog uses both hindlimbs equally, and 100 meaning that a dog will never switch from the first hindlimb it uses.

We calculated *Z*-scores, as done by other authors (Batt et al., 2007; Branson and Rogers, 2006; Wells, 2003), to classify dogs with more than 10 urinations involving a raised hindlimb as left preferent, right preferent, or ambilateral. *Z*-scores were calculated using the following equation from Branson (2006): (Number of right hindlimb raises − ½ × Total number of hindlimb raises)/sqrt (1/4 × Total number of hindlimb raises). A dog was considered left-preferent if $Z \leq -1.96$ and right-preferent if $Z \geq 1.96$ (Branson, 2006). To examine any changes that might result from analyzing data from a smaller sample of dogs, but each dog with a larger number of scores, we repeated our analyses of laterality indices, laterality strengths, and *Z*-scores for dogs with more than 20 urinations involving a raised hindlimb.

3. Results

3.1. Occurrence of urinations in which a hindlimb was raised

Out of a total 1621 urinations at the Tompkins shelter, 1218 (75.1%) involved a raised hindlimb. At the Cortland shelter, the total number of urinations was 441, with 353 (80.0%) involving a raised hindlimb. For those urinations at the Tompkins shelter that did not involve a raised hindlimb, 161 (10.0%) were lean-forwards by males and 242 (15%) were squats by females and 6 juvenile males. For those urinations at the Cortland shelter that did not involve a raised hindlimb, 40 (9.1%) were lean-forwards by males and 48 (10.9%) were squats by females and one juvenile male.

For likelihood of raising a hindlimb during urination, we found a significant effect of sex at the Tompkins shelter ($F = 68.43$, *d.f.* = 1, 1326, $P < 0.0001$) and at the Cortland shelter ($F = 30.53$, *d.f.* = 1, 310, $P < 0.0001$): at both shelters, males were more likely than females to raise a hindlimb during urination ($P < 0.0001$ at each shelter; Fig. 1). We also found a significant effect of age class on likelihood of raising a hindlimb during urination at the Tompkins shelter ($F = 16.47$, *d.f.* = 2, 1326, $P < 0.0001$) and at the Cortland shelter ($F = 12.77$, *d.f.* = 1, 310, $P = 0.0004$). At the Tompkins shelter, seniors were more likely than adults, which, in turn, were more likely than juveniles to raise a hindlimb during urination (Fig. 1A). At the Cortland shelter, adults were more likely than juveniles to raise a hindlimb during urination (data for senior dogs were not analyzed, but are included in Fig. 1B for comparison). When plotting percent of urinations involving a raised hindlimb against age as a continuous variable, we found that males older than 2 years of age used the raised-leg posture for a majority of their urinations (Fig. 2A). However, individual adult males were highly variable in their use of the raised-leg posture: whereas some males exclusively used the raised-leg posture, others used it for most but not all urinations, and still others were never observed to raise a hindlimb during urination (Fig. 2A). Only females that were at least 2 years old used the squat-raise posture (Fig. 2B).

We did not find a significant effect of reproductive status at the Cortland shelter on likelihood of raising a hindlimb during urination (% of urinations in which a hindlimb was raised, using data from adults and seniors, but not juveniles: intact males, 96.4%; neutered

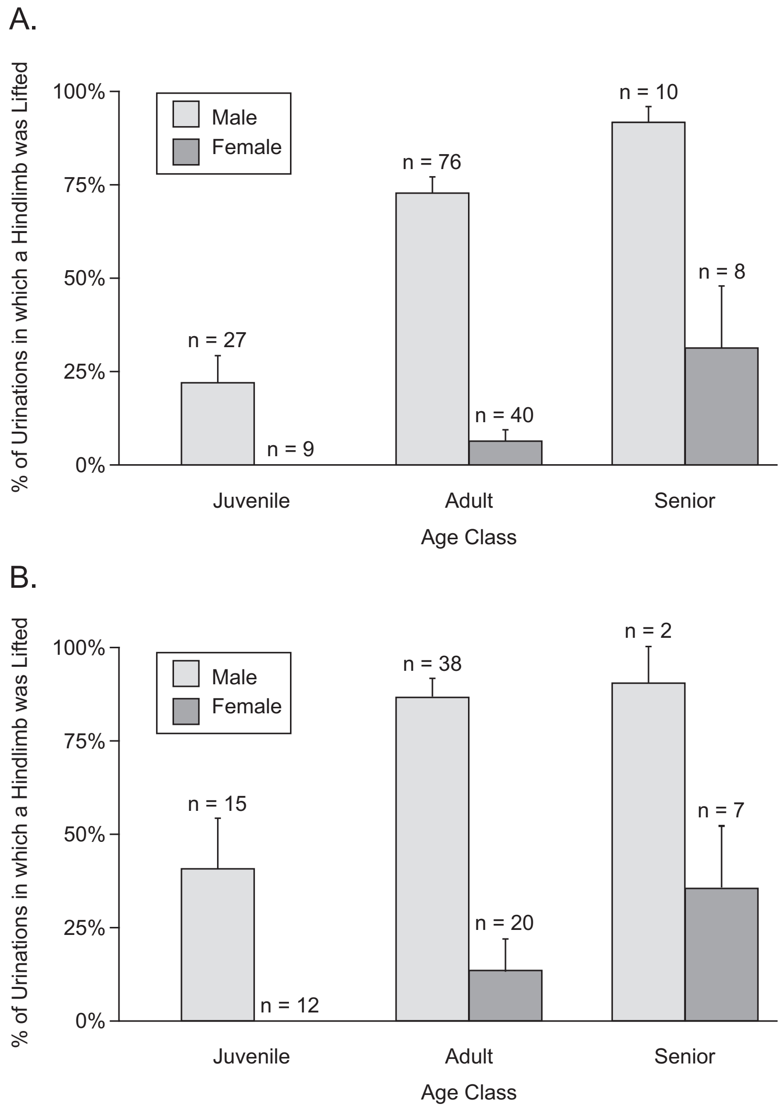

Fig. 1. Percentage of urinations by dogs that involved a raised hindlimb as a function of sex and age class. Data (mean ± *SE*) are shown for dogs from the Tompkins County SPCA (A) and the Cortland Community SPCA (B). Sample sizes for senior males at the Cortland shelter were too small to include seniors in statistical analyses; here, we included data for senior dogs for comparison.

males, 92.1%; intact females, 12.3%; spayed females; 13.7%; $F = 0.05$, *d.f.* = 1, 288, $P = 0.8177$). Likelihood of raising a hindlimb during urination was not significantly affected by time spent at either shelter (Tompkins shelter: $F = 3.58$, *d.f.* = 1, 1326, $P = 0.06$; Cortland shelter: $F = 0.08$, *d.f.* = 1, 1326, $P = 0.78$).

3.2. Laterality

We found no evidence of a population bias for dogs raising either the right or left hindlimb during urination at either shelter: 53.25 ± 0.03% of the raised hindlimb urinations at the Tompkins shelter and 43.00 ± 0.04% of the raised hindlimb urinations at the Cortland shelter involved the right hindlimb. Neither percentage was significantly different from 50%. In the model for the Tompkins shelter, 7.0% of the total variability could be explained by variability between dogs, 8.7% by variability between walks for a single dog, and the rest by variability between urinations during a single walk. In the model for the Cortland shelter, 18.0% of the total variability could be explained by variability between dogs, while the rest could be explained by variability between urinations during a single walk.

Frequency distributions for individual laterality indices for dogs with more than 10 urinations involving a raised hindlimb are shown by shelter in Fig. 3. A Shapiro–Wilk test of normality was not significant for either shelter (Tompkins shelter, *d.f.* = 35, $P = 0.351$; Cortland shelter, *d.f.* = 10, $P = 0.355$); these results confirm absence of a population bias at each shelter. The mean laterality index (± *SE*) for these dogs was 12.69 ± 5.40 for the Tompkins shelter ($n = 35$) and -13.97 ± 12.18 for the Cortland shelter ($n = 10$). The mean laterality strength (± *SE*) was 25.61 ± 3.85 for the Tompkins shelter ($n = 35$) and 28.82 ± 8.81 for the Cortland shelter ($n = 10$). *Z*-score analysis revealed that most dogs with more than 10 raised hindlimb urinations were ambilateral (Tompkins shelter, 1 left-preferent, 5 right-preferent, and 29 ambilateral; Cortland shelter, 1 left-preferent and 9 ambilateral).

Dogs ($n = 22$) with more than 20 urinations involving a raised hindlimb are described in Table 2, which also includes the laterality index and *Z*-score for each. The mean laterality index for this group of dogs was 7.70 ± 8.34 and the mean laterality strength was 28.12 ± 5.89. Most dogs in this group were ambilateral (shelters combined due to small sample size; 2 left-preferent, 3 right-preferent, and 17 ambilateral).

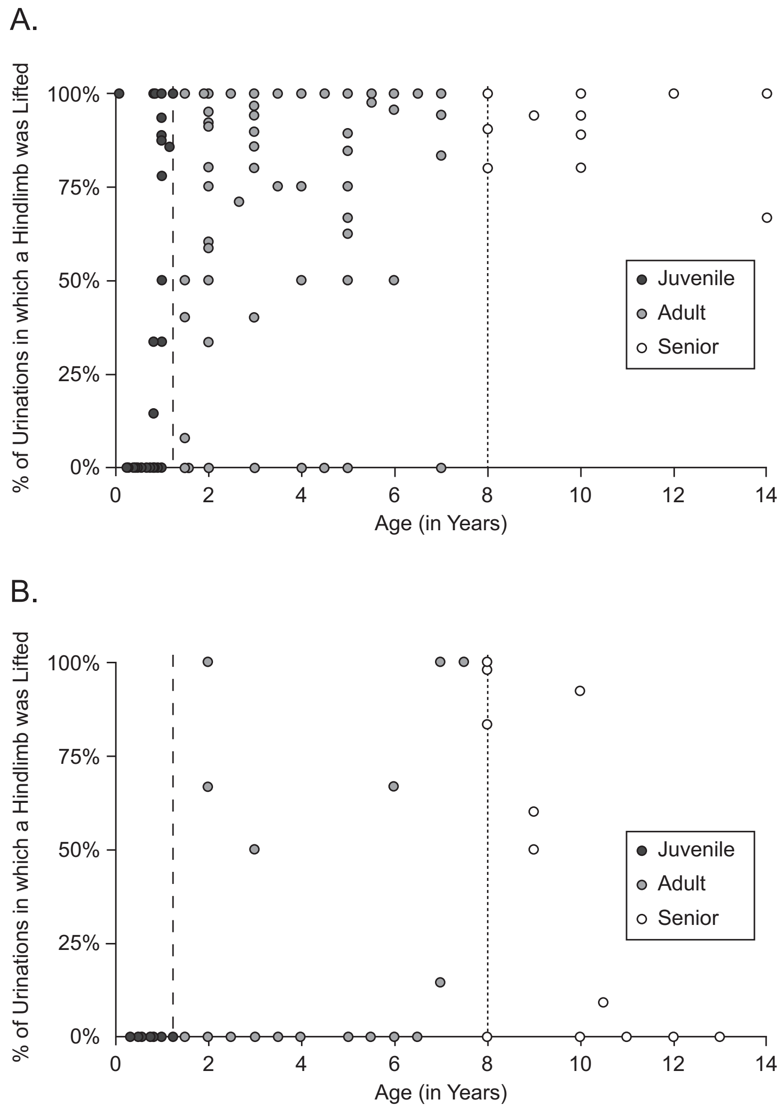

Fig. 2. Percentage of urinations by dogs that involved a raised hindlimb as a function of age as a continuous variable. Data are shown for male dogs (A; two shelters pooled) and female dogs (B; two shelters pooled). Vertical dashed lines indicate the approximate separation between juvenile and adult age classes (dashed line on left) and the separation between adult and senior age classes (dashed line on right).

4. Discussion

At both shelters, male dogs were more likely than female dogs to raise a hindlimb during urination. Our finding for shelter dogs of a sex difference in likelihood of raising a hindlimb when urinating agrees with what has been reported for free-ranging dogs (Bekoff, 1979; Cafazzo et al., 2012; Pal, 2003), dogs maintained in a laboratory colony (Sprague and Anisko, 1973), and other canids, whether free-living or captive (e.g., coyotes, *Canis latrans*, Gese and Ruff, 1997; wolves, *Canis lupus*, Asa et al., 1985). The four previous studies with dogs found that from 94 to 97% of male urinations involved raising a hindlimb as compared with 19–37% of female urinations. Three of these studies focused exclusively on urinary postures of dogs that were at least of adult age but did not distinguish between adult and senior age classes (Bekoff, 1979; Pal, 2003; Sprague and Anisko, 1973), while the fourth study did not detail urinary postures of males and females by all age classes studied (juvenile, subadult, and adult; Cafazzo et al., 2012), making direct comparisons with our data difficult. As a general statement, our values for raised-leg urinations for senior males (91% at the Tompkins shelter and 90% at the Cortland shelter) and squat-raise urinations for senior females (25% at the Tompkins shelter and 35% at the Cortland shelter) are similar to those reported previously, but our values for adult males (73% at the Tompkins shelter and 86% at the Cortland shelter) and adult females (6% at the Tompkins shelter and 14% at the Cortland shelter) are somewhat lower than previously reported. Our plot for males of percent of urinations involving a raised hindlimb versus age as a continuous variable (Fig. 2A) revealed variation in use of the raised-leg posture. Many adult males exclusively used the raised-leg posture during walks, but some used both the raised-leg and lean-forward postures, and a few were never observed to use the raised-leg posture. In fearful situations, mature male dogs sometimes temporarily revert to the juvenile lean-forward posture (Berg, 1944; Martins and Valle, 1948). Shelters are known to be challenging environments for dogs (Hennessy et al., 2001; Hiby et al., 2006), so it is possible that some males responded to shelter conditions by reverting to the juvenile posture for some or all urinations. The effect of stressful conditions on postures used by female dogs has not been studied. Our finding that most adult females at both shelters used the squat posture, rather than the squat-raise, is

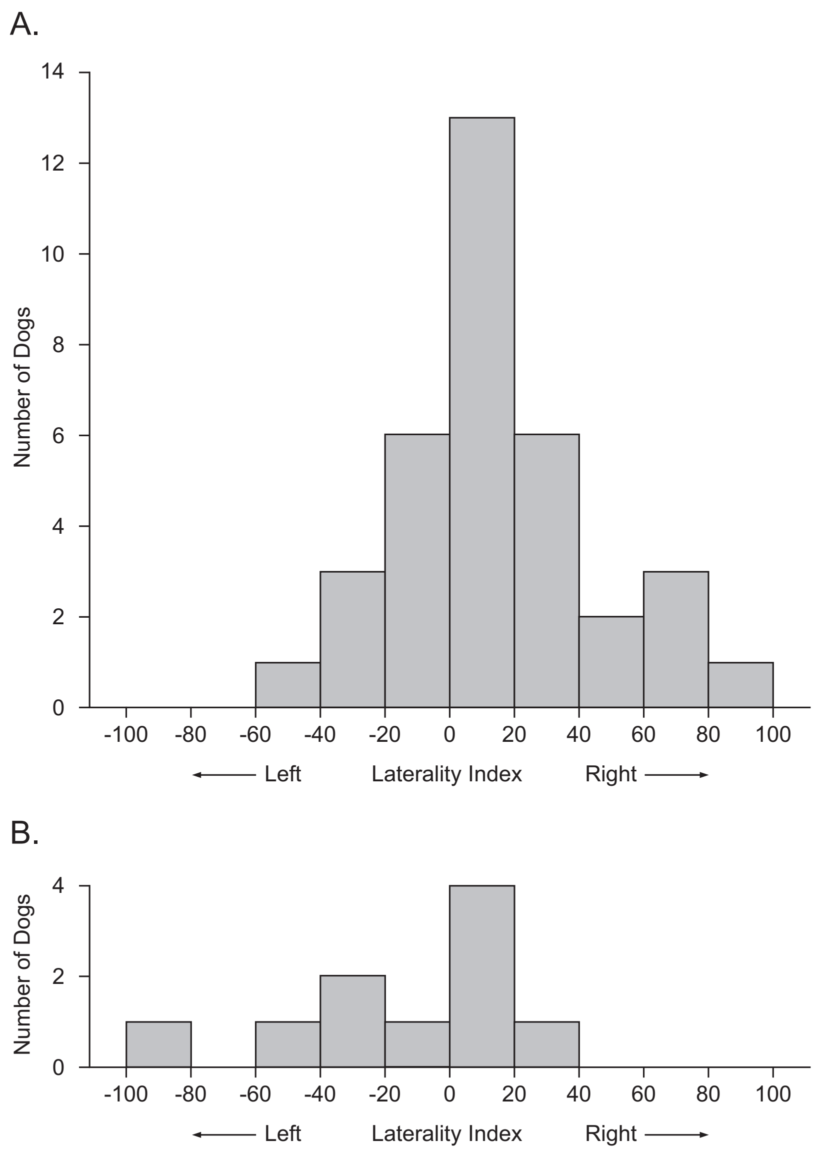

Fig. 3. Distribution of laterality indices for individual dogs with more than 10 urinations involving a raised hindlimb at the Tompkins County SPCA (A) and the Cortland Community SPCA (B).

similar to reports for female dogs in most previous studies (Bekoff, 1979; Pal, 2003; Sprague and Anisko, 1973; but not Wirant and McGuire, 2004).

Likelihood of raising a hindlimb when urinating increased with age for shelter dogs. At both shelters, adults were more likely than juveniles to raise a hindlimb, and this characterized both males and females. Our findings for juvenile and adult shelter dogs agree with those of Ranson and Beach (1985) who studied development of urinary postures in a laboratory colony of purebred beagles. These authors found that likelihood of raising a hindlimb during urination for males increased from 5% (months 2–6, before puberty) to 60% (months 7–12, puberty occurs in most males in the colony) to 96% (months 13–15, early adulthood; percentages are not given in their text but are estimated from Fig. 3 of Ranson and Beach, 1985). Ranson and Beach (1985) also found that use of the squat-raise posture by females increased from 3% of all urinations up to 6 months of age to 27% of urinations by the end of the first year. Thus, despite differences in specific percentages between our study and that by Ranson and Beach (1985), our overall finding for shelter dogs that adults are more likely than juveniles to raise a hindlimb during urination is consistent with their findings for laboratory beagles.

Our data for senior dogs suggest that canine urinary behavior continues to change after adulthood has been reached. At the Tompkins shelter, where we had sufficient senior dogs of both sexes for statistical analysis, seniors were more likely than adults to raise a hindlimb during urination, and this was true for both males and females. We found a similar pattern at the Cortland shelter, but the small number of senior male dogs precluded statistical analysis. Our data for urinary postures extend the observations of Wirant and McGuire (2004), who found that frequency of urination increased linearly with age in a sample of 12 female dogs ranging in age from 5 months to 11 years (male dogs were not studied). In contrast to our findings and those of Wirant and McGuire (2004), Ranson and Beach (1985) stated that no systematic changes in urinary behavior of normal dogs (i.e., those not subjected to experimental hormone manipulations) occur after 13–15 months of age, which they considered early adulthood, although no data on unmanipulated dogs older than 15 months were included to support their statement. Inclusion of senior dogs in future studies will help to further detail age-related changes in canine urinary behavior.

We did not find a significant effect of reproductive status on likelihood of raising a hindlimb during urination at the Cortland shelter,

Table 2
Individual hindlimb preferences for dogs with more than 20 urinations in which a hindlimb was raised.

Dog (shelter)[a]	Sex[b]	Reproductive status (walks)[c]	Raised hindlimb urinations			LI[d]	Z-score	Pref[e]
			Total	Right	Left			
Jacob (C)	M	I (1), N (2)	28	1	27	−92.86	−4.91	L
Diego (T)	M	I (1), N (3)	47	13	34	−44.68	−3.06	L
Gunner (T)	M	N (2)	23	8	15	−30.43	−1.46	A
Jimmy (T)	M	N (2)	27	11	16	−18.52	−0.96	A
Peanut (T)	M	N (4)	26	11	15	−15.38	−0.78	A
Carter (T)	M	N (6)	64	28	36	−12.50	−1.00	A
Scrappy (T)	M	N (5)	32	15	17	−6.25	−0.35	A
Amos (T)	M	N (4)	50	24	26	−4.00	−0.28	A
Danny (T)	M	N (5)	33	17	16	+3.03	+0.17	A
Jacob (T)	M	N (8)	107	56	51	+4.67	+0.48	A
Jerry (T)	M	N (7)	42	22	20	+4.76	+0.31	A
Ozzie (T)	M	N (8)	38	21	17	+10.53	+0.65	A
Diesel (T)	M	N (5)	43	24	19	+11.63	+0.76	A
Malikai (T)	M	N (1)	21	12	9	+14.29	+0.65	A
Yankee (T)	M	N (2)	21	12	9	+14.29	+0.65	A
Jack (T)	M	N (6)	42	26	16	+23.81	+1.54	A
Duke (T)	M	N (4)	42	27	15	+28.57	+1.85	A
Louie (T)	M	I (1)	21	14	7	+33.33	+1.53	A
Cassie (T)	F	S (5)	50	34	16	+36.00	+2.55	R
Teddy (C)	M	I (1), N (1)	22	15	7	+36.36	+1.71	A
Dobby (T)	M	N (5)	22	19	3	+72.73	+3.41	R
Camille (T)	F	S (7)	24	24	0	+100.0	+4.90	R

[a] T = Tompkins County SPCA; C = Cortland Community SPCA.
[b] M = male; F = female.
[c] I = intact; N = neutered; S = spayed; number of walks in parentheses.
[d] LI = laterality index; negative values indicate a left side-bias and positive values a right side-bias.
[e] Pref = preference; L = left; R = right; A = ambilateral (i.e., no side preference).

where we had sufficient intact males and females to compare with gonadectomized males and females. When considering adult and senior males, but not juvenile males, the percentage of urinations in which a hindlimb was raised was similar for intact males (96%) and neutered males (92%). These results agree with previous findings that intact adult males and neutered adult males exhibit similar urinary behavior with respect to likelihood of countermarking (Lisberg and Snowdon, 2011) and posture used when urinating (neutered males were castrated at either 4 months of age or 15–17 months of age; Beach, 1974). Males castrated within 2 days of birth, however, were less likely than intact males to show the raised-leg posture when tested in adulthood (Beach, 1974). When considering adult and senior females, but not juvenile females, the percentage of urinations in which a hindlimb was raised was similar for intact females (12%) and spayed females (14%). These findings agree with previous reports that anestrous intact and spayed females exhibit similar urinary behavior (Lisberg and Snowdon, 2011; Martins and Valle, 1948; Wirant and McGuire, 2004).

Several methods can be used to classify stage of estrous cycle in dogs; these include vaginal cytology, using vasectomized teaser males to determine estrus, and monitoring physical and behavioral signs (Pineda, 2003). We relied on reports from shelter staff that dogs were in anestrus, and not in proestrus or estrus. Staff assessments were based on physical signs and behavior, which can be less reliable than vaginal cytology under circumstances such as silent heat. Using vaginal cytology and physical signs and behavior to determine stage of estrous cycle, Wirant et al. (2007) found that privately owned Jack Russell Terriers directed a larger proportion of their urinations at obvious targets in the environment during proestrus and estrus than anestrus. In domestic dogs and other members of Canidae, directing urine at targets in the environment often involves raising a hindlimb (Kleiman, 1966). Thus, if some of the intact females in our study were incorrectly classified as being in anestrus, when they were in either proestrus or estrus, then our value of 12% of urinations involving a raised hindlimb might be high. We consider it unlikely that females were misclassified with respect to reproductive state because our value of 12% is lower (not higher) than that found for anestrous females in other studies (e.g., median proportion of directed urinations = 0.40; Wirant et al., 2007).

We found no evidence of a population-wide bias at either shelter for the hindlimb raised when urinating. These findings add to the general consensus that an overall side-bias does not exist for domestic dogs (McGreevy et al., 2010; Poyser et al., 2006; Quaranta et al., 2004; Wells, 2003). Some studies found population lateralization in opposite directions for males and females, with male dogs predominantly left-pawed and females predominantly right-pawed (Quaranta et al., 2004; Wells, 2003). The only study to find a population-wide bias was performed by Tan (1987), who found a slight right side-bias. However, his population was skewed toward females (19 out of 28 dogs), so this could account for the discrepancy between his study and later studies. Unfortunately, relatively few females in our study used the squat-raise posture, so we were unable to examine motor laterality in females versus males.

Most dogs in our study were ambilateral (i.e., non-lateralized) with respect to hindlimb raised when urinating. When using 10 urinations in which a hindlimb was raised as the minimum needed, we found that 83% of dogs at the Tompkins shelter and 90% of dogs at the Cortland shelter were ambilateral. When using 20 urinations as the minimum needed, we found that 77% of dogs were ambilateral (dogs from the two shelters were pooled for this analysis). In previous studies of motor laterality in dogs, percent of dogs characterized as ambilateral has ranged from 0 to 63%, with most studies reporting 25% or lower (see Table 1 in review by Tompkins et al., 2010b). Although our finding that most dogs are ambilateral differs from most previous studies of motor laterality involving other behavioral tasks, it is consistent with one of two previous studies of hindlimb raised during urination in dogs (these two studies were not included in Table 1 of the review by Tompkins et al., 2010b, perhaps because of their more anecdotal nature). With respect to hindlimb raised when urinating, Branson (2006) found that 13 of 16 dogs (81%) were ambilateral. In contrast, Berg's (1944) data, which included many more urinations per dog but fewer dogs than in either our study or that by Branson (2006), revealed that only one of five dogs (20%) was ambilateral (*Z*-scores calculated by us using raw data provided in Berg, 1944). These discrepant findings for the hindlimb raised when urinating illustrate the difficulty of finding consistent patterns in laterality when studies vary in sample size and number of observations per dog (Tompkins et al., 2010b).

Use of hindlimb raised during urination as the behavioral task for scoring motor laterality has disadvantages and advantages. According to Tompkins et al. (2010b), the task selected to assess laterality should be noninvasive and safe for the dog, ethically acceptable, cost effective, and repeatable; the task also should allow for sufficient repetitions and be unbiased with respect to subsamples of the study population. Hindlimb raised during urination meets many of these criteria, but falls short in terms of the difficulty associated with obtaining sufficient repetitions. Tompkins et al. (2010b) reported that number of observations per dog in previous laterality studies has ranged from 3 to 125; they recommended that future studies have at least 45 scores for each dog. We could not adhere to this recommendation for most dogs because of the challenge of obtaining multiple scores per walk for certain dogs, coupled with the transient nature of our study population (i.e., dogs were adopted before sufficient walks could be obtained). Additionally, urinary behavior is sexually dimorphic, with males urinating more frequently than females, and males being more likely to raise a hindlimb (this study; Beach, 1974; Ranson and Beach, 1985; Sprague and Anisko, 1973), so raising a hindlimb also is biased with respect to population subsamples. Some tasks, such as those involving feeding (e.g., paw used to hold a Kong toy filled with food) can be problematic because the motivation to eat varies among dogs (Tompkins et al., 2010b). Our use of the hindlimb used during urination raises motivational issues of a different nature because urination may be motivated by the need to empty the bladder (elimination) or the desire to leave a message (scent-marking). Nevertheless, use of a natural behavior avoids issues with artificial tasks, such as give-a-paw, that may be influenced by pre-training by owners (Wells, 2003), and data on hindlimb behaviors, in particular, are scarce in the literature on motor laterality (see studies covered in the review by Tompkins et al., 2010b).

Finally, canine urinary behavior appears robust to differences in methods and walking environments. For example, the leads at the Tompkins shelter were 5 m in length and those at the Cortland shelter were 1.8 m in length. Because of this difference in length of lead, and several other differences between the two shelters (e.g., size of area available for walking, which necessitated different lengths of observation periods), we analyzed data from each shelter separately. Nevertheless, our basic results are similar from the two shelters with respect to sex and age differences in likelihood of raising a hindlimb during urination (as shown in Fig. 1) and laterality results (i.e., most dogs at each shelter were ambilateral).

5. Conclusions

Dogs at two shelters exhibited basic sex and age differences in urinary postures previously reported for dogs living under other conditions. Specifically, males were more likely than females to raise a hindlimb during urination and adults were more likely than juveniles to raise a hindlimb. Our finding that seniors were more likely than adults to raise a hindlimb when urinating provides additional evidence that canine urinary behavior continues to change, even after individuals reach adulthood. An overall bias for raising either the left or right hindlimb did not characterize either shelter population, and most dogs were ambilateral. Assessing motor laterality for a natural hindlimb behavior during walks has advantages, such as ease of observation during a positive experience for dogs, and disadvantages, such as the difficulty in obtaining sufficient scores for some dogs.

Conflict of interest

The authors declare no conflict of interest.

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