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Research Article

Clinical Study of Osteoarticular Dysfunctions in Domestic Dog Puppies During Lactation and Weaning in Manual Veterinary Medicine

Yvonne Schawlb[1], Mélina Ribaud[2,3] and Jean-Pierre Pallandre[4,5]*

[1]Cabinet Vétérinaire Kiniseïs Vet, France

[2]Department of Decision Science, HEC Montreal, Montreal, Canada

[3]Department of Mathematics, Université du Québec à Montreal, Montreal, Canada

[4]Institut de Systématique Evolution Biodiversité (ISYEB), Muséum National d'Histoire Naturelle, CNRS, Sorbonne Université, Paris, France

[5]Clinique Vétérinaire du Chien Vert, Jonage, France

***Corresponding Author:** Jean-Pierre Pallandre, Institut de Systématique Evolution Biodiversité (ISYEB), Muséum National d'Histoire Naturelle, CNRS, Sorbonne Université, Paris, France.

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Abstract

This first clinical study evaluates the benefits of using manual veterinary medicine to assess and treat musculoskeletal dysfunction in very young puppies. Osteoarticular dysfunction was assessed in 75 dogs at one and two months of age. Manual therapy was performed after each evaluation. Our results show that puppies develop osteoarticular dysfunction as early as their first month of life with more dysfunctions appearing during the first month than during the second month of life. Within the musculoskeletal system, dysfunctions are not evenly distributed with limb dysfunctions accounting for around 3/4 (at one month) and 2/3 (at two months) of all dysfunctions. The shoulder is responsible for almost all disorders of the front limb, and the hip and patella for those of the rear limb. The withers region and the craniocervical junction are the most affected areas for the spine. The breed has a significant impact on the number of osteoarticular dysfunctions but morphotype, farrowing condition, and sex, have no effect on dysfunction in our study. The location of the main dysfunctions could provide a biomechanical explanation for certain orthopedic diseases that dogs can develop at an early age. Therefore, the assessment and treatment of osteoarticular dysfunctions could contribute to the prevention of orthopedic diseases in young dogs.

Keywords: Manual Veterinary Medicine; Puppies; Dogs; Orthopedics; Osteopathy; Breeds

Abbreviations

B: Beauceron; C0: Occipital Bone; C1-7: Cervical Vertebrae Rank; C-Section: Cesarean Section; CS: Cocker Spaniel; CT: Cairn Terrier; D: Dachshund; FB: French Bulldog; J: Joint; L1-7: Lumbar Vertebrae Rank; m: Mastiff; OES: Old English Sheepdog; S1: First Sacral Vertebra; ST: Shih Tzu; T1-13: Thoracic Vertebrae Rank; WHWT: West Highland White Terrier; Y: Yorkshire Terrier

Introduction

In the last decades, canine lameness as a result of non-traumatic diseases has assumed greater importance. Studies based on breed genetics, diet, activities, and other ecological traits demonstrated their influence on young dog musculoskeletal affections [1,2]. In the mean time, non-invasive treatments and rehabilitation, such as physiotherapy and manual therapy developed [3,4] but, beside outdoor activity and food quality, few options are offered to prevent non-traumatic diseases in young dogs.

In humans, the manual therapeutic approach in pediatrics has brought definite benefits to the care of newborns and even premature babies [5,6]. For example, for preterms born between 29- and 37-weeks gestation, with no congenital or genetic disease, manual management of their ailments significantly reduces the number of days spent in hospital, as well as the daily cost of treatment [5]. No undesirable side-effects of manipulations have been demonstrated, and the techniques used have no effect on weight gain in premature babies, but on their general state of health. However, their effectiveness in specific areas, such as neurological or respiratory sequelae linked to prematurity, remains difficult to demonstrate [5].

Without considering premature animals, the aim of this original study is to propose a clinical evaluation of the value of early management of domestic dog puppies (*Canis lupus familiaris*) in veterinary manual medicine consulations. First, we evaluate and record joint dysfunctions in one- and two-month-old puppies. For the purpose of this study, a dysfunctional joint is characterized by a reduction in joint amplitude. Identifying the nature of the tissue involved in the dysfunction (*e.g.*, muscle, fascia, ligament, joint capsule, articular surface) is not part of our study. Manual treatment is carried out after each evaluation. Then, we evaluate the impact of various factors likely to influence the appearance of joint dysfunctions: puppy breed, morphotype, sex and whelping conditions. We predict an influence of breed and morphotype on dysfunctions in relation to biomechanical constraints due to morphological selection. We expect that parturition conditions and, above all, obstetrical maneuvers, may also influence joint dysfunction. Gender remains an unpredictable factor. All the results will be discussed in the context of the biomechanical constraints that can impact the development of structures during growth, and the preventive and therapeutic value of early management of puppies in veterinary manual medicine.

Material and Methods

Data

For this study, 75 dog puppies with no congenital or genetic disease, belonging to 10 breeds, representing 15 litters, were recruited from the breeders (Table 1). The whelping conditions were reported and classified into three categories: (i) natural delivery without obstetric intervention; (ii) obstetric maneuver performed by the breeder (*i.e.*, pulling on the puppy); (iii) cesarean preventive section (Table 1). Consultations in manual veterinary medicine were performed on all puppies at one and two months of age. Musculoskeletal dysfunctions (*i.e.*, reduced range of mobility) observed in each animal were recorded and treated. All dogs from the same litter were examined on the same day of consultation. Docteur Vétérinaire (DV) Yvonne Schawlb examined all puppies. Only puppies present at both consultations were included in this study. All manipulations for diagnosis and treatment followed veterinary consultation ethic standards. No permits were required for the described study.

Breed	Morphotype	Number of specimen	Number of litter	Whelping conditions
Beauceron	Lupoid	8	1	Natural
Cairn Terrier	Lupoid	5	2	Natural
Cocker Spaniel	Braccoid	15	3	Natural/Maneuver*
Dachshund	Braccoid	10	2	Natural
French Bulldog	Molossoid	5	1	C-section
Mastiff	Molossoid	5	1	C-section
Old English Sheepdog	Lupoid	11	1	Natural
Shih Tzu	Molossoid	5	1	Natural
West Highland White Terrier	Lupoid	3	1	Natural
Yorshire Terrier	Lupoid	8	2	Natural/C-section**

Table 1: Dog puppies used in this study. C-section, cesarean section.

(*) Obstetric maneuver on one litter of six puppies.

(**) Cesarean section on one litter of four toy puppies, other puppies being standard Yorshire Terrier puppies.

Evaluation of osteoarticular dysfunctions

Osteoarticular dysfunctions were evaluated by passive mobilization of the joints. For the limbs, the range of mobility of the distal bone of the joint relative to the proximal bone of the joint was assessed from hyperflexion to hyperextension in the sagittal plane, from hyperabduction to hyperadduction in the transverse plane in half-flexion, from hyperinternal rotation to hyperexternal rotation in half-flexion. When one of the physiological limits in these three-dimensional directions was not reached, the joint was considered to be dysfunctional. For the spine, the range of mobility of the n-rank vertebra relative to the (n + 1)-rank vertebra was evaluated in flexion and extension in the sagittal plane, and in rotation on each side. If any of these movements was disturbed, the joint was considered to be dysfunctional. When the spine processes of a pair of vertebrae could not come together in the sagittal plane, a lack of extension (= over flexion) was considered. When the spine processes of a pair of vertebrae could not move apart in the sagittal plane, a lack of flexion (= over extension) was considered. When a spine process could not move symmetrically from one side of the spine axis to the other, a lack of rotation and side bending was considered according to vertebral biomechanics [7,8].

Statistical analyzes

The overall anatomical distribution of osteoarticular dysfunctions was calculated. The effect of breed, morphotype, sex, and farrowing conditions was calculated on the data set collected at one month of age before treatment (Table 1, Appendix 1). Morphotype classes were determined following Mégnin (1932) and Queinnec (1991) classification [9,10]: (i) lupoid, dogs with horizontal triangular head, erect ears, long muzzle, small tight lips, midline body (*i.e.*, Beauceron, Cairn Terrier, Old English Sheepdog, West Highland White Terrier, Yorshire Terrier); (ii) braccoid, dogs with prismatic head, drooping ears, muzzle as large at the base as at the tip, long drooping lips, midline body (*i.e.*, Cocker Spaniel, Dachshund); (iii) molossoid, dogs with round or cuboid head, drooping ears, short muzzle, long and thick lips, short body (*i.e.*, French Bulldog, Mastiff, Shih Tzu) (Table 1). In our study, only 3 morphotype classes (i.e., lupoid, molossoid and braccoid morphotypes) out of 4 were represented, with no specimens of the graïoid class present in our data (Table 1, Appendix 1). Because all of the recorded data did not follow the assumptions of normal distribution and homoscedasticity, we used non-parametric statistical tests [11]. Descriptive analyzes (median, first and third quartiles) were performed on the set of data. We used a Kruskal-Wallis K-test followed by Dunn post-hoc test [12] to test the dysfunctions in breeds, morphotype and whelping classes (Table 1). We tested the effect of sex on osteoarticular dysfunctions by using a Mann-Whitney U-test. The level of significance for all tests was p-value < 0.05.

Treatment

Passive mobilizations of the joints were used to treat oteoarticular dysfunctions following veterinary manual therapy standards [4,13] adapted to puppies. Joint mobility was reevaluated after treatment following the former protocol. Treatment was considered to be efficient if the range of mobility of the joint did recover after treatment, When the range of mobility of the joint did not recover after treatment, the dysfunction was eliminated from the data set because it was not possible to assess whether the lack of motion was due to ineffective treatment or to a physiological biomechanical imbalance, but this case did not occur in this study. All dysfunctions could be treated at ages of 1 and 2 months. It is salient to notice that no side effects were observed after manipulations.

To evaluate the evolution of the number of observed dysfunctions on our sample before treatment at ages of one and two months, we used a Wilcoxon signed-rank test, with a level of significance at p-value < 0.05 [27]. We also calculated Spearman correlation between the number of dysfunctions observed at one and two months of age [14].

Results

Distribution of osteoarticular dysfunctions

Tables 2-5 present the overall anatomical distribution of osteoarticular dysfunctions found in studied puppies at one month (before treatment) and 2 months (*i.e.*, one month after the first treatment and just before the second treatment) of age.

For a total of 114 dysfunctions, 89 were observed at the age of one month *versus* 25 at the age of two months (Table 2). The jaw (*i.e.*, temporomandibular joint) was never affected in any of studied

Dysfunction Localization	Number of dysfunctions		Percentage of dysfunctions	
	at 1 month	at 2 months	at 1 month	at 2 months
Jaw	0	0	0,00%	0,00%
Spine	23	7	25,84%	28,00%
Front limb	38	9	42,70%	36,00%
Hind limb	28	9	31,46%	36,00%
Total	89	25	100,00%	100,00%

Table 2: Overall distribution of osteoarticular dysfunctions found in puppies at one and two months of age.

Dysfunction Localization	Number of dysfunctions		Percentage of dysfunctions	
	at 1 month	at 2 months	at 1 month	at 2 months
Cervical joints	10	2	43,48%	28,57%
C0-C1	8	1	34,78%	14,29%
C1-C2	0	0	0,00%	0,00%
C2-C3	1	1	4,35%	14,29%
C3-C4	1	0	4,35%	0,00%
C4-C5	0	0	0,00%	0,00%
C6-C7	0	0	0,00%	0,00%
C7-T1	0	0	0,00%	0,00%
Thoracic joints	11	4	47,83%	57,14%
T1-T2	3	0	13,04%	0,00%
T2-T3	0	0	0,00%	0,00%
T3-T4	1	1	4,35%	14,29%
T4-T5	3	0	13,04%	0,00%
T5-T6	1	1	4,35%	14,29%
T6-T7	0	1	0,00%	14,29%
T7-T8	1	0	4,35%	0,00%
T8-T9	1	0	4,35%	0,00%
T9-T10	1	1	4,35%	14,29%
T10-T11	0	0	0,00%	0,00%
T11-T12	0	0	0,00%	0,00%
T12-T13	0	0	0,00%	0,00%
T13-L1	0	0	0,00%	0,00%
Lumbar joints	2	1	8,70%	14,29%
L1-L2	0	0	0,00%	0,00%
L2-L3	1	0	4,35%	0,00%
L3-L4	0	0	0,00%	0,00%
L4-L5	0	0	0,00%	0,00%
L5-L6	1	0	4,35%	0,00%
L7-S1	0	1	0,00%	14,29%
Sacrocaudal joint	0	0	0,00%	0,00%

Table 3: Distribution of spine osteoarticular dysfunctions found in puppies at one and two months of age. C0, occipital bone; C1-7, cervical vertebrae rank; T1-13, thoracic vertebrae rank; L1-7, lumbar vertebrae rank; S1, first sacral vertebra.

Dysfunction localization	Number of dysfunctions		Percentage of dysfunctions	
	at 1 month	at 2 months	at 1 month	at 2 months
Left front limb	21	4	55,26%	44,44%
Scapulo-thoracic J	0	0	0,00%	0,00%
Shoulder J	19	4	50,00%	44,44%
Proximal radioulnar J	0	0	0,00%	0,00%
Humeroradial J	0	0	0,00%	0,00%
Humeroulnar J	0	0	0,00%	0,00%
Distal radioulnar J	0	0	0,00%	0,00%
Antebrachiocarpal J	1	0	2,63%	0,00%
Proximal carpal row J	0	0	0,00%	0,00%
Distal carpal row J	0	0	0,00%	0,00%
Pisiform J	1	0	2,63%	0,00%
Carpometacarpal J	0	0	0,00%	0,00%
Metacarpal J	0	0	0,00%	0,00%
Palangeal J	0	0	0,00%	0,00%
Right front limb	17	5	44,74%	55,56%
Scapulo-thoracic J	0	0	0,00%	0,00%
Shoulder J	12	4	31,58%	44,44%
Proximal radioulnar J	1	0	2,63%	0,00%
Humeroradial J	0	0	0,00%	0,00%
Humeroulnar J	0	0	0,00%	0,00%
Distal radioulnar J	0	0	0,00%	0,00%
Antebrachiocarpal J	2	0	5,26%	0,00%
Proximal carpal row J	1	0	2,63%	0,00%
Distal carpal row J	0	1	0,00%	11,11%
Pisiform J	1	0	2,63%	0,00%
Carpometacarpal J	0	0	0,00%	0,00%
Metacarpal J	0	0	0,00%	0,00%
Palangeal J	0	0	0,00%	0,00%

Table 4: Distribution of front limbs osteoarticular dysfunctions found in puppies at one and two months of age. J, joint.

Dysfunction localization	Number of dysfunctions		Percentage of dysfunctions	
	at 1 month	at 2 months	at 1 month	at 2 months
Left hind limb	11	3	39,29%	33,33%
Sacroiliac J	2	0	7,14%	0,00%
Hip J	4	2	14,29%	22,22%
Femoropatellar J	2	1	7,14%	11,11%
Meniscal J	0	0	0,00%	0,00%
Femorotibial J	0	0	0,00%	0,00%
Calcaneotarsal J	3	0	10,71%	0,00%

Tibiotalar J	0	0	0,00%	0,00%
Cuboid metatarsal J	0	0	0,00%	0,00%
Metatarsal J	0	0	0,00%	0,00%
Phalangeal J	0	0	0,00%	0,00%
Right hind limb	17	6	60,71%	66,67%
Sacroiliac J	1	0	3,57%	0,00%
Hip J	8	4	28,57%	44,44%
Femoropatellar J	7	2	25,00%	22,22%
Meniscal J	0	0	0,00%	0,00%
Femorotibial J	0	0	0,00%	0,00%
Calcaneotarsal J	0	0	0,00%	0,00%
Tibiotalar J	1	0	3,57%	0,00%
Cuboid metatarsal J	0	0	0,00%	0,00%
Metatarsal J	0	0	0,00%	0,00%
Phalangeal J	0	0	0,00%	0,00%

Table 5: Distribution of hind limbs osteoarticular dysfunctions found in puppies at 1 and 2 months of age. J, joint.

puppies (Table 2). Spinal disorders were in the minority (25.84% and 28.00%) compared to limb disorders that totalled 42.70% and 36.00% for the front limb and 31.46% and 36% for the hind limb respectively (Table 2).

During the first month of growth, 23 spinal dysfunctions occurred, while seven occurred during the second month of growth (Table 3). Most dysfunctions were observed in the cervical (10 at one month, and two at two months) and thoracic (11 at one month, and four at two months) joints compared to the lumbar joints that had two dysfunctions at one month and one at two months (Table 3). In the neck, the craniocervical junction (*i.e.*, occipitocervical joint; C0-C1) was more concerned than all other cervical joints (eight out of 10 dysfunctions at one month of age and one out of two at two months of age; Table 3). The caudal cervical joints, from the fourth cervical vertebra (C4) to the cervicothoracic junction (C7-T1), were never affected by dysfunction. In the thoracic spine, the cranial joints were affected from the first thoracic vertebra (T1) to the tenth (T10) whereas neither the more caudal thoracic joints nor the thoracolumbar junction were affected (Table 3).

Left and right forelimbs showed rather similar results with the shoulder being more dysfunctioning than all other joints (19 out of 21 dysfunctions at one month of age and four out of four at two months of age for the left forelimb, and 12 out of 17 dysfunctions at one month of age and four out of five at two months of age for the left forelimb; Table 4). No dysfunction was found in the thoracic girdle.

The joint with the most dysfunction in the hind limbs was the hip (four out of 11 dysfunctions at one month of age and two out of three at to months of age for the left hind limb, and eight out of 17 dysfunctions at one month of age and four out of six at two months of age for the right hind "limb (Table 5)". The femoropatellar joint was the second most dysfunctional with two out of 11 dysfunctions at one month of age and two out of three at two months of age for the left hind limb, and seven out of 17 dysfunctions at one month of age and two out of six at two months of age for the right "hind limb; (Table 5)". The sacroiliac joint, calcaneotarsal joint and tibiotarsal joint are the only other articulations that showed dysfunction in the puppies studied.

Breed

Figure 1 shows the descriptive analyzes on the number of osteoarticular dysfunctions used in this study.

The Kruskal-Wallis test shows that the breed has a significant effect on the number of dysfunctions observed on puppies of 1 month of age (K = 18.34, $p < 0.05$). Dunn's tests allow us to identify differences between puppy breeds taken in pairs. We obtain two significantly different groups with Cairn Terrier (median = 0), Beauceron (median = 0) and Daschund (median = 0) on one side and Cocker Spaniel (median = 1) and Mastiff (median = 2) on the other. Cairn Terrier is also significantly different from Yorkshire terrier, Old English Sheepdog, French Bulldog and Shih Tzu. The other tests are not significant.

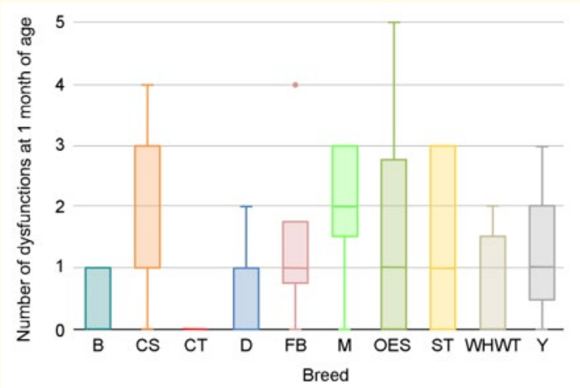

Figure 1: Box plots representing osteoarticular dysfunctions observed in puppies breeds at one month of age. B, Beauceron; CS, Cocker spaniel; CT, Cairn terrier; D, Dachshund; FB, French Bulldog; M, Mastiff; OES, Old English Sheepdog; ST, Shih Tzu; WHWT, West Highland White Terrier; Y, Yorkshire terrier.

Morphotype

Figure 2 shows the number of osteoarticular dysfunctions in morphotype classes used in this study. The Kruskal-Wallis test does not show any significant effect of the morpohotype on observed osteoarticular dysfunctions.

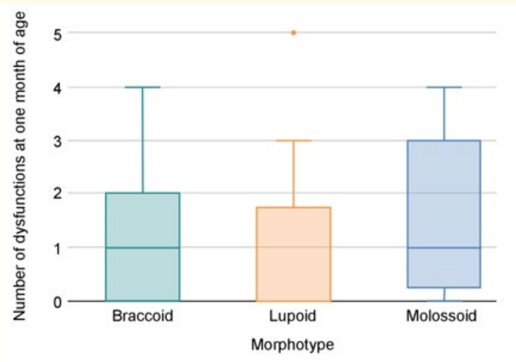

Figure 2: Box plots representing osteoarticular dysfunctions observed in morphotype classes at one month of age.

Whelping conditions

The Kruskal-Wallis test does not show any significant effect of the farrowing conditions on observed osteoarticular dysfunctions.

Sexe

The Mann-Whitney U-test does not show any significant effect of dog's sex on observed osteoarticular dysfunctions.

Evolution of dysfunctions after treatment

The Wilcoxon signed-rank test shows a significant difference (U = 939, p < 0;05) between the number of dysfunctions observed at one month of age before treatment and the number of dysfunctions observed at two months of age (*i.e.*, one month after first treatment).

Furthermore, the number of dysfunctions per individual at one month of age correlated very weakly with the number of dysfunctions at two months, with a Spearman correlation close to zero (r_s = - 0.01).

The results of the Wilcoxon test and the correlation show that the number of dysfunctions significantly changed between one month and two months in the puppies observed.

Discussion

Distribution of osteoarticular dysfunctions

This clinical study of osteoarticular dysfunctions in puppies up to two months of age shows that most disorders occur significantly during the first month of growth (Table 2; U = 939, $p < 0.05$; r_s = - 0.01). Although it is not possible to investigate dysfunctions that appear before birth (*i.e., in utero*), they remain a possibility. None of the studied dogs exhibit jaw dysfunction, suggesting that the feeding stresses associated with suckling do not impact the temporomandibular joint. Spinal axis, and thoracic and pelvic appendicular systems, account for approximately one-third of all dysfunctions each (Table 2). However, spinal joints dysfunctions are less represented than forelimb and hind limb dysfunctions both at one month (25,84%, 42,70%, and 31,46%, respectively) and two monthes of age (28,00%, 36,00%, and 36,00%, respectively; Table 2). In contrast, the distribution within each system is not homogeneous. Among the spinal joints, the atlanto-occipital joint (C0-C1) is more affected than any other joint of the spine, accounting for 34,78% and 14,29% of spine dysfunctions at one and two months of age, respectively (Table 3). This frequence of

CO-C1 disorder could be explained by obstetric maneuver. Indeed, delivery by digital manipulation can be performed when the fetus is lodged in the birth canal, in anterior presentation, by pulling carefully on the head [15]. But this hypothesis is not supported by our results, as the farrowing conditions have no impact on dysfunctions. It is salient to note that only two of the eight puppies with C0-C1 dyfunction underwent an obstetrical maneuver (Appendix 1). Although stresses due to *in utero* life on CO-C1 cannot be assessed, the impact of different constraints can be suggested during the first month of growth to explain C0-C1 disorder such as suckling position, shocks during movement or shaking by the mother. The second most represented spinal dysfunctions during the first month occur at T1-T2 and T4-T5 joints, both accounting 13,04% of spinal dysfunctions. At that age, cervical and thoracic joints account for 43,48% and 47,83% of all spinal dysfunctions, respectively (Table 3). Because of front limb muscular attachments to the spine [16], these results suggest a possible effect of front limb impacting the spine via the thoracic girdle during puppies activity in the first month of growth (e.g., crawling locomotion, feeding, body balance from the neck; [17-19]). During the second month of growth, the number of dysfunctions decreases significantly (Appendix 1; U = 939, $p < 0.05$; $r_s = -0.01$) and the number of spinal dysfunctions switches from 23 to 7 (Table 2). While the majority of spinal dysfunctions occur before one month of age, fewer cervical dysfunctions (28,57%) but more thoracic (57,14%) and lumbar (14,29%) dysfunctions occur during the second month of growth (Table 3). We hypothesize that this evolution could be related to the acquisition, during the second month, of the upright position during locomotion with a greater impact of the thoracic and pelvic girdles on the spinal column [16,18].

Right and left front limbs both account for around half of forelimbs dysfonctions (Table 4) and our study suggests no effect of lateralization on forelimbs dysfunctions at an early age.

Because the front limb is connected to all the bones of the spine from the head (*i.e., Brachiocephalicus* muscle, Rhomboid m.), to the sacral crest (*i.e., Latissimus dorsi* m.), including the ribs and the sternum (i.e., *Serratus* m., pectoral m.), and because ligaments (*e.g.*, *supraspinatus* ligament, *interspinatus* l., dorsal and ventral longitudinal l.) connect all the bones of the spinal column [14], a reciprocal biomechanical influence between the dysfunctions of the two systems (*i.e.*, appendicular and spinal systems) can be assumed.

Frontlimb most affected joint is the shoulder (Table 4). Beside the scapulothoracic junction which shows no dysfunction at any age, the scapulohumeral joint is the one with the greatest range of mobility in three-dimensional space (*i.e.*, fexion *vs* extension, abduction *vs* adduction, inner *vs* outer rotation), enabling circumduction movement, and playing a minor role in shock absorption [3,16,20]. In growing dogs, the most common shoulder orthopedic disease is osteochondritis dissecans (OCD), caused by a change in the endochondral ossification mechanism of articular growth plate, leading to thickening of the cartilage, known as osteochondrosis [15,21,22]. In affected soulders, the synovial fluid no longer nourishes the cartilage properly. The result is necrosis at the junction between cartilage and subchondral bone, followed by fissures. Contact between the synovial fluid and the subchondral bone leads to osteitis and synovitis, the cause of lameness in dogs. Several authors suggest that OCD of the shoulder could correspond to a zone of conflict between the caudodorsal part of the head of the humerus and the posterior edge of the scapula during movement and result from micro-traumas leading to osteochondrosis and then to OCD [23-26]. The intensity of the conflict may be exacerbated by the animal's mass (over 20kg at adult size), particularly in males, which grow faster and weigh more than females [25] and small breeds are very rarely affected [27]. The importance of the pressure factor between the head of the humerus and the scapular cavity could also explain why shoulders are affected bilaterally in 20 to 80% of cases [25]. In the case of dysfunctional shoulders with a lack of extension (*i.e.*, over flexion), we hypothesize that impingement of the shoulder's caudal compartment could be increased and favor OCD [28,29]. In this case, early treatment of dysfunctional shoulders could prevent OCD or promote healing at the osteochondrosis stage [25].

In contrast, the more distal joints, which are less mobile and play a more important role in shock absorption [3,16], show very little dysfunction (Table 4). However, orthopaedic elbow problems in growing puppies are very common [15,22,30]. We suggest that, independently of the genetic components of these diseases [31,32], biomechanical changes in the elbow joint may promote the development of lesions and may be related to shoulder dysfunctions. For example, a lack of shoulder extension could be compensated for by elbow extension. Over-extension of the elbow could lead to chronic compression of the anconeal process with micro trauma and lack of calcification of the growth plate [30,33], as seen previously in the case of shoulder inpingement. Additionnaly, shoulder flexion leads to light abduction and inner rotation of humerus bone [3,16]. Such excessive rotation could also be linked to coronoid process fragmentation due to similar pathogeny. Unbalanced weight baring in relationship with overflexed shouders might also be suggested as a potential origin for ulnar growth plate osteochondrosis in some radius curvus cases [15,22,34]. We hypothesize that excess tension in muscles, ligaments and fascias can generate excessive stress on the growth plates, modifying their structure and slowing down the rate of growth, or even stopping growth through calcification of the plate. From this point of view, early shoulder dysfunctions could be considered a biomechanical key to forelimb growth diseases in dogs.

Unlike the forelimb, the hindlimb has twice as many dysfunctions on the right than on the left (Table 5). Although the effect of lateralization was not evaluated in our study, the unbalanced number of dysfunctions between the right and left hind limbs suggests that effect of stresses on both legs is not symmetrical and that lateralization could affect hind limb dysfunctions. However, lateralization demonstrated between male and female [35] or between breeds or morphotype [36,37] is not supported by our study.

Muscles from hind limb connect to thoracic and lumbar vertebrae (*i.e., Erector spinae* m., *Quadratus lumborum* m., *Psoas* m.). But unlike the fore limb, the hind limb is also connected to the spine by ligaments (*i.e.*, iliolumbar l. and sacroiliac l.) and principally the tough interosseous sacroiliac ligament (*i.e., Ligamenta sacroiliaca interossea*) [8,16]. The sacroiliac joint is not very mobile, and was only affected at the age of one month. While fexion/extension movements are performed at the various joints of the hind limb with a fairly similar average range of mobility for the hip, stifle and tarsus [38-40], the abduction required during crawling is only performed at the hip [16,39,41]. Hip abduction transmits force to the pelvis and spine via the sacroiliac joint [16,41-44] and crawling locomotion could explain early sacroiliac dysfunction, which is no longer apparent at two months of age (Table 5). Hip and femoropatellar joint are respectively the first and second most dyfunctional joints in the hind limb (Table 5). Interestingly, all the femoropatellar dysfunctions occurred on a limb with concurrent hip dysfunction (Appendix 2). As hip flexion leads to abduction and external rotation of the femur [16,45], we suggest that biomechanically, an over-flexed hip can lead to excessive pressure of the patella on the medial lip of the femoral trochlea, resulting in femoropatellar dysfunction and medial dislocation of the patella. Similarly, an over-extended hip can lead to excessive pressure from the patella on the lateral lip of the femoral trochlea, promoting patellofemoral dysfunction and lateral dislocation of the patella. From this point of view, early treatment of hip dysfunction could be seen as preventive treatment of patella dislocation. Furthermore, biomechany of the hip also allow us to suggest that early hip dysfunction, mainly over-flexed hip, could favor degenaretive disorders such as hip dysplasia and Legg-Perthes-Calvé disease. Hip flexion twists the coxofemoral ligament, bringing the femoral head and the acetabulum closer together [16,39]. Within reduced acetabular space, prolonged stretching of the ligament can lead to elongation, articular surface microtrauma, and alteration of joint congruence. Several authors also suggest that Legg-Pertes-Calvé disease is the result of repeated trauma that alter the vascularization of the femoral head via the circumflex arteries and the retinacular vessels that run through the intracapsular space [46,47]. Bringing the femoral head closer to the acetabulum may be a factor that exacerbates the effect of repeated trauma to the coxofemoral compartment on the vascularization of the femoral head and neck.

Breed, morphotype and sex

Among studied breeds, the Cairn terrier, Beauceron, and Daschund, all in the same group, show fewer dysfunctions (median = 0) than the Cocker spaniel (median = 1) and Mastiff (median = 2) belonging to another group (Figure 1), with all other breeds taken in pairs showing no significant difference except for the Cairn Terrier being different from Yorkshire terrier, Old English Sheepdog, French Bulldog and Shih Tzu. This expected effect of breed on the dysfunctions observed in very young puppies, consistent with breed susceptibility to orthopedic developmental diseases [48], raises the question of the impact of breed morphology and genetic selection on early musculoskeletal dysfunctions and, probably, on the favoring of developmental diseases that may follow. We hypothesize that the musculoskeletal form-function relationship with respect to dog morphology has a crucial impact on the onset of early joint dysfunction. Figure 2 shows that there is a different number of dysfunctions according to morphotype. The lupoid type seems to have less dysfunction than the braccoid, and the molossoid more. But, unexpectedly, morphotype shows no significant effect on osteoarticular dysfunction. We suppose that this result could have been different if we had had a larger number of specimens and if representatives of the graïoid class had been present in our sample. Nevertheless, the Cairn terrier, Beauceron and Daschund breeds, which are less dysfunctional than all other breeds, belong to the lupoid and braccoid groups, while the Mastiff, which is more dysfunctional than all other breeds, belongs to the molossoid group. (Figure 1,2). These results suggest that grouping species by morphotype does not provide sufficient discrimination to predict the risk of early dysfunctions in dogs, and that racial specificities should be taken into account in a more meaningful way. Further more, our study shows no effect of sex on observed osteoarticular dysfunctions. Without predicting such results in adult dogs, we hypothesize that anatomical and functional differences between male and female puppies at an early age are not sufficiently marked to have an impact on the onset of osteoarticular dysfunction.

Whelping conditions

Because obstetrical maneuvers take place during difficult whelping conditions that put a lot of strain on the puppy due to uterine forces (*e.g.,* inertia and spasm), and because the maneuvers themselves cause significant mechanical stress on the puppy [49], we expected whelping conditions to have an impact on osteoarticular dysfunction. But our results show no effect of the farrowing conditions on dysfunction. Except for one litter of toy Yorshire Terrier, all cesarean section were performed on molossoid breeds only (*i.e.*, Mastiff and French Bulldog) confirming that the breed but not preventive cesarean section impacts dysfunction. This result also suggests that dysfunctions might set in after the birth but this remains to be investigated.

Evolution of dysfunctions after treatment

As this study is based on clinical case reports only, it does not include a control batch that could demonstrate whether the number of dysfunctions would spontaneously increase or decrease between the ages of one and two months. But considering our results (Table 2; Appendix 1; U = 939, $p < 0.05$; $r_s = -0.01$), we can assess that the treatment favored the reduction of dysfunctions at the age of two months. Also, the preponderance of limb dysfunctions over those of the spine, and the decreasing frequency of all dysfunctions diagnosed at two months, suggest that limb dysfunctions may appear before those of the spine in relation to the crawling locomotion of the puppies during the first month. But if the question of the chronology of onset of dysfunctions arises, whether disorders of the limb occur before those of the spine, or *vice versa*, remains to be more accurently investigated.

Conclusion

This first clinical study in manual veterinary medicine on musculoskeletal dysfunctions in puppies provides new data: (i) osteoarticular dysfunctions can affect puppies as early as the first month of life, (ii) puppies present more dysfunctions during the first month than during the second month of life, (iii) limb dysfunctions account for between 3/4 (at one month) and 2/3 (at two months) of all dysfunctions (Table 2). The distribution of dysfunctions within the musculoskeletal system is not homogeneous. The withers region and the craniocervical junction are the most affected areas for the spinal column (Table 3). The shoulder accounts for almost all disorders of the front limb (Table 4), and the hip and patella for those of the rear limb (Table 5).

Although very young puppies show restrictions in mobility of articular structures long before acquired orthopedic disorders become manifest, the location and frequency of dysfunctions observed leads us to hypothesize that specific orthopedic disorders in puppies [48] may be preceded by functional disorders of the locomotor system, linked to alterations in the biomechanical properties of structures acquired at an early age. This analysis points to the potential value of early management of musculoskeletal dysfunctions in puppies to prevent joint disorders during growth. However, a correlation between dysfunctional and orthopedic disorders remains to be demonstrated.

Conflict of Interest

Authors declare no conflict of interest.

Specimen	Breed	Morphotype	Delivery	Sexe	Nb dys.1	Nb dys.2
BERT MAST 24.10.1	M	M	C	M	2	0
BERT MAST 24.10.2	M	M	C	F	0	0
BERT MAST 24.10.3	M	M	C	F	2	0
BERT MAST 24.10.4	M	M	C	F	3	0
BERT MAST 24.10.5	M	M	C	F	3	1
CAZ2CAIRN 28.09.1	CT	L	N	M	0	2
CAZ2CAIRN 28.09.2	CT	L	N	F	0	0
CAZ3CAIRN 28.09.1	CT	L	M	M	0	1
CAZ3CAIRN 28.09.2	CT	L	M	M	0	1
CAZ3CAIRN 28.09.3	CT	L	M	F	0	2
CAZ11BOB 22.05.1	OES	L	N	M	5	0
CAZ11BOB 22.05.2	OES	L	N	M	1	0
CAZ11BOB 22.05.3	OES	L	N	M	0	1
CAZ11BOB 22.05.4	OES	L	N	F	2	0
CAZ11BOB 22.05.5	OES	L	N	F	0	0
CAZ11BOB 22.05.6	OES	L	N	F	3	0
CAZ11BOB 22.05.7	OES	L	N	F	0	0
CAZ11BOB 22.05.8	OES	L	N	F	0	0
CAZ11BOB 22.05.9	OES	L	N	F	0	0
CAZ11BOB 22.05.10	OES	L	N	F	2	2
CAZ11BOB 22.05.11	OES	L	N	F	3	0
CAZ3WEST 28.09.1	WHWT	L	N	F	0	1
CAZ3WEST 28.09.2	WHWT	L	N	F	2	0
CAZ3WEST 28.09.3	WHWT	L	N	F	0	0
CAZ6TECK 24.10.1	D	L	N	M	0	0
CAZ6TECK 24.10.2	D	L	N	F	0	0
CAZ6TECK 24.10.3	D	L	N	F	1	0
CAZ6TECK 24.10.4	D	L	N	F	2	0
CAZ6TECK 24.10.5	D	L	N	F	1	0
CAZ6TECK 24.10.6	D	L	N	M	0	0
CAZ COCK 30.05.1	CS	B	M	M	4	0
CAZ COCK 30.05.2	CS	B	M	F	1	0
CAZ COCK 30.05.3	CS	B	M	M	2	0
CAZ COCK 30.05.4	CS	B	M	M	1	0
CAZ COCK 30.05.5	CS	B	M	F	3	0
CAZ COCK 30.05.6	CS	B	M	M	4	0

CAZ COCK 08.06.1	CS	B	N	M	1	0
CAZ COCK 08.06.2	CS	B	N	M	0	0
CAZ COCK 08.06.3	CS	B	N	F	3	0
CAZ 4 TECK 29.08.1	D	B	N	M	0	0
CAZ 4 TECK 29.08.2	D	B	N	M	0	0
CAZ 4 TECK 29.08.3	D	B	N	F	0	0
CAZ 4 TECK 29.08.4	D	B	N	F	2	1
COM COCK 1. 0.18	CS	B	N	M	4	0
COM COCK 1. 0.19	CS	B	N	M	2	2
COM COCK 1. 0.20	CS	B	N	F	1	1
COM COCK 1. 0.21	CS	B	N	F	0	0
COM COCK 1. 0.22	CS	B	N	F	1	0
COM COCK 1. 0.23	CS	B	N	F	1	1
DEL BEAU 19.06.1	B	L	N	M	0	0
DEL BEAU 19.06.2	B	L	N	F	0	1
DEL BEAU 19.06.3	B	L	N	M	0	0
DEL BEAU 19.06.4	B	L	N	F	1	0
DEL BEAU 19.06.5	B	L	N	M	1	1
DEL BEAU 19.06.6	B	L	N	F	0	1
DEL BEAU 19.06.7	B	L	N	M	1	0
DEL BEAU 19.06.8	B	L	N	M	0	0
DEL SHI 22.08.1	ST	M	N	M	3	2
DEL SHI 22.08.2	ST	M	N	M	3	0
DEL SHI 22.08.3	ST	M	N	M	0	0
DEL SHI 22.08.4	ST	M	N	F	1	2
DEL SHI 22.08.5	ST	M	N	F	0	0
DEL 4 YORK 29.06.1	Y	L	N	F	2	0
DEL 4 YORK 29.06.2	Y	L	N	M	0	0
DEL 4 YORK 29.06.3	Y	L	N	M	1	0
DEL 4 YORK 29.06.4	Y	L	N	M	2	0
DEL YORK T 29.06.1	Y	L	C	M	3	0
DEL YORK T 29.06.2	Y	L	C	M	0	0
DEL YORK T 29.06.3	Y	L	C	F	1	0
DEL YORK T 29.06.4	Y	L	C	F	1	0
FRI BOU 26.06.1	FB	M	C	F	1	0
FRI BOU 26.06.3	FB	M	C	M	1	1
FRI BOU 26.06.4	FB	M	C	F	0	0

FRI BOU 26.06.5	FB	M	C	F	1	0
FRI BOU 26.06.6	FB	M	C	F	4	1

Appendix 1

Raw Data

Breed

B: Beauceron

CT: Cairn terrier

CS: Cocker spaniel

D: Dachshund

FB: French Bulldog

M: Mastiff

OES: Old English Sheepdog

ST: Shih tzu

WHWT: West Highland White Terrier

T: Yorshire terrier

Morphotype

B: Braccoid

L: Lupoid

M: Molossoid

Delivery

N: Natural

M: Maneuver

C: Cesarean section

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