Force plate analysis

Does training matter?

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25-03-2010

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Content

Summary

Force plate analysis (FPA) is a valuable method in veterinary medicine to study normal and abnormal gait. This method allows us to measure and study the forces involved in gait (ground reaction forces). Ground reaction forces (GRFs) can be influenced by many factors, such as velocity and morphometric differences. The present study evaluated the effects of a force plate-specific training on the GRFs in Beagles.
Eight healthy Beagles were used to obtain the measurements. Dogs were measured before (M1) and after (M2) the training regime. The conventional parameters peak, impulse, pelvic-thoracic ratio and symmetry index were evaluated for the Fz, Fy+, and Fy-. In addition, novel parameters describing the variation in GRF measurements (error parameters) for Fz, Fy+ and Fy- were assessed.
No significant differences between M1 and M2 were found for the peak, impulse, pelvic-thoracic ratio and symmetry index. Significant decreases were found for all error parameters. It may be concluded that FPA provides reliable measurements without a training regime when assessing the conventional parameters. Incorporating a training regime in force plate studies may result in a reduction in variance and consequently, smaller differences in gait may be detected and a smaller number of measurements per dog may be needed to obtain reliable data.

Introduction

"Gait is a manner of limb movement, characterized by distinctive, coordinated, and repetitive movements of the feet and limbs"[1]. When observing and analyzing the gait with the naked eye, many details can be missed and observations cannot easily be compared since human observers are subjective. For over two decades computers have been used to aid in analyzing the gait. Computer assisted gait analysis is a more accurate, efficient, objective and repeatable method than subjective observation[1-3]. It has allowed us to objectively analyze the movements (kinematics) and forces (kinetics) involved in gait and has substantially contributed to a better understanding of normal and abnormal gait [1-25].

A gait consists of strides and each stride is divided into two phases: a swing phase (the paw is in the air) and a stance phase (the paw touches the ground). The forces resulting from paw impact during the stance phase of a limb are called ground reaction forces (GRFs). GRFs can be divided into three orthogonal vectors: vertical (Fz), craniocaudal (Fy) and mediolateral (Fx) forces. The Fy can be subdivided into braking (Fy+) and propulsion (Fy-) forces (Fig.1).

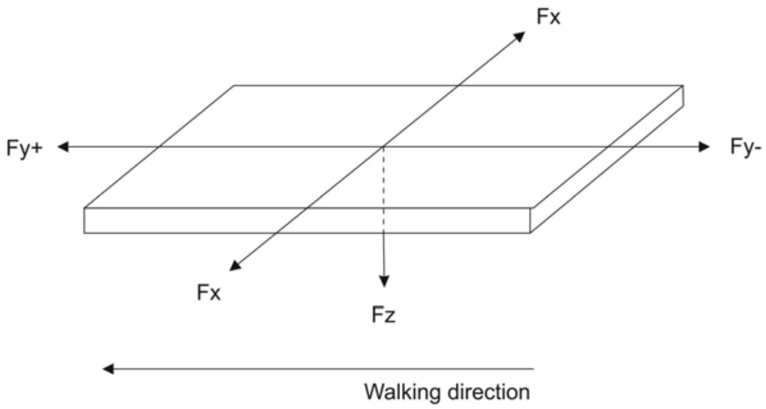

Figure 1. Schematic representation of the force plate and the ground reaction forces involved in paw placement. Fz = vertical ground reaction force; Fy+ = braking ground reaction force; Fy- = propulsion ground reaction force; Fx = mediolateral ground reaction forces.

GRFs can be measured and analyzed by a variety of gait analysis techniques. One such technique is force plate analysis (FPA). FPA involves the use of a floor-mounted force plate (FP). When forces are exerted onto the FP, piezoelectric effects are created and signals which correspond with the GRFs are sent to and stored by a computer. Data stored in the computer can be analyzed using specialized software. FPA is a reliable technique to measure these forces and it has been used by many researchers to study normal and abnormal gait [4, 7, 10, 11, 15, 16, 21, 24] and to evaluate the efficacy of therapeutic and surgical treatments of orthopedic diseases [8, 20, 23, 25].

Many factors have been shown to influence the GRF data, such as velocity, trial repetitions, morphometric differences, dog handler, starting distance, lameness, selection (for amiable disposition) and habituation (familiarizing with handler, FPA laboratory and being led by leash) [1, 2, 9, 17, 22]. However, the effect of training on FPA masurements has not been evaluated. The aim of the present study was to assess the effects of force plate-specific training on GRF measurements. It was hypothesized that training would influence GRF measurements.

Materials and methods

Animals

Eight healthy Beagles (5 males, 3 females; age range 1.7-3.7 years; weight range 11.2-17.3kg), were used. In the five weeks preceding this study, the dogs were habituated to the handler, the route to the FP laboratory, the FP laboratory itself, the observer and the FP procedures.

Experimental design

Force plate analysis was conducted at two defined time points:

- Measurement 1 (M1) was conducted once a dog was habituated and at least 10 valid FP measurements for each limb could be obtained.
- Measurement 2 (M2) was conducted 3 weeks after M1. In the 3 weeks between M1 and M2, dogs had been trained specifically in force plate procedures.

Force plate-specific training regime

Force plate training was aimed at obtaining accurate and reproducible force plate measurements. The training regime consisted of 4-5 sessions a week for 3 weeks, 12 training sessions in total for each dog. During these sessions dogs were trained using positive reinforcement. At 4 out of 12 sessions an observer was present. Before each FP-training the dog was walked. After entering the FP laboratory the dog was weighed. Training consisted of walking over the FP. Training was completed after one valid measurement for each limb in the first session, building up to twelve in the last session. After the training session the dog was additionally rewarded by play-time (*Addendum*).

Equipment for GRF measurement and data analysis

A quartz crystal piezoelectric Kistler force plate (Kistler type 9261, Kistler Instrumente AG, Winterthur, Switzerland, 40x60cm) was used. Beagles are relatively small dogs and in order to accommodate for their relatively short stride length, the length of the FP was effectively reduced to 30cm by means of boards. GRFs were measured by force transducers, which were located in each corner of the FP. Kistler 9865E charge amplifiers were connected to an analog-digital converter, which interfaced with a computer that stored the signals (sampling rate 100 Hz). The signals corresponded with the GRFs of Fx, Fy and Fz. The FP was mounted flush with the surface in the center of a 9.25 m long walkway. The middle 3.25 m was bordered by a 30cm high fence to guide the dogs over the force plate. Forward velocity was measured using two photoelectric switches spaced 3.25 m apart and centered on the force plate. Recordings were automatically started and stopped by these switches.

Experimental and data collection protocol

Each dog was weighed on an electronic scale at the start of both M1 and M2. A handler guided the dogs on a leash over the FP at a walking gait and velocity was aimed at a constant speed between 0.9 – 1.3 m/s. At both M1 and M2, a minimum of 10 valid steps per limb was collected for each dog. A step was considered valid when a full forefoot strike on the FP was followed, after a short interval, by a full strike of the ipsilateral hind foot, with the contralateral limbs clear of the FP. In case of strain on the leash, pulling to one side or distracting head-movements, the measurement was considered invalid. During all measurements an observer was present to evaluate the validity of each run.

Data analysis

Labview (version 8.0) software was used for data processing and analysis. All forces were normalized for body weight. Per dog, ten valid steps for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs were analyzed and average values were calculated for the following parameters:

- Peak force (P): defined as the maximum force during the stance phase (Fig. 2).
- Impulse (I): defined as the total force multiplied by the stance time.
- Pelvic thoracic ratio (PT-ratio): defined as the sum of the peak forces of the pelvic limbs divided by the sum of the peak forces of the thoracic limbs.
- Symmetry index (SI): defined as the ratio between the peak force of the left limb and the peak force of the right limb. In every calculation, the largest value was used as the denominator. The SI was calculated for the thoracic and pelvic limbs.

In addition, the following parameters, termed error parameters, were calculated for the peak, impulse and total force, based on the same ten valid steps per limb per dog:

- Error of the peak (EP) force: defined as the standard deviation (SD) of the average peak.
- Error of the impulse (EI): defined as the SD of the average impulse.
- Error of the total force (ET): defined as the SD of the average total force at a standardized time scale. Total force was obtained after the stance time for each step was scaled to 100 standardized units.

All parameters were calculated for Fz, Fy+, and Fy-. For each dog, values obtained at M1 were compared to values obtained at M2. The walking velocity (absolute value and error) was also analyzed.

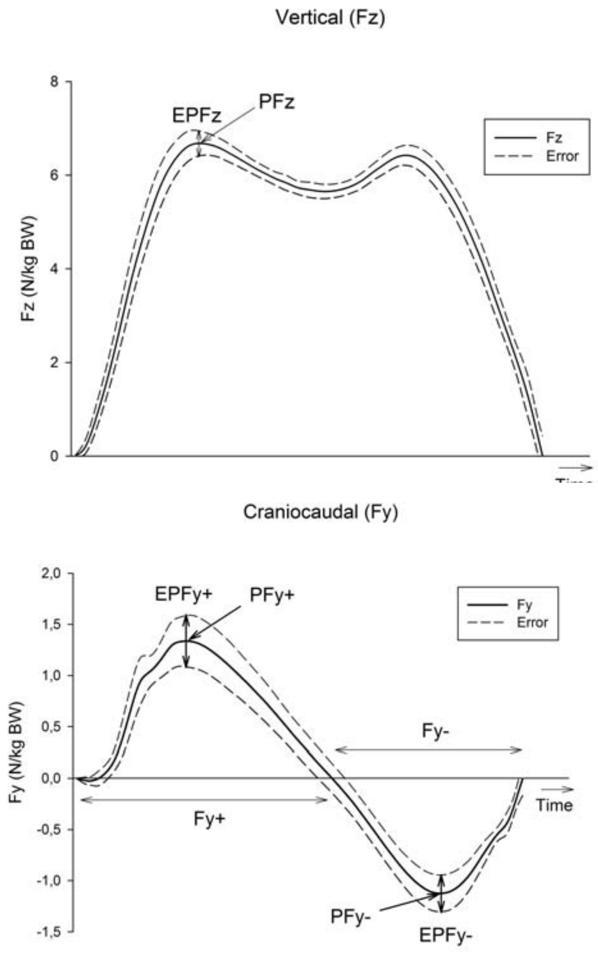

Figure 2. Force-time curves of the vertical ground reaction force (Fz) and of the craniocaudal ground reaction force (Fy).
Once the stance phase begins, ground reaction forces (GRFs) are measured. The GRFs reach a maximum (peak) during the braking phase, followed by the rollover of the paw (Fy is zero). Subsequently, the propulsion phase starts, forces reach a second peak and finally, GRFs go back to zero at toe off.

Fy+ = Braking phase
Fy- = Propulsion phase
PFz = Peak vertical force
PFy+ = Peak braking force
PFy- = Peak propulsion force
EPFz = Error of the peak vertical force
EPFy+ = Error of the peak braking force
EPFy- = Error of the peak propulsion force

Statistical analysis

Statistical analysis was conducted using SPSS software (version 17.0). The Shapiro-Wilk normality test, PP-plots and QQ-plots were used to confirm the normal distribution of the data. If necessary, extreme residuals were removed in order to obtain a normal distribution. For each parameter, paired t-tests were used to test whether the parameter values obtained at M1 significantly differed from the values obtained at M2. $P<0.05$ was considered statistically significant and $P\geq0.05$ and <0.10 was considered a trend.

Results

No significant differences were found for any of the peak, impulse, or ratio parameters for Fz, Fy+ or Fy- (Tables 1 and 2). Trends towards increasing values were found for PFy+ PL (+10.48%; P=0.097) (Fig. 3) and for the PT-ratio of PFy+ (+9.66%; P=0.094) (Fig. 4). Velocity showed no significant difference between M1 and M2. A trend was found towards a decrease in the error of the velocity (-22.2%; P=0.051) (Table 3).

Table 1. Means ± SD (n=8) at Measurement 1 (M1) and Measurement 2 (M2) and P values resulting from the paired t-tests, for the peak (P) forces (N/kg BW) and impulses (I) (Ns/kg BW) of Fz, Fy+, and Fy- for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs.

Parameter	Limb	M1	M2	P-value
PFz	TL	6.821 ± 0.249	6.746 ± 0.232	0.412
	TR	6.768 ± 0.367	6.755 ± 0.319	0.863
	PL	4.638 ± 0.316	4.675 ± 0.406	0.669
	PR	4.515 ± 0.378	4.567 ± 0.363	0.658
IFZ	TL	1.963 ± 0.262	1.977 ± 0.217	0.593
	TR	1.964 ± 0.277	1.964 ± 0.254	1.000
	PL	1.055 ± 0.163	1.076 ± 0.130	0.184
	PR	1.069 ± 0.154	1.078 ± 0.125	0.712
PFy+	TL	1.331 ± 0.197	1.258 ± 0.296	0.274
	TR	1.231 ± 0.151	1.218 ± 0.179	0.684
	PL	0.651 ± 0.234	0.719 ± 0.235	0.097
	PR	0.667 ± 0.169	0.683 ± 0.183	0.720
IFy+	TL	0.172 ± 0.050	0.175 ± 0.053	0.320
	TR	0.160 ± 0.038	0.157 ± 0.033	0.682
	PL	0.046 ± 0.023	0.040 ± 0.021	0.602
	PR	0.047 ± 0.018	0.045 ± 0.019	0.633
PFy-	TL	-0.971 ± 0.162	-0.986 ± 0.128	0.684
	TR	-0.991 ± 0.216	-0.982 ± 0.216	0.731
	PL	-0.688 ± 0.122	-0.680 ± 0.152	0.715
	PR	-0.730 ± 0.130	-0.728 ± 0.117	0.935
IFy-	TL	-0.100 ± 0.028	-0.102 ± 0.022	0.686
	TR	-0.104 ± 0.031	-0.103 ± 0.033	0.700
	PL	-0.099 ± 0.023	-0.094 ± 0.027	0.181
	PR	-0.104 ± 0.029	-0.102 ± 0.022	0.806

Table 2. Means ± SD (n=8) at Measurement 1 (M1) and Measurement 2 (M2) and P values resulting from the paired t-tests, for the Symmetry Indices (SI) and PT-ratios (P/T) of the peaks for Fz, Fy+, and Fy-, and for the velocity.

Parameter	Limbs	M1	M2	P-value
SI Fz	Thoracic	0.975 ± 0.020	0.975 ± 0.022	0.999
	Pelvic	0.942 ± 0.039	0.942 ± 0.033	0.989
SI Fy+	Thoracic	0.915 ± 0.093	0.910 ± 0.075	0.914
	Pelvic	0.779 ± 0.099	0.839 ± 0.071	0.151
SI Fy-	Thoracic	0.904 ± 0.084	0.920 ± 0.055	0.571
	Pelvic	0.897 ± 0.105	0.904 ± 0.078	0.792
P/T PFz		0.675 ± 0.056	0.685 ± 0.050	0.224
P/T PFy+		0.513 ± 0.127	0.562 ± 0.100	0.094
P/T PFy-		0.739 ± 0.147	0.724 ± 0.118	0.615
Velocity		1.084 ± 0.118	1.061 ± 0.072	0.567

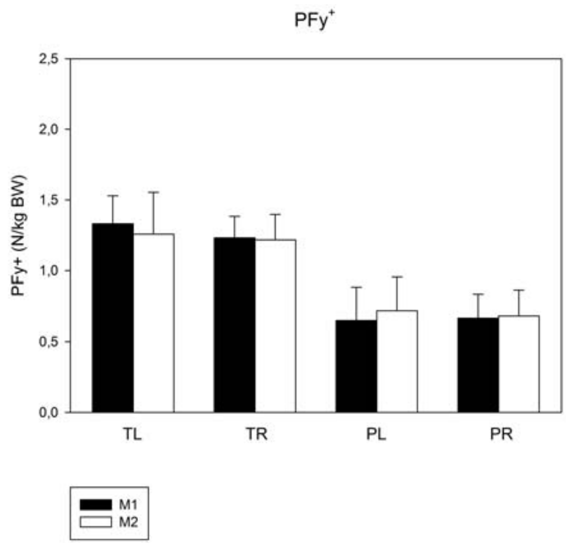

Figure 3. Means + SD (n=8) for PFy+ at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL) and pelvic right (PR) limbs.

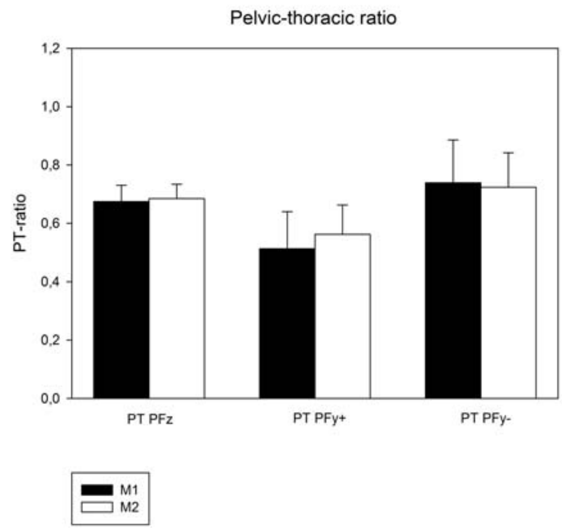

Figure 4. Means + SD (n=8) for the PT-ratios of the peak forces at Measurement 1 (M1) and Measurement 2 (M2). A trend towards increasing values was found for the PT-ratio of PFy+.

The EPFz of both pelvic limbs decreased significantly after FP-training (-38.5% and -32.2% for PL and PR, respectively) (Fig. 5). The EIFz decreased significantly for TR and PL (-38.8% and -28.5%, respectively) (Fig. 6) and showed a trend towards decreasing values for PR (-22.9%; P=0.094).The ETFz was found to be significantly smaller for all four limbs (-19.2%, -20.1%, -25.4%, and -26.3% for TL, TR, PL and PR, respectively) (Fig. 7).

The EPFy+ of both thoracic limbs decreased significantly, -39.6% and -28.3% for TL and TR, respectively (Fig. 8). The EIFy+ significantly decreased for TR (-27.4%) and showed a trend towards decreasing values for TL (-35.3%; P=0.054) (Fig. 9). The ETFy+ significantly decreased in both thoracic limbs, (-32.6% and -23.8% for TL and TR, respectively) and showed a trend towards decreasing values for PL (-18.7%; P=0.081) and for PR (-21.0%; P=0.096) (Fig. 10).

The EIFy- decreased significantly for PL (-26.8%) (Fig. 11). The ETFy- was found to be significantly smaller for PL (-35.0%) and showed a trend towards decreasing values for PR (-23.0%; P=0.054) (Fig. 12).

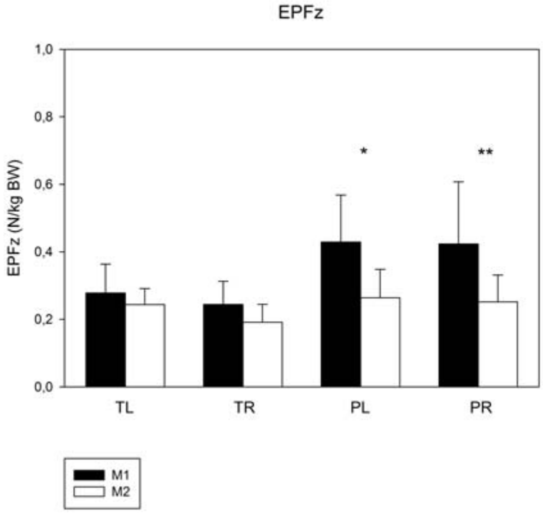

Figure 5. Means + SD (n=8) for the EPFz at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs.
** Indicates a significant difference of P<0.05 between M1 and M2. ** Indicates a significant difference of P<0.01 between M1 and M2.*

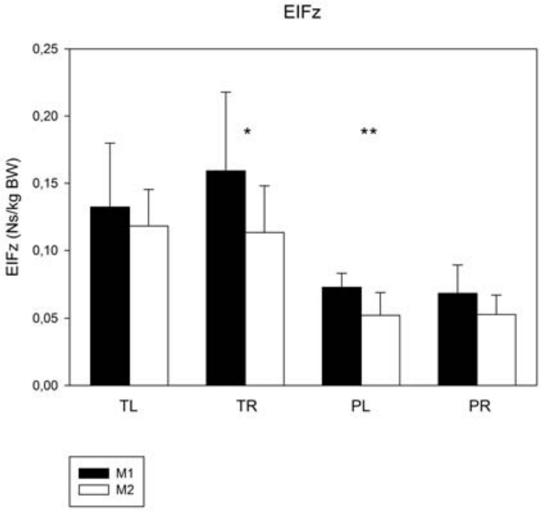

*Figure 6. Means + SD (n=8) for the EIFz at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs. * Indicates a significant difference of P<0.05 between M1 and M2. ** Indicates a significant difference of P<0.01 between M1 and M2.*

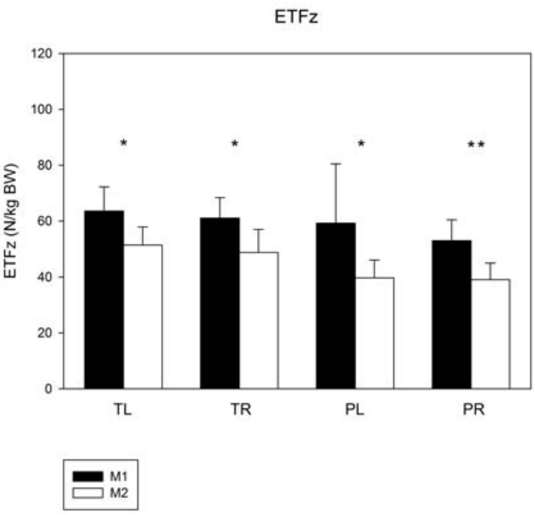

Figure 7. Means + SD (n=8) for the ETFz at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs.
** Indicates a significant difference of P<0.05 between M1 and M2. ** Indicates a significant difference of P<0.01 between M1 and M2.*

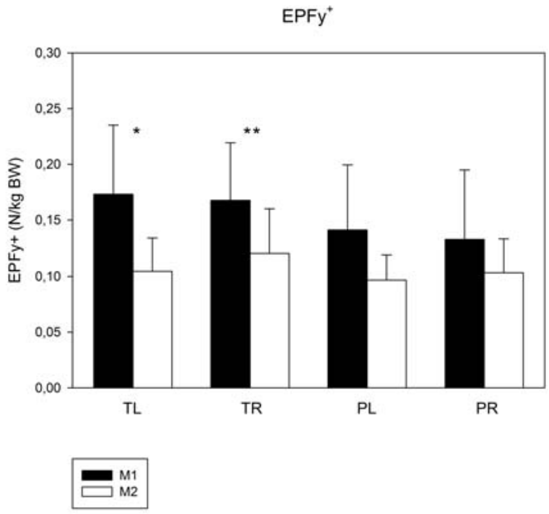

Figure 8. Means + SD (n=8) for the EPFy+ at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs.
** Indicates a significant difference of P<0.05 between M1 and M2. ** Indicates a significant difference of P<0.01 between M1 and M2.*

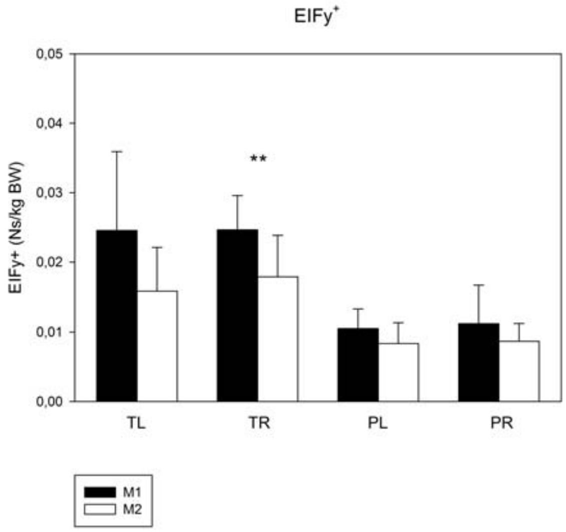

Figure 9. Means + SD (n=8) for the EIFy+ at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs.
** Indicates a significant difference of P<0.01 between M1 and M2.

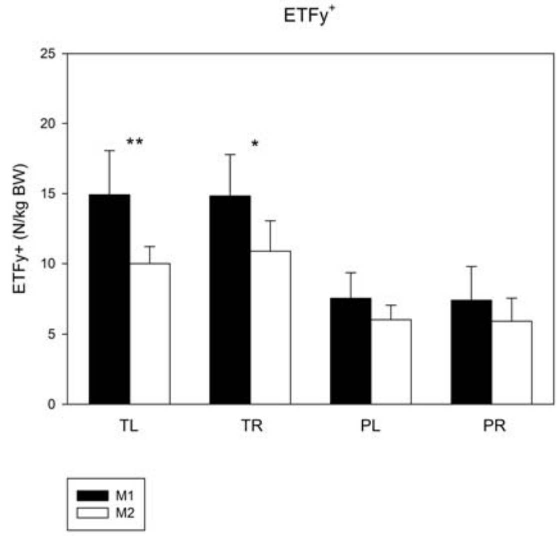

Figure 10. Means + SD (n=8) for the ETFy+ at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs.
* Indicates a significant difference of P<0.05 between M1 and M2. ** Indicates a significant difference of P<0.01 between M1 and M2.

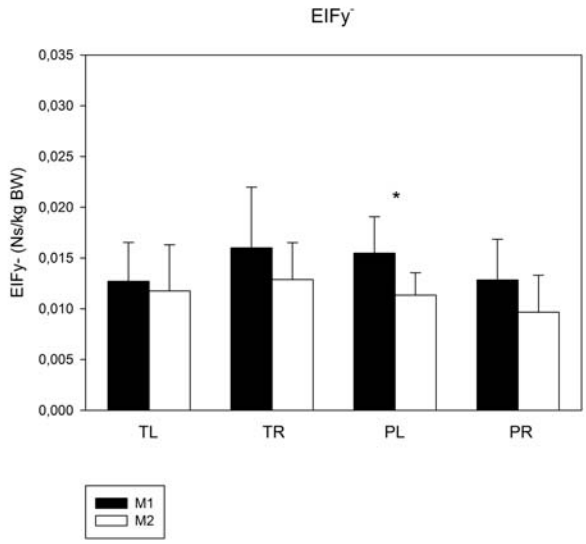

Figure 11. Means + SD (n=8) for the EIFy- at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs.
* Indicates a significant difference of P<0.05 between M1 and M2.

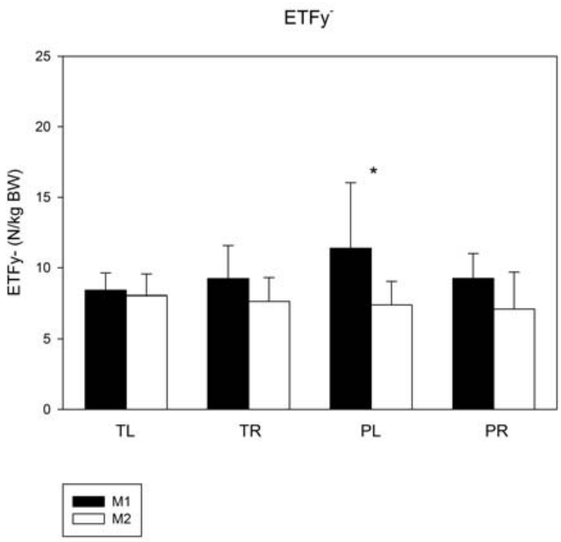

Figure 12. Means + SD (n=8) for the ETFy- at Measurement 1 (M1) and Measurement 2 (M2) for the thoracic left (TL), thoracic right (TR), pelvic left (PL), and pelvic right (PR) limbs.
* Indicates a significant difference of P<0.05 between M1 and M2.

Table 3. Means ± SD (n=8) at Measurement 1 (M1) and Measurement 2 (M2) and P values resulting from the paired t-tests, for the errors of peaks (EP), impulses (EI) and total forces (ETF) for Fz, Fy+, and Fy-, and for the error of the velocity.

Parameter	Limb	M1	M2	P-value
EPFz	TL	0.278 ± 0.086	0.244 ± 0.048	0.431
	TR	0.244 ± 0.069	0.192 ± 0.053	0.111
	PL	0.429 ± 0.139	0.264 ± 0.084	0.036
	PR	0.366 ± 0.096	0.248 ± 0.085	0.001
EIFz	TL	0.132 ± 0.047	0.118 ± 0.027	0.520
	TR	0.172 ± 0.051	0.105 ± 0.028	0.002
	PL	0.073 ± 0.010	0.052 ± 0.017	0.037
	PR	0.069 ± 0.021	0.053 ± 0.014	0.094
ETFz	TL	63.640 ± 8.613	51.418 ± 6.473	0.022
	TR	61.092 ± 7.336	48.790 ± 8.235	0.015
	PL	52.661 ± 11.026	39.289 ± 6.711	0.012
	PR	52.991 ± 7.448	39.053 ± 5.948	0.002
EPFy+	TL	0.173 ± 0.062	0.105 ± 0.029	0.023
	TR	0.168 ± 0.052	0.120 ± 0.040	0.004
	PL	0.141 ± 0.058	0.097 ± 0.022	0.107
	PR	0.133 ± 0.062	0.103 ± 0.030	0.171
EIFy+	TL	0.025 ± 0.011	0.016 ± 0.006	0.054
	TR	0.025 ± 0.005	0.018 ± 0.006	0.005
	PL	0.011 ± 0.003	0.008 ± 0.003	0.272
	PR	0.011 ± 0.006	0.009 ± 0.003	0.292
ETFy+	TL	15.598 ± 3.551	10.511 ± 1.394	0.005
	TR	15.411 ± 2.960	11.739 ± 2.704	0.013
	PL	7.118 ± 1.223	5.789 ± 1.119	0.081
	PR	7.328 ± 2.314	5.784 ± 1.489	0.096
EPFy-	TL	0.089 ± 0.027	0.094 ± 0.040	0.784
	TR	0.116 ± 0.033	0.099 ± 0.022	0.348
	PL	0.090 ± 0.041	0.068 ± 0.019	0.138
	PR	0.066 ± 0.015	0.053 ± 0.018	0.074
EIFy-	TL	0.013 ± 0.004	0.012 ± 0.005	0.701
	TR	0.016 ± 0.006	0.013 ± 0.004	0.283
	PL	0.015 ± 0.004	0.011 ± 0.002	0.035
	PR	0.013 ± 0.004	0.010 ± 0.004	0.111
ETFy-	TL	8.411 ± 1.226	8.039 ± 1.524	0.622
	TR	9.230 ± 2.341	7.658 ± 1.645	0.284
	PL	11.387 ± 4.641	7.404 ± 1.624	0.031
	PR	9.241 ± 1.762	7.115 ± 2.575	0.054
Error Velocity		0.144 ± 0.050	0.112 ± 0.037	0.051

Discussion and conclusion

Force plate measurements have been stated to be reliable and reproducible when careful collection protocols are used [18, 26]. Researchers have studied many possible causes for variability in data, such as starting distance, velocity and habituation [9, 22, 27]. To the author's knowledge, no previous gait analysis study has evaluated the effects of a training regime on FPA measurements.

In the present study it was evaluated whether FP-specific training had a significant effect on FP measurements. Parameters were assessed for the vertical (Fz) and craniocaudal (Fy) ground reaction forces. Previous studies have shown that the mediolateral GRF (Fx) is relatively low in amplitude and exhibits a high intradog variation, which makes it less useful for analysis[1]. Therefore, no parameters for Fx were assessed in the present study. The peak, impulse and ratio parameters for both the Fz and Fy were studied which are conventional parameters in FPA, commonly used to assess limb function. None of these parameters significantly changed due to the training regime. This shows that FP-specific training does not lead to significantly different results in conventional parameters and affirms that FPA is a reliable method for gait analysis.

In addition to the conventional parameters, error parameters describing the reproducibility of FP measurements were evaluated. These parameters are not commonly used in FPA. In all error parameters of the peak, impulse and total force significant changes between M1 and M2 were found. The results showed that training resulted in more reproducible maximum vertical force values of the pelvic limbs. Furthermore, intradog variation in limb function during the complete stance phase, with respect to vertical load, decreased significantly for two limbs. The total force of the vertical load stabilized significantly for all four limbs. This shows that after three weeks of FP training dogs exhibited a more repeatable vertical load pattern.

A reduction in variation was also found for the peak braking forces of both thoracic limbs at M2. A more constant limb function during the whole stance phase is implied for the thoracic limbs as well (TR significant, TL trend). The total braking force showed to be more repeatable in both thoracic limbs (significant) and in both pelvic limbs (trend). After training, limb function was more constant with respect to the propulsion phase for one of the pelvic limbs. The total propulsion force was more constant for both pelvic limbs (PL significant, PR trend). A trend towards more reproducible maximum propulsion force was found for one pelvic limb.

It must be noted that M1, M2, and the training sessions were performed by a single handler. Therefore, at M2, the dogs had not only been trained specifically in FP procedures, but a better rapport between the dogs and the handler had been established as well. This improved rapport may have influenced the variance. In order to separate the two factors and study the sole effects of training, the trainer should not be the handler at either M1 or M2.

All but one of the measurements have been conducted by a single handler. It has previously been shown that the percentage of variance attributable to handlers is trivial and the results are not significantly influenced by using multiple handlers[1, 28]. However, since this study analyzed error parameters, the use of a single handler for all measurements would have been preferable. Furthermore, since each dog served as its own control, the dog handler at M1 should preferably be the same at M2.

Training did not have a significant effect on the peak, impulse and ratio parameters. This shows that, when using these parameters to assess limb function, measurements are reliable without the need for FP training. However, smaller errors allow for the detection of smaller differences. Therefore, it may be beneficial to incorporate FP-specific training in studies in which the detection of small differences in gait is desirable. Since inclusion of a training regime prior to a study may reduce the variation of FP measurements, fewer measurements per dog may be needed for reliable data. However, training dogs may not be practical in clinical studies, especially not when using the 3-week training period. A reduction of the training period or the number of training sessions while maintaining similar decreases in error parameters, would increase the practicality of a training regime. Future research should be done to assess this possibility.

In FPA studies many different breeds are used, such as Labrador retrievers and Greyhounds, which are relatively larger dogs than Beagles. Therefore, the effects of training on GRF measurements need to be evaluated in other breeds as well. In addition, in the present study the walking gait was analyzed, whereas the trot is another gait regularly used for analysis. Therefore it would be interesting to assess whether FP-specific training could show similar effects on GRF measurements when using larger breeds and when analyzing the trot.

In conclusion, it was proven that FP-specific training did not have a significant effect on the conventional force plate parameters, whereas parameters describing the variation in GRFs were significantly changed. Incorporation of a training regime in experimental studies may reduce the required number of measurements per dog and may increase the sensitivity of FPA.

Acknowledgements

I would like to thank my supervisors professor Herman Hazewinkel, dr. Björn Meij and drs. Luc Smolders for giving me the opportunity to conduct this research project and learn what conducting research entails.
I thank Luc Smolders especially for his guidance in the stage of the statistical analysis and for his advice with respect to this rapport and the presentation. I thank Arie Doornenbal for his help with getting familiar to the FP equipment and procedures and for his time spent as an observer during the measurements and training sessions. I would like to thank Claudia Vinke for advising me on the habituation and training of the dogs.
I would also like to thank Jeannette Wolfswinkel for her help with (logistic) problems and the volunteers of the 'Adopt a doggy' program who have walked (and are still walking) the dogs. I also thank the animal caretakers for their help in getting to know the dogs and allowing the dogs a daily play time in an outside pen. Last but not least I would like to thank Arthur, my family and friends for their moral support.
As a final note, a personal goal during this study was to enlarge my skills in handling dogs and I can say that I amply accomplished this goal.

Addendum: Daily routine, habituation and force plate-specific training regime

Daily routine:
Thirty minute roaming in an outside pen, two dogs (cage-mates) at a time. One walk of 20-30 minutes, by handler or volunteers of the 'Adopt a doggy' program (see below).

Habituation:
The dogs were quite afraid of all kinds of audio-visual stimuli and of people, to the extent that no FP measurements could be conducted. Therefore these dogs needed habituation, for which I consulted a behavioral specialist (Claudia Vinke). The habituation process proved to be extensive and took approximately five weeks.
First, the dogs were habituated to the handler (in the case of 'Bleu' it took two weeks to earn his trust) by sitting outside their cage, giving attention, walking the dogs, playing with the dogs, then basic commands were taught. Since time was limited to habituate the dogs to the stimulus-rich clinic (which was on the route to get to the FP laboratory) an alternative, quiet route was found to which the dogs were habituated. Then dogs were habituated to the FP laboratory, which was quite well insulated (little audio-visual stimuli were present) and as a result dogs were quickly habituated to this laboratory. Unfortunately sometimes the construction work outside of the laboratory proved to be too noisy for the dogs in which case the habituation process was interrupted. Since these dogs were quickly distracted by the sounds of the construction work the habituation to the FP procedures took quite some time.
I noticed that playing with the dogs improved their confidence and their willingness to cooperate, therefore play was an important part of the habituation process. In order to further improve the well-being of the dogs and aim to improve their ability to recuperate from and handle unexpected events I set up the 'Adopt a doggy' program (Figure 13). Volunteers temporarily adopted a dog, which meant they walked a dog in a group, two to four times a week (which took quite some logistic planning). I noticed that the dogs became more used to audio-visual stimuli and to the presence of people. I also noticed an improvement in the way the dogs were able to deal with and recuperate from unexpected situations, not only during the walks outside but on the route inside and in the FP laboratory as well. Thus decreasing the influence of audio-visual stimuli encountered on the route to and audio stimuli heard in the FP laboratory. Unfortunately, one dog proved to be difficult to habituate to the FP procedures and was not able to recuperate from loud audio stimuli coming from the construction work outside of the laboratory, even after seven weeks of habituation. This dog was taken out of the study (not out of the 'Adopt a doggy' program) and replaced by another dog which was then habituated as well.
To much of my delight, the 'Adopt a doggy' program is still being continued.

Force plate-specific training regime:
Twelve sessions, 4-5 sessions a week for 2-3 weeks. During training sessions dogs were trained using positive reinforcement. Rewards consisted of a treat or petting and praising (which reward was chosen depended on the response of the individual dog). During 4 out of 12 sessions an observer was present.
Before each FP-training the dog was walked. Starting with 15-20 minutes, cutting down to 5 minutes before the last training. After entering the FP laboratory the dog was weighed. Training consisted of walking over the FP. Training was completed after one valid measurement for each limb in the first session, building up to twelve in the last session.
After the training the dog was additionally rewarded by play-time (petting, running after and catching treats or a ball, finding hidden treats, pulling and chewing on a floss rope) in order to

end each session in a positive and relaxed way. The play-time started with 15-20 minutes for the first session, ending with 5 minutes after the last session.

Figure 13. Flyer 'Adopt a doggy!

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