MEASUREMENT OF GROUND REACTION FORCES ON LIMBS OF CALVES IN A STANDING STATIC POSITION

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Abstract. The force plate is a device widely used for gait analysis in humans determining the ground reaction forces on limbs. In this study, the ground reaction force in calves were measured. Five male Girolanda breed calves with 15 to 60 days of life were placed in standing position with one of the limbs in contact with a force plate connected to a computer. The forces were measured considering the four limbs independently. Three measurements were taken for each limb. The results showed that the reaction forces were greater on anterior limbs (P<0.05) and that most part of body weight was placed on thoracic region of these animals. There were no significant differences between left and right in both front and hind limbs. These finds are according with results obtained from other species and the percentual distribution of the weight (57.4%) was close to that previously established on literature. It was concluded that the proposed methodology using force plate is a useful method for determination of body weight distribution on cattle limbs. The data generate by this study has been used as the basis for the development of a computational model for studying fractures in long bones for cattle.

Keywords: ground reaction force, force plate, static, calves, biomechanics.

1. INTRODUCTION

An important parameter for Biomechanics studies is the knowledge and analysis of forces and accelerations acting on living organisms. In general, Biomechanics can be defined as Mechanics applied to Biology (Fung, 1993). The different fields of Applied Mechanics are also related to Biomechanics, i.e., the principles of Static are used to determine the magnitude of forces that act in the elements of muscle skeletal system (Özkaya and Nordin, 1999).

In quadrupeds, the bones of the limbs when static or in movement undergo the action of complex forces. In a static condition, these bones resist the action of gravity, supporting the weight of the body and the simultaneous muscular activity necessary to keep the position. Thus, the knowledge and use of the concepts of Mechanics applied to Biology is specially indicated, serving as an useful tool to clinicians of veterinary medicine.

In orthopedic human studies, there are many works in the literature showing biomechanical forces, which were obtained by *in vivo* experiments and by estimated data based on corporal weigh distribution (Fernandes et al, 2002; Gefen, 2002; Rafferty and Seret, 2003). However, it has not been found in veterinary literature information about values of ground reaction force in cattle. With the aim to support a project about femoral implants, the ground reaction forces in calves on standing static position were measured in this study. A methodology for measuring the forces was tested and a new method for determination of ground reaction forces is presented.

2. MATERIALS AND METHODS

The experiment was performed in the Laboratory of Biomechanics of the School of Physical Education, Physiotherapy and Occupational Therapy of the Federal University of Minas Gerais (UFMG). This laboratory has a force plate (model: OR6-7, AMTI, U.S.A.) inlaid and leveled to the ground and programs for signal acquisition and data analysis (SIMI Motion 6.0). In this study it was registered only the vertical force component acting on limbs of five male Girolanda breed calves with 15 to 60 days of live. The normal reaction is a force in vertical direction, corresponding to part of the animal's weight (Fig. 1). This technique is widely used in this laboratory for experiments with human beings (Menzel et al, 2005), not having been used for studies in calves.
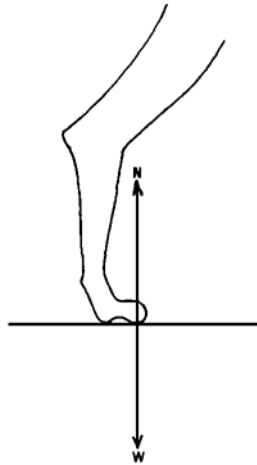
Figure 1. Representation of the normal reaction force (N)

The animals, identified by ear tags, were previous weighed at the Veterinary Hospital of the UFMG and taken to Laboratory of Biomechanics to perform the experiment. The laboratory floor was covered with rubber plates in order to avoid slippage. A square made of adhesive tape was placed over the rubber plates in order to identify the force plate location. The animals were placed in a symmetrical standing position with one of the limbs in contact with a force plate connected to a computer which registered the data. The forces were measured considering each of the four limbs independently (Figs 2a and 2b). Three measurements were taken for each limb in a total of twelve measurements per animal and sixty values for the group. In each measurement, the curve of the force vs. time was obtained. The considered reaction force was that corresponding to a region of graph in which the forces reached constant values. Mean forces of each limb and the percentage of these related to the animal weight were calculated for each animal. Mean weights from the front and hind limbs, and from the right and left ones were statistically compared by the paired Student's t test, considering $P < 0.05$.
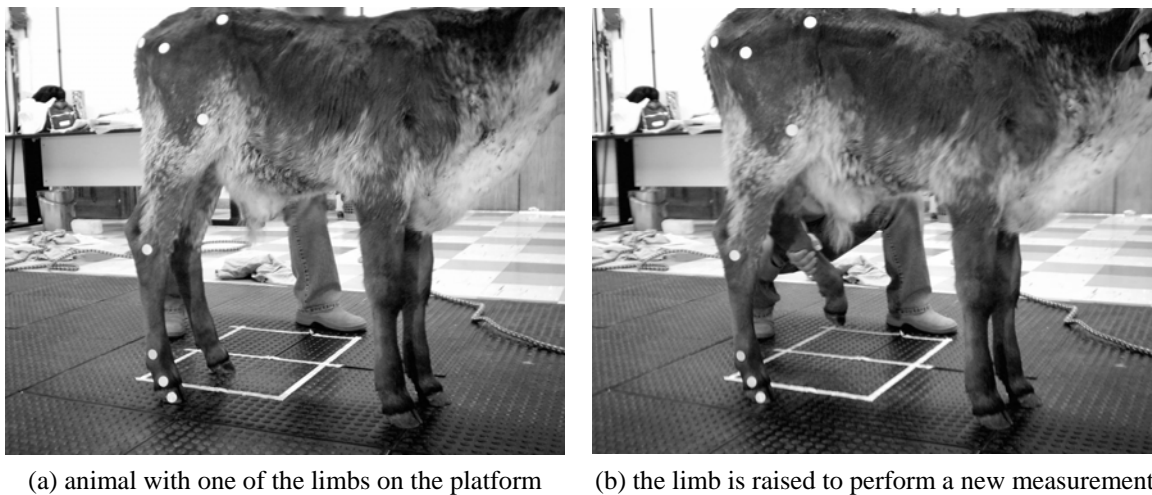

(a) animal with one of the limbs on the platform   (b) the limb is raised to perform a new measurement

Figure 2. Procedure of measurement of the reaction force in calves

3. RESULTS AND DISCUSSION

Table 1 shows the values of the weights measured for the five animals.

Table 1. Weights of the animals used in the experiment

Calf	B 122	B 125	B 129	B 130	B 131
Weight (N)	1274.0	931.0	686.0	539.0	617.4

Despite having similar ages (15 to 60 days), there was a variation among calves' weights, with a mean of 809.5N and standard deviation of 298.2Ñ. Such variation was related to factors such as growing and development of those animals.

An example of the graph generate for each measurement can be seen in Fig. 3. The vertical line that cuts the graph in the region of stabilization corresponds to the value considered for statistical analysis.
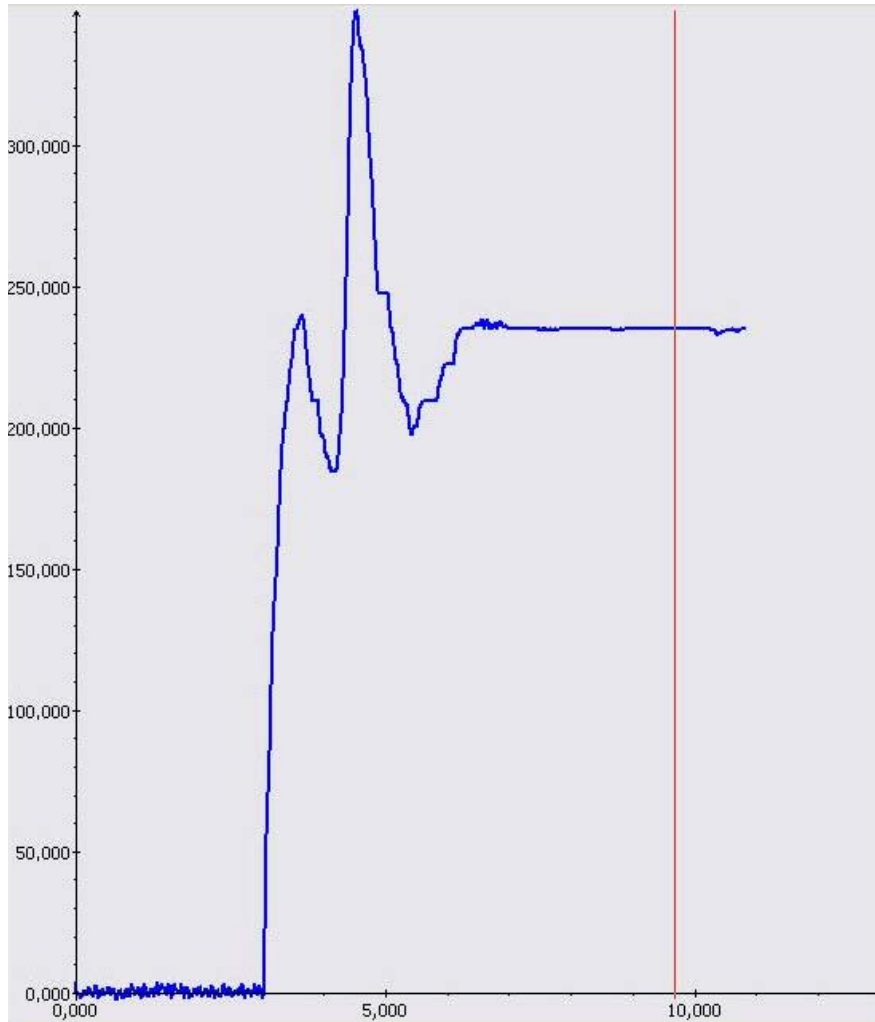

Figure 3. Graph of ground reaction force in a standing static standing position

Table 2 shows the values of the considered forces of each graph with their respective means and standard deviations (SD). At the bottom of table the total mean and standard deviation for each limb are shown.

Table 2. Ground reaction forces registered for each calf in three measurements (F1, F2 and F3)
with mean and standard deviation for each limb.

Calf	Force	Right Front – RF (N)	Left Front – LF (N)	Right Hind – RH (N)	Left Hind – LH (N)
122	F1	210.96	367.46	212.84	206.58
	F2	160.88	369.34	224.73	194.06
	F3	185.92	369.96	222.23	205.32
	Mean	185.92	368.92	219.93	201.99
	SD	25.04	1.30	6.27	6.89
125	F1	312.37	285.36	234.75	209.71
	F2	261.04	274.81	247.89	210.33
	F3	312.37	299.22	223.48	210.33
	Mean	295.26	286.46	235.37	210.12
	SD	29.64	12.24	12.22	0.36
129	F1	172.77	224.73	136.46	134.59
	F2	175.28	212.21	148.36	171.52
	F3	160.25	187.17	161.5	85.76
	Mean	169.43	208.04	148.77	130.62
	SD	8.05	19.12	12.53	43.02
130	F1	225.36	137.72	160.88	123.94
	F2	262.29	150.24	160.25	112.05
	F3	215.97	122.69	136.46	135.84
	Mean	234.54	136.88	152.53	123.94
	SD	24.49	13.79	13.92	11.90
131	F1	190.93	157.75	147.73	104.54
	F2	155.24	170.27	108.29	105.79
	F3	206.58	178.41	118.31	91.39
	Mean	184.25	168.81	124.78	100.57
	SD	26.31	10.41	20.50	7.98
Total Mean		213.88	233.82	176.28	153.45
Total SD		51.68	93.96	48.40	49.38

It was possible observe some differences on data for the same animal during the measurement process. The results of statistical analysis showed that reaction forces with calves in standing static position were greater on anterior limbs, (213.88 ± 51.68N, right and 233.82 ± 93.96 N, left) with $P < 0.05$, than in the hind limbs (176.28 ± 48.40 N, right and 153.45 ± 49.38 N, left).

The percentage of each mean reaction force (showed in Tab. 2) with the corporal weight (showed in Tab. 1) were obtained (Tab. 3) with their respective mean. This mean value corresponds to the portion of the corporal weight (W) supported by each limb.

Table 3. Percentage of each mean reaction force with the corporal weight

Calf	RF mean / W (%)	LF mean / W (%)	RH mean / W (%)	LH mean / W (%)
122	14.6	29.0	17.26	15.85
125	31.7	30.8	25.28	22.57
129	24.7	30.3	21.69	19.04
130	43.5	25.4	28.30	23.00
131	29.8	27.3	20.21	16.29
Mean	28.86	28.56	22.55	19.35

4. CONCLUSIONS

It was concluded that most part of corporal weight (57.42%) is placed on the thoracic region of these animals (front limbs), where it is also placed the centre of gravity. There were no significant differences between left and right sides in both front and hind limbs. These finds were according with results obtained from other species and the percentual distribution of the weight was close to that previously established on literature (Badoux, 1986). Thus, the proposed methodology using force plate was considered an useful method to verify body weight distribution on cattle limbs. The data generated by this study were considered important since it has been the basis for the development of a computational model for studying fractures of long bones in cattle (Rodrigues et al, 2007).

5. ACKNOWLEDGMENTS

6. REFERENCES

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5. RESPONSIBILITY NOTICE

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