A PRELIMINARY EVALUATION OF GROUND REACTION FORCES ON LARGE ANIMALS HIND LIMBS DURING GAIT

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Abstract. *There is a scarcity of information regarding gait analysis in cattle. The aim of this work was to conduct a pilot study trying to verify the ground reactions during bovine locomotion. A male calf (120 days, 136 kgf) was conducted over a base with a force plate connected to a computer, which registered the ground reaction force vertical component . The images of the animal gait were also registered with a high speed data acquisition system, which allowed to determine the initial angle for the contact of the limb with the force plate. Fourteen in twenty attempts were considered successful when the animal stepped on the force plate with one of the hind limbs. The registered mean values (±SD) for the maximal forces were 698.91±51.50N and 618.24±10.10N for the right and left hind limbs, corresponding to 52% e 46% of the calf weight respectively. The variation of forces with time resulted in curves with a M form, with clear indication of the initial contact, load response, terminal weight bearing and flight stages. This curve behaviour was considered similar to those seen in natural humane gait. It was concluded that the determination of ground reaction forces with the force plate is an useful method for studying bovine motion, and that a bovine hind limb can be loaded for more than half of body weight during motion.*

Keywords*: animal gait, force plate, kinetic, biomechanics, calves.*

1. INTRODUCTION

Gait is a common type of motion that occurs in all quadruped mammals. During the motion, the animal body is alternatively sustained by two or three limbs in all stages of the gait (Badoux, 1986). In gait analysis, kinematics parameters such as speed and joint angles are measured experimentally, while the study of forces related to movement is performed by kinetics (Saad et al, 1996). The results obtained with these studies can be useful for treatment of diseases related to locomotor apparatus such as lesions and bone fractures.

In case of bone fractures treatment in large animals (horses and cattle), the knowledge of forces during gait is an important parameter to be used in projects related to the development of devices for bone fixation, such as implants. These implants must resist the load that acts on musculoskeletal system, providing stabilization of bone fragments and allowing immediate recovery, once such animals need to bear weight and walk after surgery.

For large animals, many studies can be found in literature about gait and forces analysis in horses (van Weeren, 2001; Bobbert and Santamaría, 2005) due to the historical importance of these animals for small load transportation and sport modalities. However, information about gait analysis in cattle was not found. So this paucity motivated this work, which was a pilot study, aimed to perform a preliminary gait analysis in a calf, attempting to verify the ground reaction force during locomotion.

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 platform (model: OR6-7; AMTI, U.S.A.) inlaid and leveled to the ground and programs for signals acquisition and data analysis (SIMI Motion 6.0). The force platform (or force plate) can be used to measure the ground reaction force during gait on the three axes. Thus, the three force components (vertical, lateral and horizontal) can be obtained (Araújo et al, 2004). In this study, only the vertical component of ground reaction force was registered, which is the force with main magnitude and that supports the body weight during gait (Vaughan et al, 1999).

A male calf (120 days, 136 kgf) was conducted over a ground with a force plate connected to a computer, which registered the vertical component of the ground reaction force. First of all, a test was made to observe the animal behavior when exposed to the laboratory environment and to the experimental method. The laboratory floor was covered with rubber plates in order to avoid slippage. A 9-meter long and 1-meter width pathway was built using the rubber plates. A square made of adhesive tape was placed over the rubber plates in order to identify the force plate location. When the calf passed through the force plate, it should step on it with one of the hind limbs (Fig. 1). Once it happened, the time and the force magnitude changing during the contact of limb with the plate were registered.

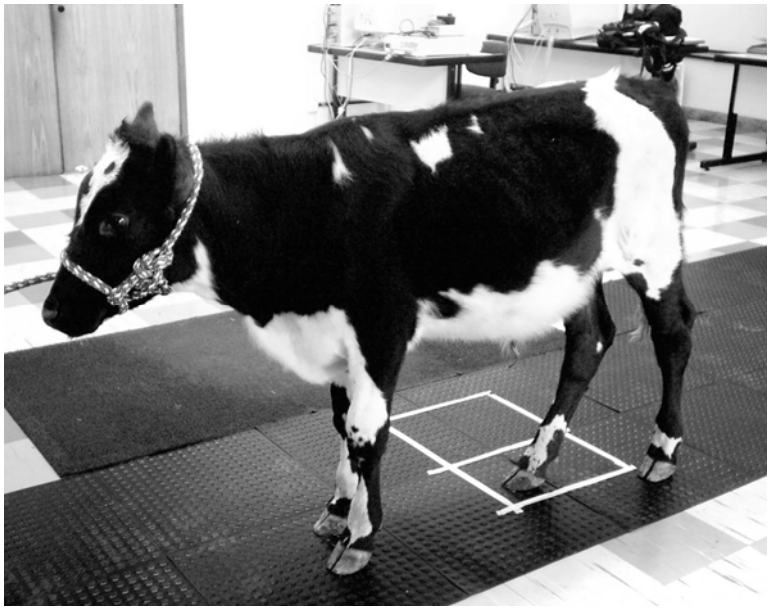

Figure 1. The calf stepping with the right hind limb over the force plate during the experiment.

The images of the animal gait were also registered. Videos were recorded with a high-speed video system (Basler 601f camera) operating at 60 Hz of frequency acquisition. The data combined with a computer-assisted evaluation for the analysis of gait patterns (SIMI Motion 6.0), allowed the complete analysis of the calf's gait. This evaluation was performed by with the completed digitalization of movement of the hind limb during the contact with force platform. To allow the digitalization, the limb was previously labeled with reflexive adhesive (3M™) over the joints, since femur-pelvis joint down to the claw. These points were subsequently linked to obtain the digitalized image of the limb.

3. RESULTS AND DISCUSSION

The animal was able to walk normally and could step on the force plate in 70% of attempts (fourteen in twenty). Due to imposed methodology, the data of eleven attempts was registered. Nine of those were with the left hind limb and two with the right hind limb. Graphs with the collected data were plotted showing the force variation during the period of contact with the force plate. Figure 2 shows the graph of force vs. time.

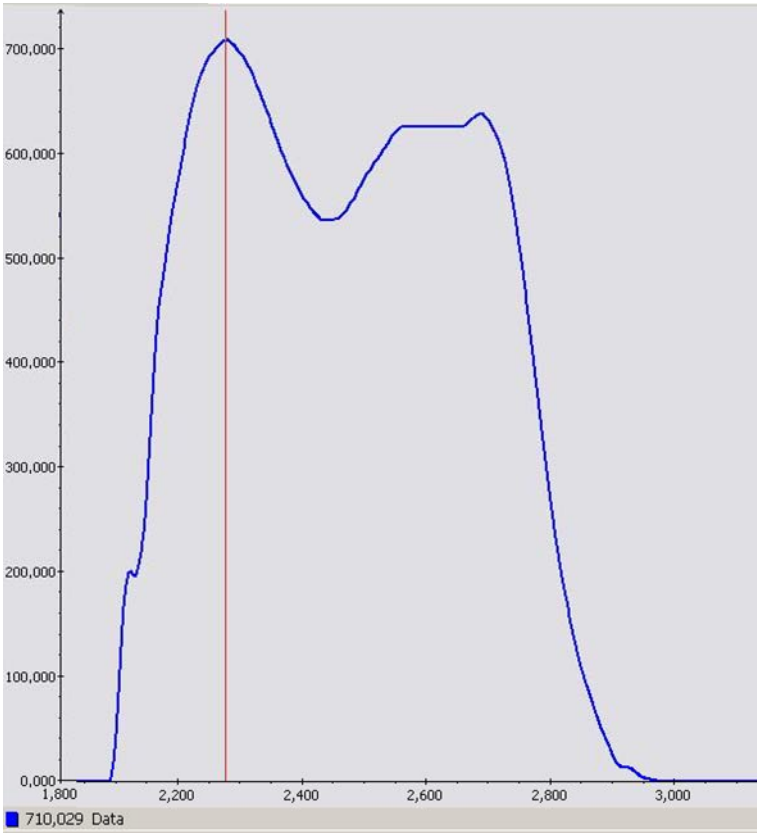

Figure 2. Variation of the force during the contact with the force plate

Starting from zero, the graph had a first peak corresponding to the initial contact of the limb with the force plate (initial contact stage). This maximum force is the most critical, as it is mainly supported by the bone structure. Secondly, the graph had a descent that corresponds to the response of muscular group of limbs to the load (load response stage). A new peak, lower than the first, corresponds to terminal weight bearing stage. Finally, in the flight stage, the contact ended and the force plate was unloaded. Due to represent a critical value, the ground reaction force considered was that corresponding to the maximum peak of graph. The period of contact of the limb with the force plate was of about one second. The graphs of force vs. time have an M form with clear indication of the initial contact, load response, terminal weight bearing and flight stages. This profile was considered similar to those found in the literature for natural humane gait (Vaughan et al, 1999). In spite of find that the graphs have a form considered similar, it is not objective of this study to establish some comparison or correlation with the human gait.

The values of maximum forces were taken from each graph and were statistically evaluated. They correspond to nine forces from right hind limb and two from left hind (Tab. 1).

Table 1. Values of the maximum vertical ground reaction forces on gait during the contact with the force plate

Force	Right hind limb (N)	Left hind limb (N)
F1	664.19	611.10
F2	813.80	625.38
F3	688.60	*
F4	652.23	*
F5	710.03	*
F6	701.71	*
F7	736.30	*
F8	672.33	*
F9	651.04	*
Average	698.91	618.24
Standard Deviation	51.50	10.10

*: values not measured

The mean value of the maximum ground reaction forces were 698.91±51.50N for the right hind limb and 618.24±10.10N for the left hind limb, corresponding to 52% and 46% of the animal weight, respectively.

The image digitalization process demanded a special effort for obtaining a complete image of limb contacting with the platform. It was necessary to get the frame by frame image since the beginning of contact to the final contact instant. Figure 3 is the digitalized image of the first frame showing the initial contact of the right hind limb with the force plate. The analysis of this image allowed the determination of the initial angle of the femur with the horizontal line in the sagittal plane, which the value 127º. This value was very close to the angle corresponding to the maximum force, once the fully contact happens during one second. The data obtained with the image digitalization will be useful in determining kinematics parameters such as vector coordinates, velocity and accelerations, analysis beyond the objectives of this study.

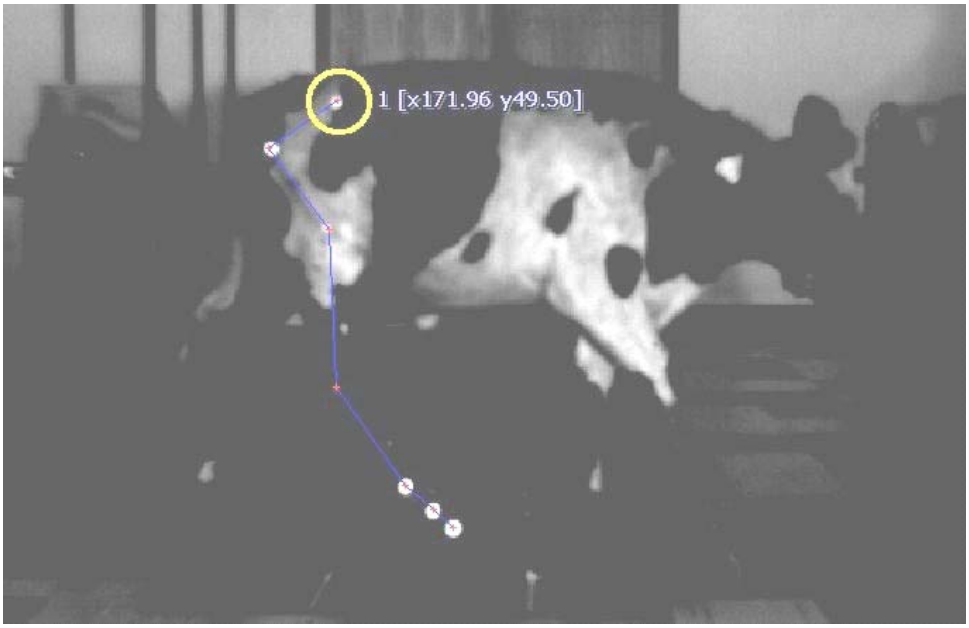

Figure 3. Digitalized image of the first frame showing the initial contact of the right hind limb with the force plate

4. CONCLUSIONS

This pilot study was performed to obtain information about ground reaction force produced by calves on gait, once this data weren't found in literature. The results show that the experimental determination using the force plate is a viable method and can be applied for calves. Latter, for new experiments, other animals should be used to represent a statistically significant sample. It is advisable that the animals to be used must be previously trained to gait without human interference, mainly if they were young animals.

Although the obtained data were for only one calf, the values of forces and angle will be considered as initial values in theoretical and experimental projects developing orthopaedic devices for large animals, specifically the specie used in the experiment.

5. ACKNOWLEDGMENTS

To State University of Bahia Southwest that provided a doctoral scholarship (PPG-UESB) for the first author during his studies in Brazil at Federal University of Minas Gerais. To CAPES, that provides a doctoral scholarship for the first author during his studies at Technical Superior Institute in Lisbon. To FAPEMIG and CAPES for financial support.

6. REFERENCES

Araújo, C.C., Preis, C., Ribas, D.I.R., Faller, L., Israel, V.L. and Rech, V., 2004, “Sistemas de Avaliação da Marcha Humana”, IX Congresso Brasileiro de Informática em Saúde, Ribeirão Preto, SP.

Badoux, D.M., 1986, “Biostática e Biodinâmica Gerais”, Anatomia dos animais domésticos, Getty, R. (Ed.), 5ª ed. Rio de Janeiro: Guanabara, pp. 47-79.

Bobbert, M.F. and Santamaría, S., 2005, “Contribution of the forelimbs and hind limbs of the horse to mechanical energy changes in jumping”, The Journal of Experimental Biology, 208, 249-260.

Saad, M., Battistella, L.R. and Masiero, D., 1996, "Técnicas de Análise de Marcha", Acta Fisiátrica, 3 (2): 23-26.
SIMI MOTION. http://www.simi.com/
Vaughan, C.L. Davis, B.L. and O'Connor, J.C., 1999, "Dynamics of Human Gait", 2nded, Cape Town: Kiboho Publishers, 153p.
van Weeren, P.R., 2001, "History of Locomotor Research", In: Equine Locomotion, Back, W. and Clayton, H.M. (Eds.). London: W.B. Saunders, pp. 1-34.

5. RESPONSIBILITY NOTICE

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