A SLIP Model to predict the dynamics of rapid tetrapod locomotion during hind-leg single support

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Summary

Greyhounds are the fastest canine in the world and sustain unique types of injuries which are rarely seen in other breeds of dogs. Track surface is one of the primary injury contributing factors. There has been little research on the interaction of greyhound's dynamics with the track surface. Thus, in this study, a three degrees-of-freedom model of greyhounds' body and underneath surface using spring loaded inverted pendulum modelling is designed. The results showed that the forces acting on the hind-leg were substantially affected when the surface compliances altered from relatively hard (natural grass) to relatively soft one (synthetic rubber). The forces acting on the hind-leg were almost nine times that of the forces acting on the dog's centre of mass for natural grass surfaces. This highlights the importance of optimum surface design in the safety and welfare of these animals.

Introduction

Race track surface is one of the main injury contributing factors and ideally should act to absorb the impact forces of the paws while providing traction for a controlled gallop and efficient use of energy. In addition to the research on surface composition of race tracks, there is still a big gap on an interaction of race track surface with greyhounds sprinting.

To study the impact of surface compliance on the biomechanics of rapid tetrapod locomotion, a spring-loaded-inverted-pendulum (SLIP) model is deployed. The model is a three-degrees-of-freedom (3-DOF) system, representing the greyhound's body and the surface below [1]. The right hind-leg single support phase (RH single support) during galloping gait is considered due to its high rate of injuries and also its primary function in powering the locomotion [2, 3].

Methods

High frame rate videos of greyhounds galloping on a straight section of a track were captured and analysed to get the initial conditions required for the model (Fig.1.A). The SLIP model of greyhounds during hind-leg single support is designed (Fig.1.B).

The mechanical properties of surfaces were obtained by an enhanced Clegg Hammer impact test designed to measure the spring and damping coefficients [4] (Fig.1.C). The Lagrange method was deployed to derive the equation of motion. The equations were numerically solved using Runge-Kutta method in MATLAB R2018b.

Results and Discussion

The model could predict the overall load acting on galloping greyhound's centre of mass (CoM) and hock, during hind-leg single support on grass (k=107 kN/m) and rubber (k=68.2 kN/m). In order to calculate the ground reaction forces (GRF) during RH single-support, the absolute value of hind-leg compression was used, generated by the model and multiplied by the spring coefficient of the leg [5]. The peaks of GRF on both surfaces were similar (810 N) suggesting that surface compliance does not affect the CoM dynamics. To obtain the forces acting on the hind-leg (Impact Force) during RH single-support, the surface compression was multiplied by the surface stiffness coefficient. Three peaks were observed in Impact Forces for both surfaces (Fig.1.D) and the second peak was the highest of all these peaks. This peak suggests the surface compliance affects the dynamics of hind-leg during RH single-support.

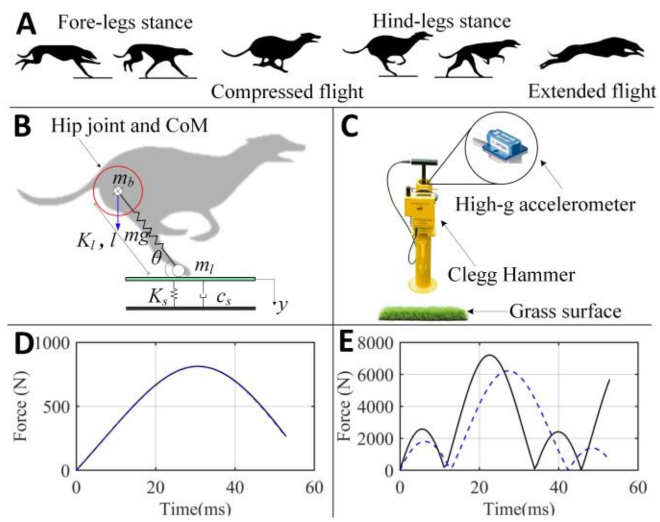

Figure 1: Full stride of a galloping greyhound (A). SLIP model (B). Clegg Hammer impact test (C). GRF (D) and the Impact Force during RH single support (E). Rigid black and dashed blue lines represent grass and rubber surface respectively.

Conclusions

The results showed that surface compliance does not have any considerable effect on the GRFs acting on CoM. Increasing the surface spring coefficient by 36%, resulted in an almost 13% increase in the Impact Force acting on the hind-leg. This study also showed the importance of optimum surface design in reducing catastrophic injuries in racing greyhounds.

References

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