MODIFYING LANDING MAT MATERIAL PROPERTIES TO REDUCE INJURIES IN GYMNASTICS LANDINGS

Chris Mills[1], Matthew T. G. Pain[2] and Maurice R. Yeadon [2]

[1]School of Sport and Health Sciences, University of Exeter, St. Luke's Campus, Exeter, UK, EX1 2LU, chris.mills@exeter.ac.uk
[2]School of Sport and Exercise Sciences, Loughborough University, Ashby Road, Loughborough, UK, LE11 3TU.

INTRODUCTION

Many sporting activities, from running to Artistic Gymnastics, involve a landing component. Several factors may contribute to the frequency and severity of injuries during landing including body position at the instant of touchdown, performance execution and the landing surface (McNitt-Gray, 2000).

In Artistic Gymnastics the landing mat is standardised by the international governing body (F.I.G.) and the standards are based upon the need to establish uniformity of the equipment used during competition rather than purely musculo-skeletal issues (McNitt-Gray, 2000). A better landing mat may exist that could reduce injury risk whilst allowing the gymnast to maintain a landing technique that minimises landing deductions.

The aim of this study is to determine the material properties of a landing mat that minimise internal loading and external forces experienced by the gymnast during landing.

METHODS AND PROCEDURES

A subject-specific 7 link planar model representing the gymnast was constructed using visualNastran 4D (Figure 1). This model has previously been successfully evaluated against gymnast landings (Mills et al., 2008).

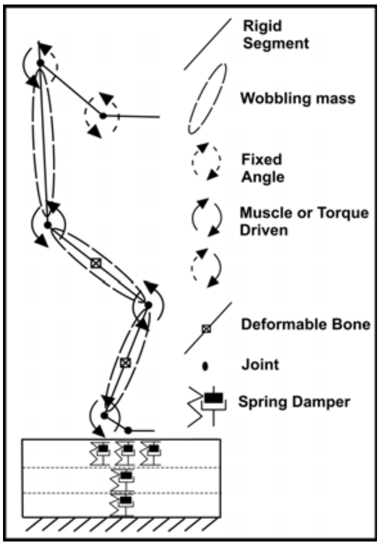

Figure 1. Simulation model of the landing mat and the gymnast.

The competition landing mat's material properties were based upon rigid body impact tests performed independently (Pain et al., 2005). The landing mat model was based upon a multi-layer spring-damper design and evaluated using the independent impact tests (Mills et al., 2006). This 6 parameter landing mat model combined sufficient detail allowing the modification of the stiffness and damping parameters for each of the independent layers of the mat.

The stiffness and damping characteristics for each layer of the mat were optimised using a Simplex algorithm to minimise the GRFs. Since the muscle activation histories remained unchanged from the model evaluation any decrease in external GRFs may also result in decreased internal loading.

RESULTS

Optimisation of the six landing mat parameters resulted in the peak vertical (Figure 2) and horizontal ground reaction force being reduced.

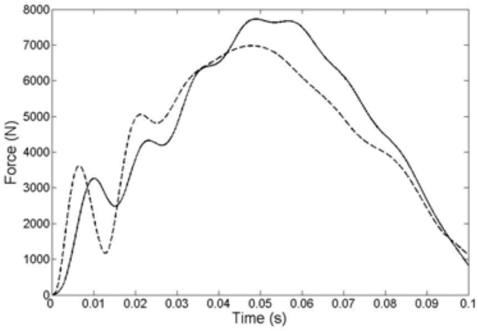

Figure 2. VGRF after optimisation of landing mat properties (Solid line = matching simulation, dashed line = opt simulation).

This reduction in peak GRFs was also accompanied by a decrease in peak shank (Figure 3) and femur bone bending moments.

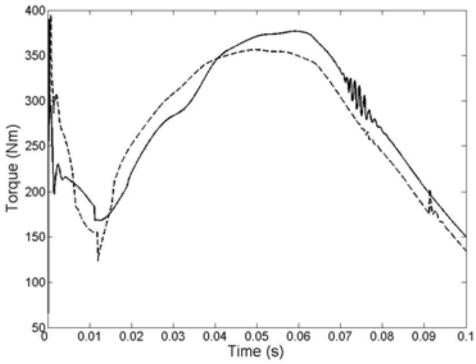

Figure 3. Shank bone bending moments during landing. (Solid line = matching simulation, dashed line = optimised simulation).

The optimisation of the landing mat parameters were characterised by minimal changes to the landing mat's stiffness (<0.5%) but increased damping (272%).

DISCUSSION

The most significant finding of this study was that modifying the material properties of the competition landing mat could reduce the peak GRFs and internal loading on the gymnast during landing. A reduction in forces on and inside the musculo-skeletal system could help to reduce the injury risk associated with landing (McNitt-Gray et al., 2000).

The increased damping in the optimised mat may alter the physical recovery of the mat to its original shape. This may also compromise the stability and therefore affect the recovery of balance of the gymnast. A finite element model could help to reproduce the surface area deformation seen in the impact tests (Pain et al., 2005). It is also possible that increased damping may cause increased initial foot contact forces. The use of a thin, soft additional layer to reduce this potential foot problem needs investigating.

The solution found here is likely to be a local minima, near to the original F.I.G. competition mat and although this may be a shortcoming of the study in methodological terms it does not affect the major finding.

Local solutions may also be more useful from an applied point of view as a true global solution may require very different manufacturing processes to construct the landing mat. The local minimum solution means that minor manufacturing changes to the material properties of the mat would result in the gymnast experiencing reduced internal loading forces.

REFERENCES

Mills et al., (2008). *J of Biomech*, 41, 621-628.

Mills et al., (2006). *J of App Biomech*, 22, 103-111.

Pain et al., (2005). *Med Sci. Sports & Exerc*, 37, 1754-1760.

McNitt-Gray, J. L. (2000). *Encyclopaedia of Sports Medicine: Biomechanics in Sports*. IOC, Blackwell Science, pp.523-549.