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Title: Engineering theory can help dancers dance better and safer

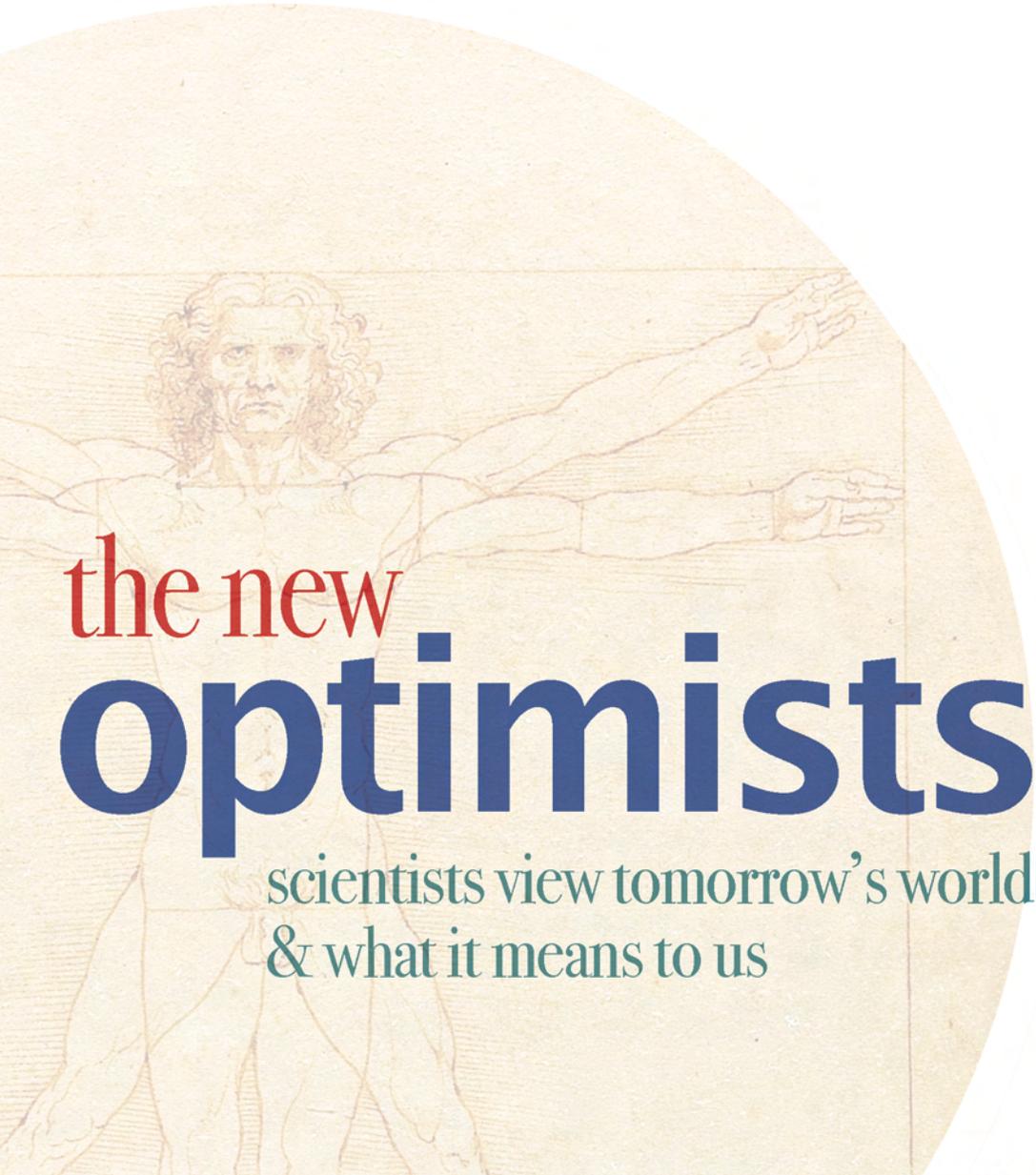
Chapter & version: Published version

Original citation: Shippen, J. (2010) 'Engineering theory can help dancers dance better and safer ' in *The New Optimists: Scientists View Tomorrow's World & What it Means to Us*. ed. Keith Richards. Birmingham: UK: Linus Publishing

Publication website: <http://newoptimists.com>

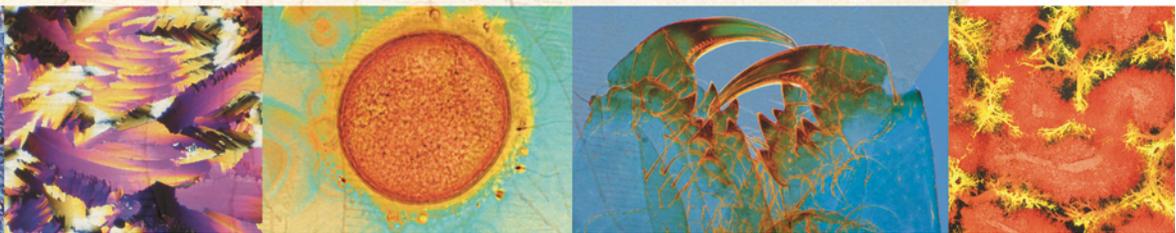
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Available in the CURVE Research Collection: March 2012



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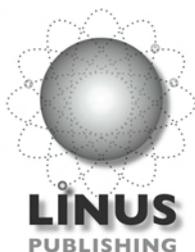
edited by **KEITH RICHARDS**
with a foreword by **Jenny Uglow**

The New Optimists

Scientists View Tomorrow's World & *What It Means To Us*

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Linus Publishing Company Limited

The Moseley Exchange
149-153 Alcester Road
Birmingham
B13 8JP

www.newoptimists.com

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A CIP Catalogue record for this book is available from the British Library.

ISBN 978-1-907843-00-6

Typeset by Etica Press Ltd, Malvern, Worcestershire WR14 1ET

Printed and bound in Great Britain by Thomson Litho Ltd, East Kilbride,
Scotland

Engineering for dancers – modelling movement

James Shippen

Injury rates are higher for dancers than for footballers, Formula 1 racing drivers and builders. Not only do dancers have to jump, land, twist and stretch but they have to appear elegant and effortless at the same time. It can be no surprise therefore that placing these demands on the body often results in injuries.

Engineers know a lot about loads in structures, and what is a dancer's body if not a very complicated structure? Currently research is being undertaken to try to understand the movements of the dancer's body using engineering theory and, hopefully, in the longer term moving towards a situation where this knowledge can be used to advise the dancer on how to reduce injury rates.

The process of analysing a dancer's performance will typically

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commence by measuring their movements. Traditionally this has been done by taking a video of the movement, but this approach has the disadvantage of yielding only a two-dimensional image of subject, which makes accurately measuring angles and translations difficult and permanently limits the observer to the original position of the camera.

A preferable approach is to capture the dancer in three dimensions using equipment more normally found in large research hospitals or in Hollywood to create computer-animated graphics for the latest blockbuster. These techniques and equipment enable accurate measurement of the dancer's performances and have the additional advantage that it is possible to observe from any vantage point at any time in the future. However, the approach has the disadvantage that currently the equipment required for the measurement costs many thousands of pounds – though hopefully this will ease with time.

Together with the movement of the dancers, it is also important to know the external forces acting on the performers' bodies. These forces can be many times body weight and can cause injuries, especially when the body is in a posture that means it cannot resist the load. Most of this force is normally provided during contact with the floor. For example, think of the forces exerted by the floor on the dancer during landing following a large jump. However, if a pair are dancing together, the weight of the female on the male during a lift will cause large loads in his back and a horizontally cantilevered female will also experience large stresses in her back. Floor loads are typically measured by forceplates (similar to very accurate bath scales) buried into the performance floor of the laboratory.

We now have recorded the movement of the dancers and the forces that are being applied to them, which means that, together with the body mass distribution, we can calculate the torques that are occurring at all of the joints. Interesting as this is, it does not directly indicate whether an injury will result in either the short or long term. To get a step closer we must investigate how the body reacts to this situation in terms of the loads that occur in each of the muscles and at the joints. Unfortunately, it is impractical and unethical to implant load measurement devices into the muscles and joints and therefore we have to calculate these forces indirectly.

thinking differently

There are many more muscles in the body than the joints which they control and therefore there is not a unique solution to the distribution of loads in the muscles. To break this impasse we have to make an assumption about how the brain recruits muscles throughout the body to achieve the desired movements.

It seems reasonable to assume that the brain will attempt to turn off all the muscles as much as possible whilst still generating enough torque to overcome external forces and to move the body. This strategy can be justified by appreciating that by turning the muscles off as much as possible, the preponderance to fatigue will be reduced and this would have evolutionary benefits in the event of an unanticipated attack. Applying this assumption permits the calculation of the loads in the muscles.

A muscle which crosses a joint will not only produce a torque at the joint but will also affect the contact force which that joint experiences. As the muscles around a joint typically operate at much smaller distance than the external, inertial and gravitational forces which they counteract, the forces in the muscles can be very large and therefore so will be the joint contact forces – but it is now possible to calculate these internal joint loadings.

The mathematics for the analysis of dancers as described would have been regarded as pedestrian by Newton 300 years ago. The recent advances have been made possible by the ability to undertake the analysis within a practical time and without errors by using modern digital computing. For example, the three-dimensional reconstruction of the dancers' movements can be undertaken in real time.

The quality of the results from the analysis is very dependent on the quality of information in the biomechanical model of the dancers. The model will contain characteristics of the joint anatomy and muscle physiology. It is very difficult to obtain this information across the whole in a self-consistent manner because often the data will have to be extracted from multiple sources and synthesised into the single entity. Also, due to the complexity of human musculature and scarcity of data, it is inevitable that some muscles will not be represented in the model and it is a judgement call as to which can be safely eliminated. For example, it should not be

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controversial that facial muscles do not play a large locomotive role, but do the muscles associated with the hand?

Additionally, we need to improve our understanding of the injury processes that result from these loads. Dancers are not in the business of wanting to know how many Newtons of force are in their tibialis anterior or the compressive Hertzian contact load under their medial femoral epicondyle. They want to know if the steps they are performing will injure them and cut short their career, or worse.

We can compare the loads generated in the muscles with the ability of the muscles to tolerate those loads: if the former greatly exceeds the latter, injury is possible. But this is a crude criterion.

I am optimistic that engineering theory can help dancers dance better and more safely. We have made significant advances in the ability to investigate the loads experienced by dancers during rehearsal and performance, but there is still a long way to go.