

# INFLUENCE OF PEDALLING SPEED AND DIRECTION ON PATELLOFEMORAL JOINT FORCES DURING ECCENTRIC ERGOMETRIC CYCLING

<sup>1</sup> Johan Wasserfall, <sup>2</sup>Willem van der Merwe and <sup>1</sup> Christopher L Vaughan

<sup>1</sup>Department of Human Biology, University of Cape Town, South Africa

<sup>2</sup>Sports Science Orthopaedics Clinic, Cape Town, South Africa

## INTRODUCTION

Eccentric ergometric cycling recently started to be included in rehabilitation exercise programmes. However, very little published data exist on eccentric cycling, even though there are significant differences between eccentric and conventional (concentric) ergometric cycling. During eccentric cycling the ergometer drives the legs and the patient tries to resist the motion, resulting in an eccentric contraction of the quadriceps.

In a previous study [1] much higher maximum forces were measured during eccentric cycling than during conventional cycling. This is in agreement with the force-velocity characteristic of eccentric muscle contraction.

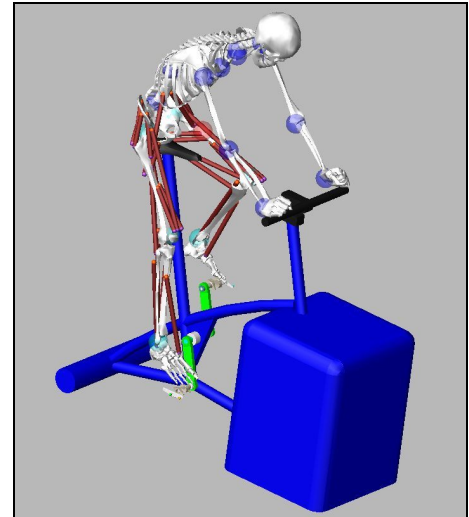
In order to evaluate the influence of pedalling speed and direction on patellofemoral joint forces during eccentric ergometric cycling, recorded data were used to drive forward-dynamic simulations of a three-dimensional computer model of a human subject pedalling an eccentric exercise cycle.

## METHODS

Pedal forces, EMG and motion data were captured as a human subject pedalled on a Grucox eccentric ergometer. Two pedal dynamometers were used to measure the normal and tangential pedal forces in the plane of the ergometer. Data were captured at various pedalling speeds and directions. Note that no method exists to control the work done by the subject and exertion is entirely under the subject's control. The subject was instructed to resist the pedal motion as best as possible without pulling on the handle bars or standing in the pedals.

LifeMOD software was used to construct a three dimensional dynamic computer model of the subject pedalling the eccentric ergometer (Figure 1). A detailed computer model of the subject's right knee was included (not shown) in order to calculate joint contact forces.

Inverse dynamic simulations were run for each scenario in order to establish the displacement histories of the muscles and joints. This was followed with forward dynamic simulations during which the muscle excitation patterns, which correspond to the muscle length histories and the pedal forces, were calculated.



**Figure 1:** Computer model of the subject pedalling the eccentric ergometer.

## RESULTS AND DISCUSSION

Peak forces normal to the pedal (Table 1) show a tendency to increase with pedalling speed, but only for the lower speeds. For higher speeds the increase is much lower and the relationship to speed is much less clear. It is thus suggested that in the case of eccentric cycling, pedalling speed may have a lesser effect on muscle forces than conventional cycling. This is believed to be a combined result of the force-velocity characteristic of eccentric muscle contraction, the perceived effort exerted by the subject and the body weight of the subject. Body weight is probably a major limiting factor as the subject tends to reduce resistance when lifted out of the saddle by the ergometer.

## CONCLUSIONS

Increased pedalling speed during eccentric cycling does not necessarily result in increased muscle forces. However, the lowest pedal forces were measured at low speeds and these speeds should probably be recommended during the initial part of an exercise programme. Further analysis will be done on the muscle excitation and joint contact forces.

## REFERENCES

1. Harman E, et al., *Journal of Biomechanics*, **21**, Issue 10, Page 878, 1988.

**Table 1:** Peak forces (N) at various pedalling speeds (rpm) measured normal to the pedal.

Pedal forces (N)	Pedalling speed (rpm)					
	5	20	30	60	-30	-60
Left pedal	336	519	549	525	600	681
Right pedal	424	512	532	669	544	528