METHOD FOR THE DETECTION OF FATIGUE DURING GYMNASTICS TRAINING

Karen T Beatty, Andrew S McIntosh and Bertrand O Frechede

Biomechanics and Gait Laboratory, The University of New South Wales, Sydney, Australia

The purpose of this study was to determine if acceleration measured at the pelvis was a suitable indicator of fatigue in gymnasts. Fourteen gymnasts performed vertical jumps and drop landings pre and post a fatiguing jumping activity. Peak acceleration during landing for jumps and drops increased significantly after fatiguing activity. Acceleration is a tool that can be collected with limited disruption to gymnastics training and an increase in peak acceleration during landing of simple jumps appears to be a useful tool for determining whether gymnasts are fatigued.

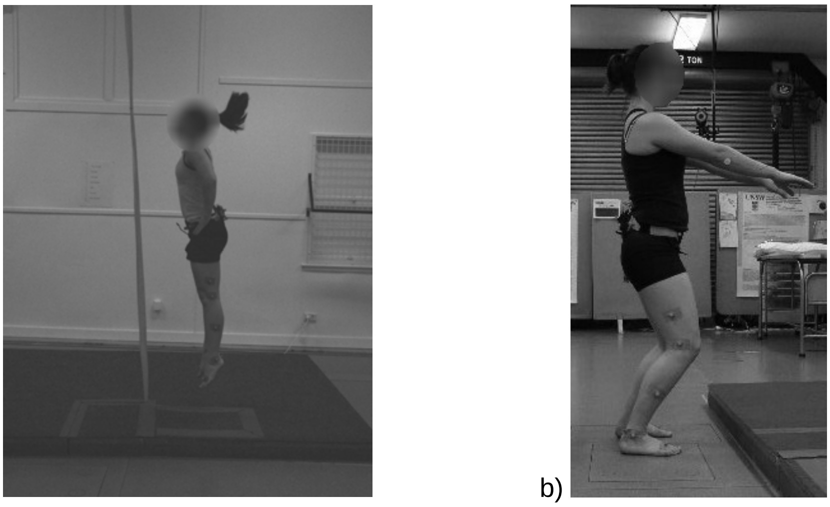
KEY WORDS: gymnastics, injury, fatigue, acceleration.

INTRODUCTION: Fatigue, in the many forms it may take, has the potential to affect training, injury tolerance levels, biomechanical response, perception and awareness of loads, cognition and assessment of risks, competitiveness/motivation and skills performance. Muscular fatigue is a factor that may influence loads on the extremities, as energy absorbing tissues may be less able to absorb and transfer the energy effectively. Muscular fatigue is hence suggested as a possible risk factor for injury (Madigan and Pidcoe 2003). Gymnastics is a high risk sport and one in which a range of components must be executed correctly for a single skill to be performed successfully.
It is not known whether or not a gymnast becomes fatigued during a training session of up to four hours, or how the risk of injury is increased in the case of fatigue. Therefore the aims of this project were to develop methods useful for examining the presence of fatigue in a gymnastics training setting. It was conjectured that there may be some change in acceleration characteristics during landing from a jump after fatiguing exercise.

METHOD:

Data Collection: Acceleration at the pelvis was collected during drop landings and landings from vertical jumps before and after a fatigue protocol. Several tools were used to indicate the presence of fatigue after the fatigue protocol was performed. These included electromyography of the gastrocnemius muscle during a static single leg toe raise, movement of the centre of pressure under the foot during single leg balancing, jump height and a perceived exertion rating.
Fourteen competitive female gymnasts were recruited from a gymnastics training centre in the Sydney metropolitan area. Participants were aged between 16 and 22. At the time of testing they were competing between levels six and ten of the Australian gymnastics levels system. The experiments were conducted at the University of New South Wales in the Biomechanics Laboratory in the School of Safety Science.
The activities were chosen because of their specificity to gymnastics skills. Participants were instructed to bring the body to rest in a squat similarly to the competition requirement for landings. During the vertical jump participants were to jump as high as possible each time and the drop height was 35 cm.
Acceleration data were collected using a Microstrain telemetric V-Link data logger with two accelerometers (IC sensors 3031-050) mounted orthogonally, sampling at 352Hz. The accelerometer array was positioned to approximate the location of the centre of mass of the whole body as this would allow concurrent data collection with other projects and result in minimal disruption to gymnasts when training. A waist belt with the data-logger and accelerometers was placed on the gymnasts' pelvis and waist and leg straps on the belt were tightened as much as permitted by the gymnast and secured by Velcro. A piece of foam was then wedged between data-logger and sacrum in an attempt to further reduce

movement artefacts caused by movement of the data-logger that was not representative of sacral movement. The mass of the system was 0.3 kg.
Jump height was measured using the peak height of the trajectory of a marker at the sacrum which was collected using a Vicon 612 System. The jump height was calculated as the peak height of the trajectory during jumping minus the standing height of the marker.
The protocols included a measurement protocol and a fatigue protocol. During the measurement protocol data for indication of fatigue were collected and then acceleration during five vertical jumps and five drop landings were collected. The fatigue protocol was designed to induce a defined level of fatigue in the participants. Participants were well trained gymnasts and a relative level of fatigue defined by a reduction in jump height during goal oriented jumping was preferred over a protocol consisting of a set number of fatiguing tasks. Borg's rating of perceived exertion (Borg 1970) was also used to monitor fatigue.
The fatigue protocol consisted of one standing vertical jump approximately every four seconds, with the hands kept on the hips to maximise lower body involvement and speed the onset of fatigue. The measurement protocol was performed first followed by the fatiguing protocol. During the fatigue protocol participants continued jumping until two consecutive jumps reached only 95 percent of the original jump height at which time the measurement protocol was repeated. The fatigue protocol was repeated twice more and the measurement protocol repeated when 2 consecutive jumps reached only 90 percent and 85 percent of original jump height. This resulted in one pre-fatigue set of data and three post-fatigue sets of data.



a) b)

Figure 1 a) Fatigue protocol jump, b) landing from measurement jump or drop

Data Analysis: Acceleration data were filtered using a fourth order low pass Butterworth filter with a cut-off frequencies of 15 Hz. EMG data were treated with a high pass filter with a cut off frequency of 20Hz as well as an anti-aliasing low pass filter with a cut-off frequency of 500Hz prior to data acquisition. Matlab® software was then used to perform Fourier transforms of EMG data for analysis of the mean and median frequencies as well as to calculate peak acceleration during each landing.
Significant differences in results between conditions were determined using a two-way ANOVA with replication.

RESULTS: Gymnasts reported anecdotally that at the end of the testing procedure they felt similar to how they felt at the end of a training session and that as each fatigue jump set progressed it became more difficult to motivate themselves to jump as high as possible. Each fatiguing phase lasted approximately 15 minutes, resulting in approximately 225 vertical jumps in each fatiguing phase and 675 jumps in total. On average participants demonstrated fatigue on three of the five indicators (2-4).
Peak acceleration during landing at the pelvis increased for both tasks (see Figure 2). A two-way ANOVA with replication showed that there were differences between groups ($p < 0.001$).

The first post-fatigue tests showed peak accelerations 136% of values found during pre-fatigue tests. Post-fatigue 2 and 3 tests were 140% of pre-fatigue values. Acceleration was seen to have increased after fatigue consistently for each subject in the study. Data were skewed towards lower peak accelerations. The mean, median and standard deviation are shown in Table 1. Perceived exertion increased as jump height during the fatigue protocol decreased.

Table 1 Mean, median and standard deviation of peak acceleration across fatigue conditions (m.s-2)

	Mean	**Median**	**Standard Deviation**
Pre- fatigue	28	21	23
Post-fatigue 1	37	31	22
Post-fatigue 2	40	38	19
Post-fatigue 3	40	38	19

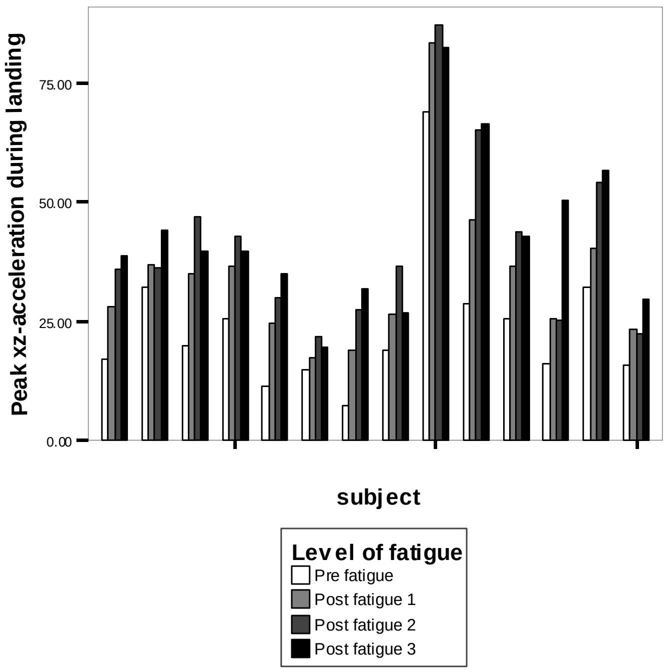


Figure 2. Change in peak local z-acceleration for each subject during landing, n = 134 trials for each fatigue level total, n is between three and five for each fatigue level for each participants

DISCUSSION: The indicators used showed that subjects were fatigued and subjects reported reduced motivation to continue jumping as high as possible and that it required considerable concentration in order to achieve the greatest height possible. It is obvious that a reduction in motivation may affect the outcome of the performance of a gymnast and this may, as well as being an effect of fatigue, contribute to the effects of fatigue in kinetics and kinematics.

Changes in acceleration were expected during landing after fatigue and that these changes would be useful as a portable tool for identifying the presence of fatigue in the field. Significant increases were seen in the peak acceleration during landing from both the vertical jump and the 35 cm drop and were consistent for each participant. This change in acceleration was seen during landing from low heights – being those the gymnast could propel themselves to from a static start and the 35cm drop. During training and competition gymnasts are exposed to landings from much higher heights as they tumble on the floor and perform dismounts from different apparatus above the ground. As a result the increase seen in acceleration measured from these landings of greater demand may be greater than those seen in this laboratory study.

It is proposed that values of 140% of initial peak acceleration values during landing from a vertical jump be seen as an indicator for the presence of fatigue and a point at which a training session is discontinued. Further tests with more demanding landing tasks may elucidate the change in acceleration which best indicates fatigue.

CONCLUSION: The intention of the project was to analyse whether there were any changes in acceleration during landing after intermittent fatiguing activity, similar to that which would likely to be imposed during gymnastics training. The fatigue protocol focused on the lower body and involved a number of jumps comparable to the number of skills reported to be performed during a training session. In addition to markers of fatigue used, the reports of gymnasts that they felt similar to how they felt at the end of a training session support the suggestion that fatigue is present during gymnastics training and may therefore contribute to injury risk. The measurement of acceleration pre- and post-training can provide information regarding the actual presence of fatigue during gymnastics training and assist with determining how this fatigue may contribute to injury risk.
A consistent increase in peak acceleration at the pelvis as well as the jerk for all subjects was demonstrated after fatiguing jumping, indicating that acceleration can provide information regarding changes in the way that the musculoskeletal system performs after fatigue.

REFERENCES:

Borg, G. A. V. (1970). "Perceived exertion as an indicator of somatic stress." Scandinavian Journal of Rehabilitation Medicine 2-3: 92-98.

Madigan, M. L. and P. E. Pidcoe (2003). "Changes in landing biomechanics during a fatiguing landing activity." Journal of Electromyography and Kinesiology 13(5): 491-498.