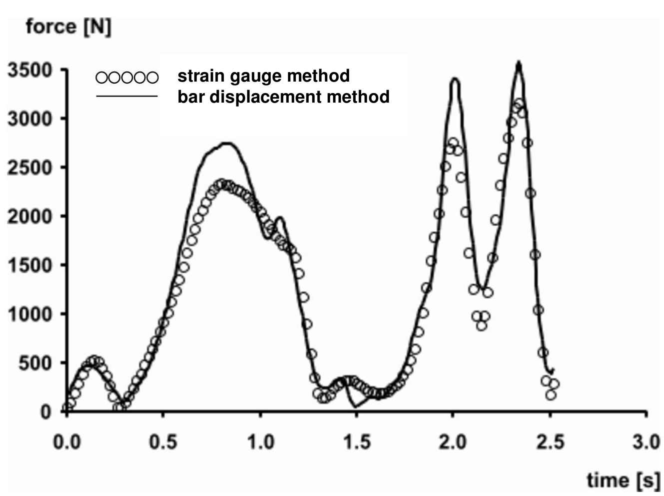
Kerwin, D.G. and Hiley, M.J. 2003. Estimation of reaction forces in high bar swinging. Sports Engineering, 6 (1), 21-30.

Reaction forces experienced by gymnasts swinging on the high bar may be determined indirectly using inverse dynamics analysis or may be measured using strain gauges. The accuracy of inverse dynamics analysis may be poor due to errors in the estimated inertia parameters and in the accelerations obtained from digitised data. On the other hand the use of strain gauges is not always possible in elite competition. This paper presents a method for estimating the reaction forces based on the linear displacements of the bar.

Under a central load of 2200 N the bar must produce a vertical deflection of 0.10 m ± 0.01 m. When the load is removed the bar must resume a straight line with no deviations from its original shape (FIG, 1989). Although there is no recommendation regarding the tension in the cables they must be capable of withstanding a load of 8000 N. The FIG requirements suggest that the high bar behaves like a linear spring (based on Hooke's Law). If this is the case the displacement in the bar would be proportional to the load applied to it. If the relationship between displacement and load were known it would be possible to estimate the reaction forces from the linear displacements of the bar obtained from video analysis.

The bar was modelled as a point mass attached to horizontal and vertical linear springs (obeying Hooke's Law) with stiffness coefficients determined from static loading. The stiffness coefficients of the bar were determined with three different tensions in the stabilising cables of the high bar. A force and video analysis of regular and accelerated backward giant circles was performed. Estimates for the reaction forces were obtained by multiplying the bar displacements from the video analysis by the stiffness coefficients determined from the static loadings. Comparisons were made between the estimated reaction forces and the reaction forces recorded using strain gauges attached to the high bar.

Root mean squared differences between estimated and recorded reaction forces were on average within 99 N for three regular and three accelerated giant circles. This was less than 3.5% of the range of forces recorded. The method was able to estimate the peak reaction forces to within 7% on average, which compares favourably with 24% reported by Gervais (1993) using inverse dynamics.



High bar forces obtained from strain gauges (circles) and from bar displacement method (solid line)

Using a static calibration and displacements of the bar determined from video analysis the reaction forces experienced by a gymnast circling the high bar can be accurately estimated. Although there was a tendency with the present method to over-estimate the peak forces, superior results to those obtained using an inverse dynamics analysis (Gervais, 1993) were achieved. It is important to note that the bar used in the present study was less stiff in the horizontal direction. This is likely to be the case for all competition high bars due to the arrangement of the stabilising cables and mountings to the uprights. If only a vertical calibration is possible in the competition arena (or gymnasium) an appropriate adjustment to the horizontal stiffness of the bar must be made. It was also interesting to note the small changes in bar stiffness coefficients with increasing tension in the stabilising cables. It would therefore be possible to calibrate the bar before and/or after a competition. Even if a gymnast or coach altered the tension in the stabilising cables it is unlikely to greatly effect the forces determined using the present method. It is also proposed that having a third video camera with a small field of view zoomed in on the centre of the bar is expected to further improve the accuracy of the proposed method.