SUMMARY
The sole-specific ground reaction model parameters can have major implications in determining the effect of footwear on locomotion. Previous studies reported the ground reaction model parameters for a categorical hard and soft sole [1]. The purpose of this study was to use a parametric surface fitting method to extract the sole specific ground reaction model parameters during running. The in-shoe pressure measurement and motion capture techniques were utilized to quantify the sole reaction force-deformation behavior. A parametric surface fitting technique was used to extract the sole reaction model parameters from the data.

INTRODUCTION
The ground reaction model parameters relate the deformation pattern of the interface between the ground and the body to the reaction force generated at this interface. The sole behavior can be modeled as a mechanical system represented by a nonlinear spring and damper, and the vertical ground reaction force can be formulated according to the following equation [1].

\[ F = A \cdot (a \cdot (x)^b + c \cdot (x)^d \cdot (v)) \]

Where \( F \) represents the vertical ground reaction force, \( A \) is the plantar area of the contact point, \( x \) represents deformation and \( v \) represents deformation rate. The constants \( a, b, c, \) and \( d \) represents the sole specific parameters. The first term \( (a \cdot (x)^b) \) represents the nonlinear stiffness term, the second term \( (c \cdot (x)^d \cdot (v)) \) represents the damping term that is a nonlinear function of deformation and a linear function of deformation rate. Previously these ground reaction model parameters were determined using a trial and error procedure in which the force-deformation curve predicted from the simulated pendulum impact tests were compared with the force deformation curve of the pendulum test data [2]. In previous studies utilising simulation techniques a different set of ground reaction model parameters were reported for the categorical hard and soft shoe [3, 4]. While the categorical ground reaction model parameters are useful for the general impact modeling purposes, they do not reflect the behavior of a specific shoe sole under loading. The purpose of this study was to develop a method of extracting the sole-specific ground reaction model parameters using a parametric surface fitting approach.

METHODS
For the purpose of this study a participant was asked to run on a treadmill at velocities of 10, 12, 14 and 16 KPH. In-shoe pressure measurement system (F-Scan, Tekscan, USA) was used to measure the force on the most lateral aspect of heel region as the first point of contact with the ground. The deformation of the sole was measured using motion capture system (Vicon, OMG, UK). A set of markers on the perimeter of the interface between the upper and the sole were used to measure the sole deformation on the most rear lateral aspect of the shoe during the stance phase. The force and deformation measurements sampling at 250 Hz were synchronised. The force, deformation and deformation rate were imported to Matlab® surface fitting toolbox. A surface fit represented by equation 1 was fitted to the data to extract the model parameters.

RESULTS AND DISCUSSION
Figure 1 shows a parametric surface represented by Equation 1. The surface parameters were found as \( a=1091, b=1.035, c=105 \) and \( d=0.458 \). It is evident that the surface represented by equitation 1 provides a moderate fit to the data indicated by a R-squared value of 0.62.

CONCLUSIONS
The surface fitting approach showed to be a useful tool for quantifying the sole-specific ground reaction model parameters. An improvement in the surface fitting technique and fitting the surface to a smaller deformation range may
lead to a better fit goodness.

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REFERENCES