Prospective Study of Kinetic Factors Associated with Tibial Stress Fractures in Runners

Michael B Pohl [1], Irene S Davis [1,2] and Joseph Hamill [3]

[1] University of Delaware, Newark, DE, USA
[2] Drayer Physical Therapy institute, Hummelstown, PA, USA
[3] University of Massachusetts, Amherst, MA, USA
E-mail: pohl@udel.edu

INTRODUCTION

Tibial stress fractures are a common overuse injury found in female runners. In a study of 1076 female runners, the incidence of tibial stress fracture and stress syndrome were reported to be 3 and 5% respectively (Taunton et al., 2002). A stress fracture is one of the most serious injuries given they require up to eight weeks of rest from high impact activities such as running. The risk of re-injury is high and if left untreated they can progress to a macrofracture.

A number of kinetic loading variables have been associated with the incidence of tibial stress fractures in cross-sectional studies. Impact peak (IPEAK), vertical instantaneous load rate (VILR), vertical average load rate (VALR), vertical impact peak (IPEAK) and peak positive tibial acceleration (PPA) were found to be greater in subjects who had suffered a previous stress fracture when compared to controls (Milner et al., 2005). In addition, the adduction freemoment (ADDFM) has been reported to be greater in stress fracture subjects (Milner et al., 2006). Hence high loading in both vertical and longitudinal directions may be risk factors in runners obtaining a tibial stress fracture.

Although greater loading has been identified as risk factors for stress fractures, it remains unclear whether this is a cause or consequence of the injury. Prospective studies are required to gain further insight into this relationship. The aim of this study, therefore, was to compare pre-existing loading mechanics in a group of female runners who went on to develop a tibial stress fracture/reaction versus healthy controls. It was hypothesised that IPEAK, VILR, VALR, PPA and ADDFM would all be higher in subjects who demonstrated a prospective tibial stress fracture/syndrome.

METHODS

The data are part of an ongoing prospective study of females currently running a minimum of 20 miles per week. An instrumented baseline gait analysis was performed at the commencement of the study when subjects were free from injury. Participants ran overground at 3.7 ms^{-1} along a 25m runway containing a force plate. Retroreflective markers were attached to the lower extremity and an accelerometer mounted on the distal medial aspect of the tibia. Kinematic data were collected at 120Hz using a 6 camera Vicon system (Oxford, UK). Kinetic data from the force plate and accelerometer were sampled at 960Hz. Three-dimensional kinematics and kinetics of five trials were calculated for both lower extremities.

Participants then reported their subsequent running mileage and injuries on a monthly basis for a period of two years. To date, fourteen subjects (22±8 y, 22±8 mpw) have gone on to sustain a tibial stress fracture/reaction. A tibial stress reaction was operationally defined as tibial pain and tenderness located over a diffuse bony area of several centimeters. Stress reactions have been included in the injury group since it has been shown to be part of a continuum of bony injury leading to a stress fracture (Anderson et al., 1997). Comparisons were made between the injured group (TSF) and 14 age and mileage (24±7 y, 24±8 mpw) matched control (CON) runners. Statistical analyses were not conducted due to the small sample size. Instead a 15% difference between groups was defined as being clinically relevant.

RESULTS AND DISCUSSION

Table 1: Differences in loading variables between PTSF and CON groups.

	CTRL	PTSF	%diff
IPEAK (BW)	1.6	1.8	11.8
VILR (BW/s)	80.9	81.9	1.2
VALR (BW/s)	69.7	69.4	0.6
PPA (g)	4.8	5.6*	16.4
ADDFM ($x10^{-3}$)	4.6	6.3*	36.3
IMP (s) ($x10^{-3}$)	0.1	0.5*	338.0

* Greater than 15% difference between PTSF and CON.

A comparison of the variables of interest is shown in Table 1. As hypothesized, PPA was more than 15% greater in the PTSF group compared to controls. Given the repetitive nature of running, even small increases in loading may be magnified over thousands of consecutive foot strikes. The fatigue limit of bone is dependent on the magnitude of the load per cycle and the number of cycles over which this loading is performed. An increase in PPA would result in an increase in the load per cycle placed on the bone. Hence, this would increase the chance of exceeding the fatigue limit of the bone, thus resulting in a stress fracture.

The remaining vertical loading variables, IPEAK, VILR and VALR were not found to be different between groups. This is in contrast to the results of Milner et al. (2005), who found these loading variables to be elevated in subjects who had previously suffered a stress fracture. However, their study was retrospective and it is possible that IPEAK, VILR and VALR were altered as a result of the stress fracture injury.

Both ADDFM and IMP were greater in the PTSF group. A greater peak ADDFM implied there was a greater resistance to toe-out in runners who went on to develop a stress fracture/reaction. The elevated impulse signifies that this increased resistance to toe-out was evident throughout the stance phase. Hence, increased torsional loads in the tibia may also increase, thereby elevating an individual's risk of developing a stress fracture

SUMMARY

Results from this prospective study suggest that runners who go on to develop a tibial stress fracture/syndrome exhibit greater vertical and torsional mechanical loads. This suggests that interventions to reduce these loads during running may decrease the risk of sustaining a stress fracture.

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