

# RELATIONSHIP BETWEEN GROUND REACTION FORCE AND ACCELERATION AT TIBIA AND FEMUR DURING HEEL TOE RUNNING

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## Introduction

The ground reaction force (GRF) acting on the foot during heel toe running is commonly accounted as the input signal for shock waves travelling up the skeletal system. Bio-negative and bio-positive effects are often implicated to vibrations caused external by impact forces (Whittle 1999; Lafortune 1995). How the GRF acts as an input signal for the shock waves and how the shock waves are transferred up the skeletal system is, however, not well understood. Skin mounted accelerometers do not permit accurate measurement of such vibrations. Therefore the purpose of this study was to investigate in vivo the effect of the GRF as an input signal to tibia acceleration and the effect of this as an input signal on femur acceleration.

## Material and Methods

Four male volunteers participated in this study (age: 18-40 years, mass: 77-89kg). To avoid skin movement artefacts one intracortical Hoffman bone pin (diameter 3.0mm, length, 60mm) was inserted with the complete thread into the lateral condyle of the right tibia under local anaesthetic. A second pin was inserted into the lateral condyle of the femur. A miniature piezoresistive accelerometer (Kistler piezotron, 8694M1; mass: 2.5g) and a marker array for kinematic analysis was attached on each pin. The subjects ran with a self selected speed ( $2.8\text{m/s} \pm 0.3$ ) under three different shoe conditions. Three valid trials of each subject under each condition were examined. The sampling rate of the analog data was 2500Hz. As the natural frequency of the instrumented bone pin was over 120Hz (experimentally determined) the acceleration data was filtered by means of an FFT bandpass (1Hz - 100Hz). A period of 75ms after heel contact was analysed. The parameters observed were peak GRF (p\_grf), peak tibia (p\_atib) and peak femur (p\_afem) acceleration. An ANOVA was calculated to exclude the influence of the different shoe conditions. A regression analysis was calculated to analyse the relationship between p\_grf, p\_atib and p\_afem for each subject separately as well as for all subjects together.

## Results and Discussion

The ANOVA revealed no significant differences ( $p \leq 0.05$ ) between the shoes in p\_grf, p\_atib and p\_afem. The regression coefficients for all subjects together and for each individual are listed in Tab. 1.

Tab. 1: Regression coefficients (R) between p\_grf and p\_atib as well as between p\_atib and p\_afem. Significant correlation are indicated by \* ( $p < 0.05$ ) and \*\* ( $p < 0.01$ ).

	all	sub1	sub2	sub3	sub4
R (p_grf & p_atib)	.39*	.68*	.77*	.86**	.24
R (p_atib & p_afem)	.86**	.38	.97**	.78**	.44

Fig. 1 shows the relationship between  $p_{grf}$  and  $p_{atib}$  with the related regression line for each individual. The graphs indicate that the relationship differs between individuals. When all subjects were analysed together, a relationship appeared to exist between  $p_{grf}$  and  $p_{atib}$  as well as between  $p_{atib}$  and  $p_{afem}$ . A more detailed analysis, however, shows individual differences. For subject 4 for example the GRF appears not to be the input signal for atib. Looking at the transmission from the tibia to the femur it appears that for subjects 2 and 3 higher values of  $p_{atib}$  lead to higher values of  $p_{afem}$ . This is not true for subjects 1 and 4. These inter individual differences could be caused by different orientation of body segments (knee or ankle angle) or muscle activity. Material properties of the cartilaginous tissues of the related joints or morphological differences of these tissues could also influence the transmission of shocks and vibrations along the skeletal system.

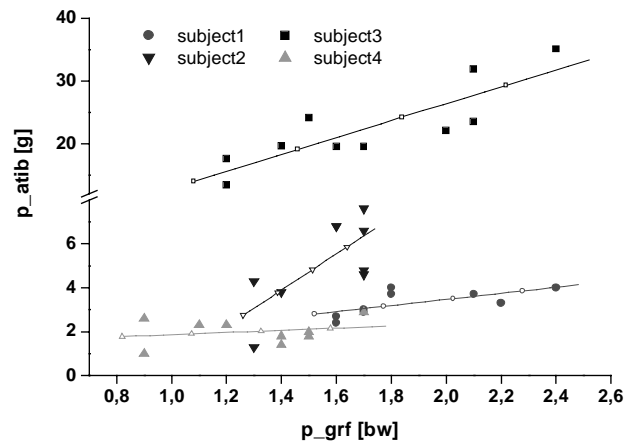


Fig. 1: Relationship between  $p_{grf}$  and  $p_{atib}$  with regression line for each subject

### References

- Whittle, M.W. 1999. *Gait Posture* 10; 264-275  
 Lafortune M 1995. *J Biomechanics* 1, 113-117