REPORTING SHEAR GROUND REACTION FORCES DURING SKATEBOARD LANDINGS

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INTRODUCTION

Skateboarding is a popular activity that had over 11 million participants in the US alone during 2005 (Anon, 2006). Despite its popularity, little is known about the biomechanics of this growing sport. To rectify this we aimed to analyze one of the more popular maneuvers practiced by skateboarders, the *rail slide,* and, in the process, examine ways to analyze and report shear force data.

In most human locomotion movements (i.e. walking and running) the subject's body is oriented parallel to the direction of forward motion. In board sports however, such as skateboarding and snowboarding, the subject's body is oriented perpendicular to the direction of forward motion. Therefore, we propose a new naming convention when describing the axes of board sport shear ground reaction force (GRF) movements.

The terms nose ground reaction forces (NGRF) and tail ground reaction forces (TGRF) will be used to describe the movements of the system's center of mass towards the nose or the tail of the skateboard. The terms front-side ground reaction forces (FGRF) and back-side ground reaction forces (BGRF) will be used to describe the movement of the system's center of mass towards the front toe-side edge of the board (i.e. an anterior body movement) or back heel-side edge of the board (i.e. a posterior body movement). The proposed axis system can be seen in Figure 1.

In addition, due to the uniqueness of each landing, subjects rarely landed on top of their skateboards in plane with the orthogonal Fx and Fy axes of the force plate. Therefore, we were curious about how correcting for these off-angled landings with a cosine correction coefficient might affect shear force results acting upon the system of subject and skateboard.

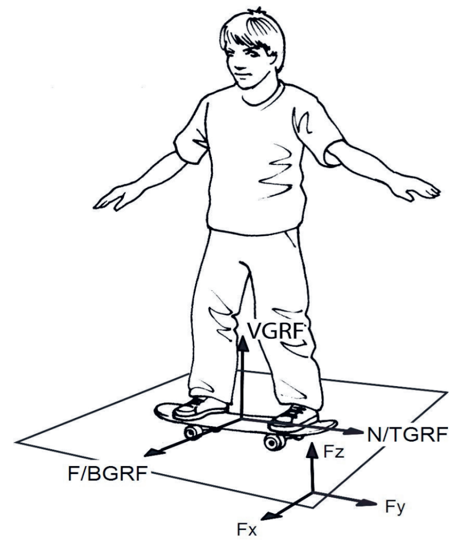

Figure 1. Skate and force plate axes.

METHODOLOGY

GRF and moment data were collected on 12 healthy top-amateur and professional male skateboarders (BM = 70.2 ± 9.1 kg) as they slid down a sloping handrail on their skateboards, eventually leaving the rail and landed on a force plate (AMTI model BP12001200) located at the base of the rail. A successful landing trial was defined when subjects landed on top of their skateboards with all four wheels completely hitting the force plate before eventually rolling off the plate without falling. Each subject performed only 3 trials due to the violent nature of these landings. All subjects wore the same model of skate shoes. However, each subject used his own skateboard for reasons of safety. GRF and moment data were collected for 8 seconds at 1000 Hz for each landing. A 4^{th} order low pass Butterworth filter was applied to the data with a cutoff frequency of 100 Hz.

Center of pressure (COP) coordinates (x,y) were calculated using force and moment data from the force plate and the manufacturers specified vertical offset (Zoff) of the plate (see equations below). By plotting the coordinates against each other we could track the direction of motion of the COP across the force plate. A best fit line was calculated for a portion of the data when the entire skateboard was still on the plate and the system was relatively stable. Usually this portion of data occurred towards the end of the trial just before the skateboard's front wheels rolled off the force plate. The slope of the best fit line was calculated and an angle of motion of the COP was calculated against the original Y-axis of the force plate. The cosine of this angle was then multiplied to the original Fx and Fy GRF data to calculate the new N/TGRF and F/BGRF data.

$$COP(x) = \left[\frac{\left(My + \left(Zoff * Fx\right)\right)}{Fz}\right] * (-1) \qquad COP(y) = \left[\frac{\left(Mx - \left(Zoff * Fy\right)\right)}{Fz}\right]$$

RESULTS

The F/BGRF and the N/TGRF results were quite variable both within subjects and between subjects. The only regular feature of the F/BGRF curve we can report is that the sinusoidal shape of the curve seemed characteristic of an oscillation: an expected result given the nature of stabilizing body movements. The average offset angle between the skateboard and the force plate was found to be 11.6º ± 5.5º, though offset angles across all trials and subjects ranged between 0.8º and 29.2º. Mean BGRF forces during the landings were found to be 944.6 ± 145.3 N, while mean FGRF forces were found to be 549.6 ± 210.1 N. N/TGRF results were found to be relatively minimal due to the fact the wheels on the skateboard were free to roll upon landing. Mean TGRF forces during the landings were found to be 489.1 ± 258.3 N, while mean NGRF forces were found to be 51.1 ± 31.0 N.

DISCUSSION

Shear forces in the landing trials were found to be quite variable both within and between subjects. This seemed largely due to two factors: the instability of the skaters on their boards shortly after landing and slight differences in orientation of the board relative to the force plate. Upon first landing, the subject may not be centered on their board in the transverse (front-back) and frontal (nose-tail) planes. The instability of these landings, both front to back and nose to tail, required the subject to make corrective movements to stabilize their position on the board. These stabilizing movements, which were different for each subject and each landing, created, in part, the observed variability we measured.

By examining the data from the trial with the greatest offset angle (29.2º), we found that differences in the skateboard's orientation upon landing can affect shear force variability within a subject by as much as 13%. This suggests that the magnitude of off-angle-landing errors may indeed be significant. Our enthusiasm for this conclusion is somewhat tempered by the fact that the COP coordinates take some 20 to 30 ms to find a consistent orientation and that this may undermine the estimation of an accurate offset angle. Nevertheless, such off-angle landings seem common in other sports as well as skateboarding and snowboarding and our data suggest that this may lead to significant errors in the reporting of shear forces. We propose the use of similar cosine error correction procedures and reporting conventions that more accurately convey the body's orientation to the force plate's orthogonal planes. Compared with the conventional approaches these modifications should enhance our collective understanding of shear forces and the effects they have on the body.

REFERENCES

Anonymous. (2006). *Sports participation topline report.* North Palm Beach, FL: SGMA International.