EFFECTS OF USING HEEL WINDOWS AND SINGLE SUBJECT ANALYSIS TO MEASURE REAR FOOT MOTION DURING RUNNING

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INTRODUCTION

It has been suggested that screening individuals prospectively for injury risk factors may help reduce the number of running related injuries [1]. Since rear foot motion during running is often cited as a contributing factor to overuse injuries, any prospective screening should include a measure of rear foot movement. While tracking markers can be placed directly on the shoe, bone pin studies have indicated that shoe motion is not the same as true rear foot motion [2]. As a solution some authors have advocated the use of windows in the shoe heel counter with markers attached directly to the foot for tracking rear foot motion during running [3]. However, to date, no study has used a three dimensional (3D) analysis to evaluate differences in rear foot motion when measured by placing markers directly on the shoes or by using heel windows.

Additionally, most studies on running injuries use a group design where the average performance of an injured group is compared to the average performance of a non-injured group. However, the performance of any one individual rarely, if ever, matches the average group performance [4]. This is especially true in assessing injury risk, when it is deficits or changes in a single individual that are of concern, not how they compare to an average group performance [4]. In these situations a single subject analysis might yield insights which are masked during a traditional group analysis.

Therefore, the purposes of this study were to use a 3D analysis to compare differences in rear foot motion between markers placed on the shoes and markers placed directly on the rear foot using heel windows. A second purpose was to determine the influence of group verse single subject analysis on any kinematic differences.

METHODS

Thirteen subjects who ran at least 20 miles per week were recruited for this study. Twenty nine reflective markers were attached to the subject's bony landmarks. The shoe markers consisted of two markers along the vertical bisection of the heel counter with a third marker on the lateral side of the shoe. The heel windows markers were placed in the same locations, with marker bases attached directly to the rear foot and extending through holes cut in the heel counter. For each condition, subjects ran approximately 40 laps around a 25 meter track in the laboratory with data being collected over a 5 meter segment of each lap. An 8 camera motion capture system (Motion Analysis Corp) recorded marker position data at 200 Hz while three AMTI (Advanced Mechanical Technology, Inc) force plates recorded ground reaction forces at 1000 Hz.

For the group analysis, 10 trials were used to create an average profile for each subject. Variables of interest included rear foot eversion excursion, percent stance at maximal eversion, maximal instantaneous eversion velocity, and maximal instantaneous vertical loading rate. These were calculated with custom LabView (National Instruments) software. A coefficient of multiple correlation (CMC) was calculated to examine the repeatability of the ankle joint inversion-eversion curve. Each foot was analyzed separately. Significant differences between conditions were evaluated with a dependent observations *t* test, with α set to 0.05.

With the exception of the CMC, the same variables were examined using a single subject analysis. At least 8 trials per condition were used for each subject. Significant differences between trials under both conditions were evaluated on an

individual subject basis with both an independent observations *t* test and a statistical method called Model Statistics [4]. Again, α was set to 0.05.

RESULTS AND DISCUSSION

Due to subject drop out, only 20 feet were included in the final analysis. The results of the group analysis are shown in Table 1. The only significant difference between marker conditions was in the CMC values, with the heel windows markers indicating greater variability in movement patterns. These results suggest placing the markers on the shoe artificially reduces the variability in the measured movement patterns.

Table 1. Results of the group analysis. ***** indicates significant difference between marker conditions.

Parameter	Shoe Markers	Heel Windows
Eversion Excursion (°)	13.66 (± 6.76)	13.83 (± 6.91)
Percent Stance at Max. Eversion (%)	36.76 (± 12.00)	36.77 (± 14.87)
Max. Instant. Eversion Velocity (°/s)	269.50 (± 117.60)	260.60 (± 115.10)
Max. Instant. Vertical Loading Rate (N/Kg BW/s)	84.47 (± 18.47)	82.23 (± 17.16)
CMC Value	**0.92 (± 0.07)**	**0.87 * (± 0.12)**

The lack of significant differences between conditions for the other variables is most likely due to the individualized nature of subject responses, an example of which can be seen in Figure 1. Similar individualized response patterns were observed for the other variables of interest. However, some of the changes were up to 40% in magnitude, suggesting there were differences between conditions; they were just not identified by the group analysis.

Both the *t* test and Model Statistics results indicated that individuals who demonstrated large percent changes in the group analysis did in fact have significant differences between the two marker conditions. Table 2 shows the number of feet with significant differences between conditions under the single subject analysis.

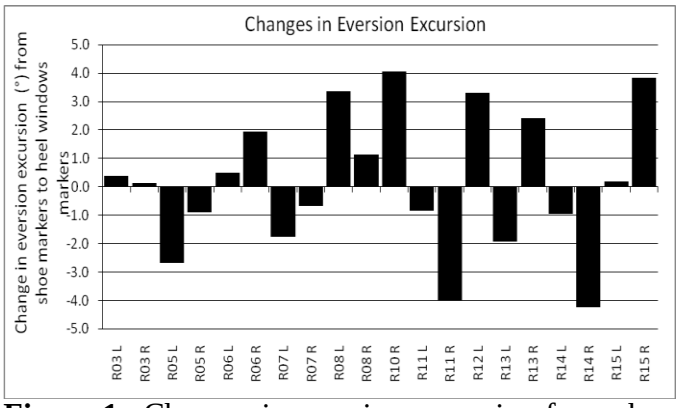

Figure 1. Changes in eversion excursion from shoe markers to heel windows markers

Table 2. Number of feet demonstrating significant differences between marker conditions under the single subject analysis

Parameter	Number of feet with significant differences between marker conditions
Eversion Excursion (°)	10
Percent Stance at Max. Eversion (%)	10
Max. Instant. Eversion Velocity (°/s)	7
Max. Instant. Vertical Loading Rate (N/Kg BW/s)	2

Overall the results of this study suggest joint kinematics and kinetics, as well as the variability in movement patterns of the rear foot, are different when measured with shoe based or heel windows markers. However, given the individualized responses observed in this study, these differences only become evident when the data is analyzed on an individual subject basis, a fact which has important implications for addressing prospective injury risk in runners.

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