Analyzing Changes in Running Symmetry in the Lead-Up to Injury

Client: Dr. Rodu

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Abstract

This report examines changes in running symmetry before and after injury using step-level data from wearable sensors. We found that injured runs show greater asymmetry and greater variability, especially in shock and pronation, and that these imbalances often worsen over the course of a run. These trends suggest that tracking symmetry in real time could help detect fatigue and prevent injury through early intervention.

Contents

1 Introduction

1.1 Background

Running is a repetitive, high-impact activity, and even small imbalances between limbs can contribute to overuse injuries.In this study, we examined how a runner's gait changes over time as they In this study, we examined how runners' gait changed over time with nudging, particularly prior to the diagnosis of a left leg injury. We collected gait data using RunScribe Inertial Measurement Units (IMUs) placed on the runners' right and left shoes. These units recorded variables such as impact of each step, contact time, and forward lean.

The dataset contained 19 runs. The earlier runs were performed without injury, while the later runs were performed after injury. This timeline provided a unique opportunity to explore whether an increase in gait asymmetry could be detected as injury progressed and fatigue developed.

1.2 Client Objective

Dr. Rodu is interested in understanding:

- Whether certain gait variables show greater left-right imbalance in injured runs
- How variability in these asymmetry measures compares between healthy and injured periods
- Whether asymmetry worsens across the course of a single run (a proxy for fatigue)
- Offer clear and practical summaries that could guide injury prevention

2 Data and Methods

2.1 Data

To investigate changes in left and right leg balance over time, we used a sensor-captured dataset. The main analysis steps are summarized below:

First, we labeled each run as "healthy" or "injured" based on its duration. Earlier runs (`run ID` < 200000) represented a healthy state, while later runs were associated with injury progression. We then narrowed the dataset to include only steps with data from both limbs. For each complete step, we calculated the left-minus-right difference of the five variables of interest:

- **Impact**: Vertical force when the foot strikes the ground
- **Braking**: Horizontal deceleration at foot strike
- **Shock**: Combination of impact and braking
- **Contact Time**: Duration the foot is in contact with the ground
- **Pronation**: Degree of inward foot roll between max pronation and toe-off

To summarize variability within each run, we computed the Relative Standard Deviation (RSD) for each variable:

$$RSD = \frac{\texttt{Standard Deviation}}{\texttt{|Mean|}} * 100$$

This gives a percentage that reflects how consistent the runner's left-right balance is within a run.

Finally, to examine how fatigue might affect gait balance, we measured how these step differences changed over the course of each run. We normalized the step index to create a 0–1 scale (start to end of run), allowing us to visualize trends regardless of run length.

3 Methodology

In this section, we describe how we summarized and visualized the asymmetry patterns, and present the major findings in two parts: differences between healthy and injured runs, and how gait symmetry changes throughout a single run (a proxy for fatigue). These analyses are supported by visualizations and brief interpretations to make the findings more accessible.

3.1 Summary Metrics by Injury Status

To evaluate whether symmetry varies depending on injury status, we computed the Relative Standard Deviation (RSD) for each variable within every run. This allows us to capture how much step-to-step variation exists in asymmetry. We then compared these distributions between healthy and injured runs.

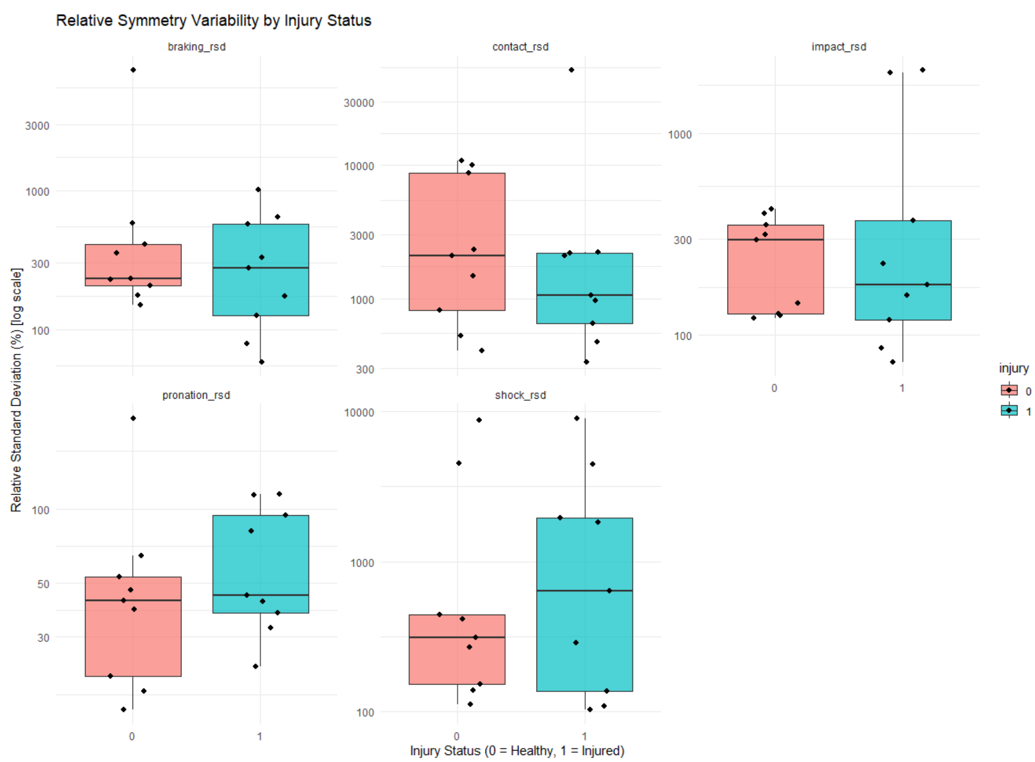

Figure 1: Boxplots comparing RSDs for injured vs. uninjured runs

We found runs performed during the injury period consistently show greater asymmetry. In particular:

- **Shock RSD** is notably higher, with a median RSD more than twice the healthy baseline.
- **Pronation** and **contact time** also show increased variability, indicating instability in foot placement and contact duration.
- The greater spread of values among injured runs suggests inconsistent mechanical compensation patterns.

3.2 Fatigue Effects Across the Course of a Run

To assess whether asymmetry worsens with fatigue, we normalized step index (from 0 at the start to 1 at the end of each run). We then visualize trends in step-level asymmetry over time.

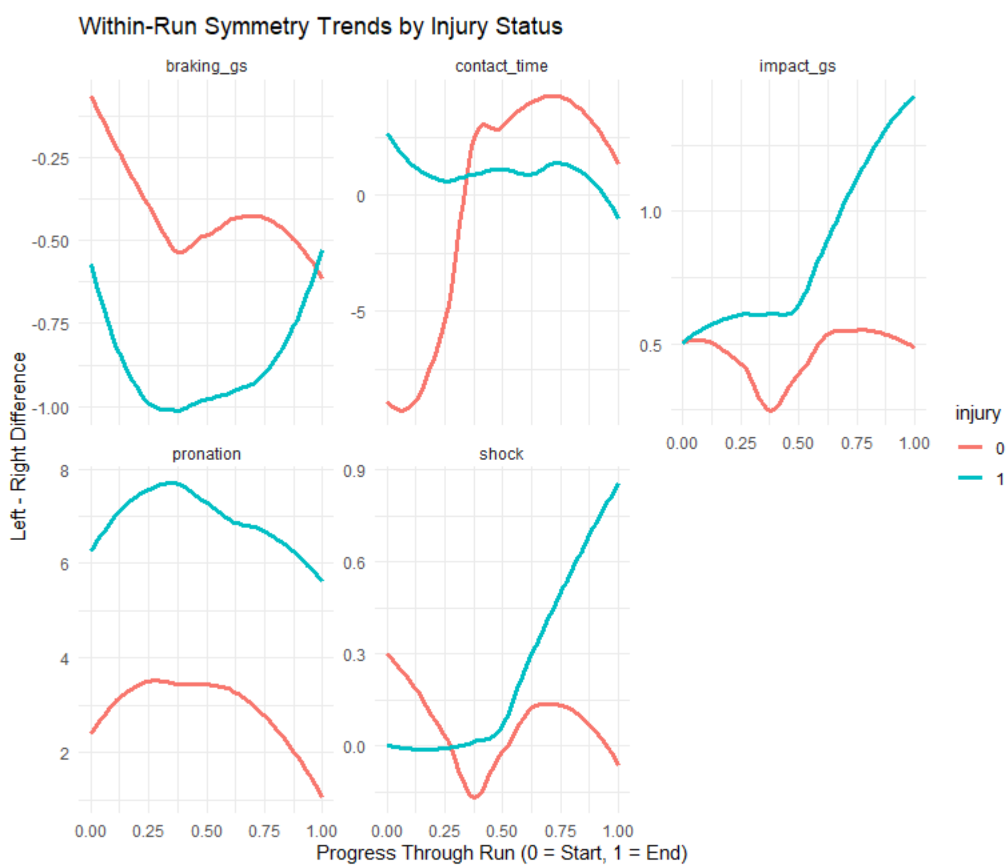

Figure 2: Fatigue curves showing smoothed asymmetry trends over normalized run duration

Note, none of the symmetry trends are centered around zero. This may reflects the runner's natural baseline asymmetry. Even when healthy, individuals may favor one side slightly. What's important is the direction and change over time, not whether the curve crosses zero.

1. **Braking**:Both injured and healthy runners show a U-shaped pattern. However, injured runs start at a more negative value and show deeper asymmetry.
2. **Contact Time**: Injured runs start with a strong left-right imbalance (around -7 ms), then stabilize around 0. This pattern may reflect an initial stiffness or load difference that resolves as the runner adapts.
3. **Impact**: Impact asymmetry increases steadily during injured runs, while remaining flat in healthy runs. This indicates accumulating asymmetry, likely due to discomfort or reduced strength.
4. **Pronation** asymmetry shows similar curve shapes for both groups, the overall level is higher in injured runs. This may reflect a pre-existing imbalance that is exacerbated under injury rather than entirely caused by it.
5. **Shock**:Injured runs show a clear rising trend from 0.2 to nearly 0.9. Healthy runs have a gentle dip and recover to baseline.

3.3 Example: Comparison: Injured vs. Uninjured Run

To further illustrate the differences between injured and healthy conditions, we compared one representative injured run and one uninjured run across all five symmetry variables. Figure 3 presents the step-by-step left-minus-right difference for each variable, overlaid with LOESS-smoothed trends.

Shock and **Impact**: Injured runs show elevated values and clear upward drift, signaling increasing imbalance in force distribution over time. Uninjured runs remain more stable around a baseline.

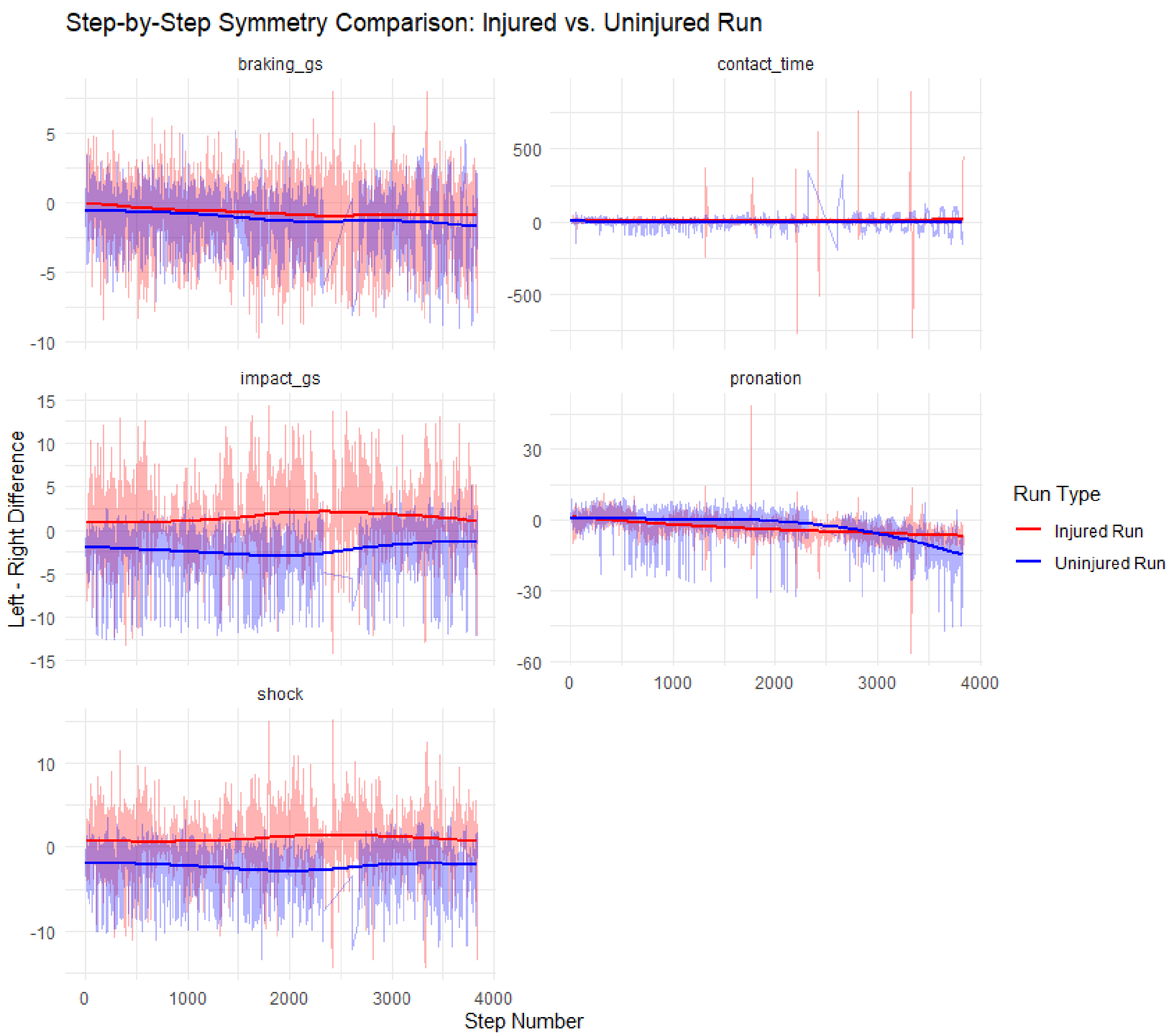

Figure 3: Step-by-step symmetry comparison across five variables — injured vs. uninjured run

Braking: Both runs show downward trends, but the injured run starts lower and displays higher variability, suggesting uneven braking compensation. **Contact Time**: Data from both runs contain several outliers, especially in the injured run, likely due to brief sensor disruptions. However, healthy patterns still appear more consistent. **Pronation**: Injured runs demonstrate a greater negative slope and wider spread of values, indicating progressive asymmetry in foot roll.

These examples reinforce prior findings: injured runs display greater variability, wider ranges, and stronger fatigue-related shifts across multiple gait features.

4 Conclusion

This report explored whether biomechanical symmetry metrics can indicate injury or fatigue in a runner over time. We found that **shock** and **pronation** are the most sensitive variables to injury status, showing elevated and increasingly unstable asymmetry in injured runs. Injured runs also demonstrated a wider spread in variability (RSDs), including extreme outliers, compared to the more consistent patterns seen in uninjured runs. Step-level analyses revealed that asymmetry often worsens as a run progresses, pointing to the compounding effects of fatigue.