



I Measure U



IMU-Step

Dashboard Summary

9.53g
Impedance Analysis

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1 Introduction

In running based sports, the majority of injuries tend to occur in the lower limbs. For example, among adults aged 25 to 40, the **most common injuries** in basketball, soccer, baseball and softball were fractured or sprained ankles and knees.

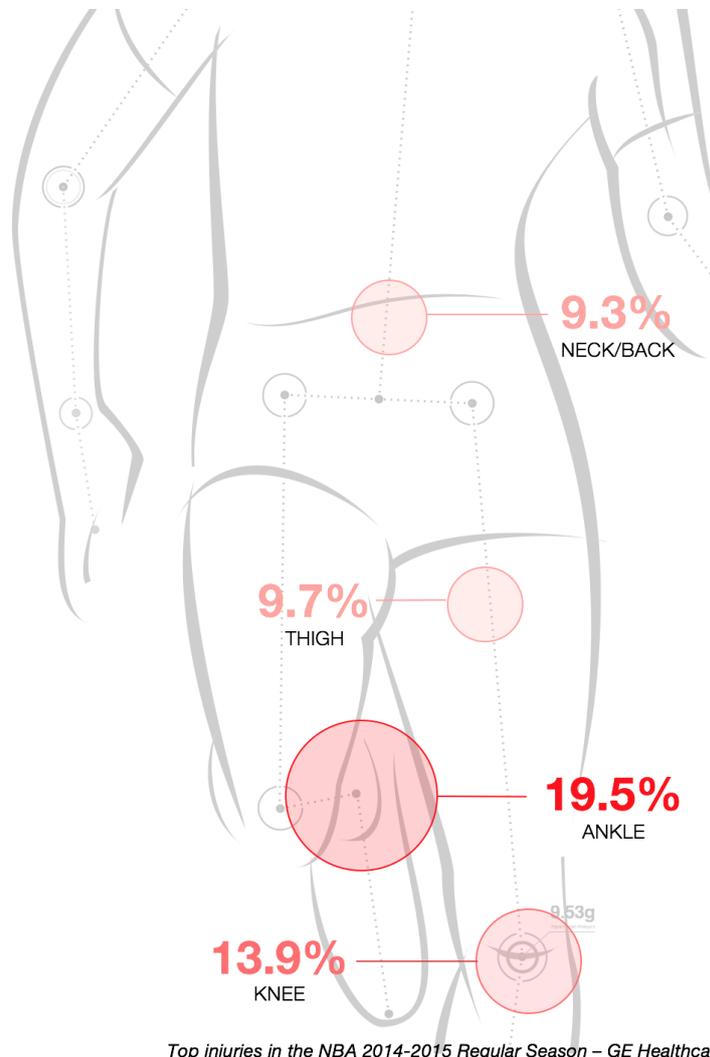


Figure 1: Injury stats in the NBA 2014-2015 Regular Season from GE Healthcare.

IMU Step allows coaches, physios and sports scientists to precisely manage an athlete's lower limb workload in order to:

1. Reintroduce them to loading through a return-to-play protocol
2. Mitigate their risk of lower limb injury post-rehab

IMU Step uses several metrics derived from our sensors to measure athlete lower limb workload. These metrics can also be used to prescribe workload based on the personal historical workload of an athlete. For example, by knowing the workload of certain activities measured using IMU Step, you can prescribe future custom training regimes personal to an athlete.

All athlete metrics and workload information is presented in an online dashboard. This document describes in detail the two views of the online dashboard:

- Step View
- Asymmetry View

2 Step View Summary

Figure 2 (below) is the "Step View" of the IMU Step dashboard. It contains two graphs, one table, and controls for filtering the information they show. The purpose of this view is to interpret the "intensity" or "workload" of different activities across different time scales.

Full SeasonEx

Step Intensity and Bone Loads

35



Session 9/15/2016

Number of Steps and Bone Load vs. Time (mins)

Full SeasonEx

Weight: 119 kg Height: 215 cm

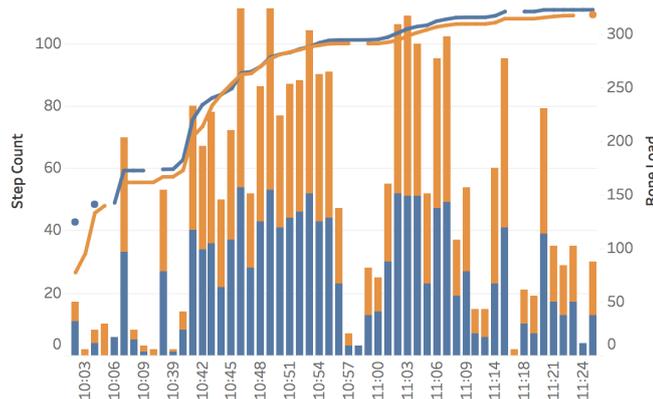
Position: C

9/15/2016

# Total Steps	2,698
# High	262
% High	9.71%
Session Bone Load	323
A:C (Bone Load)	1.00
Session Minutes	85

Date Range 8/30/2016

12/10/2017



KEY

Foot
■ right
■ left

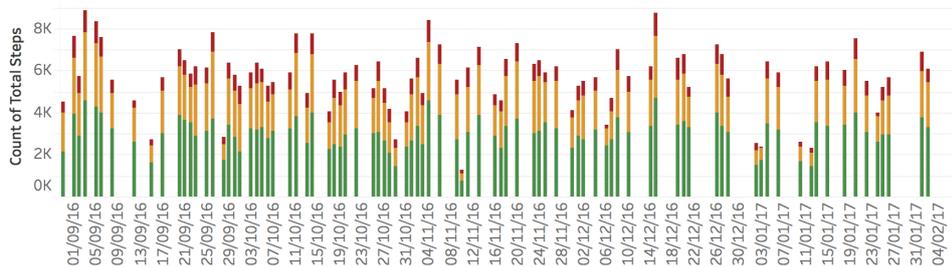
Step Date

9/15/2016

Step Time (min)

1

All Sessions by Day Total Step Count by Intensity per Day



Select Intensity Level:

High ■
 Medium ■
 Low ■

KEY

Date Fidelity

Day

Figure 2: The "Step View" of the IMU Step dashboard.

For example, in order to estimate the workload for a certain drill during a session, the Session Graph (Figure 3) has a per-minute breakdown of the whole session, showing total step count and bone load for the left and right legs. In this graph, between 10:41am and 10:56am, there was a period where more steps were taken per minute than at the start of the session. This indicates that this period had a higher "workload" or "intensity" than at the start of the session due to the fact that more steps per minute occurred in this time frame.

Session 9/15/2016

Number of Steps and Bone Load vs. Time (mins)

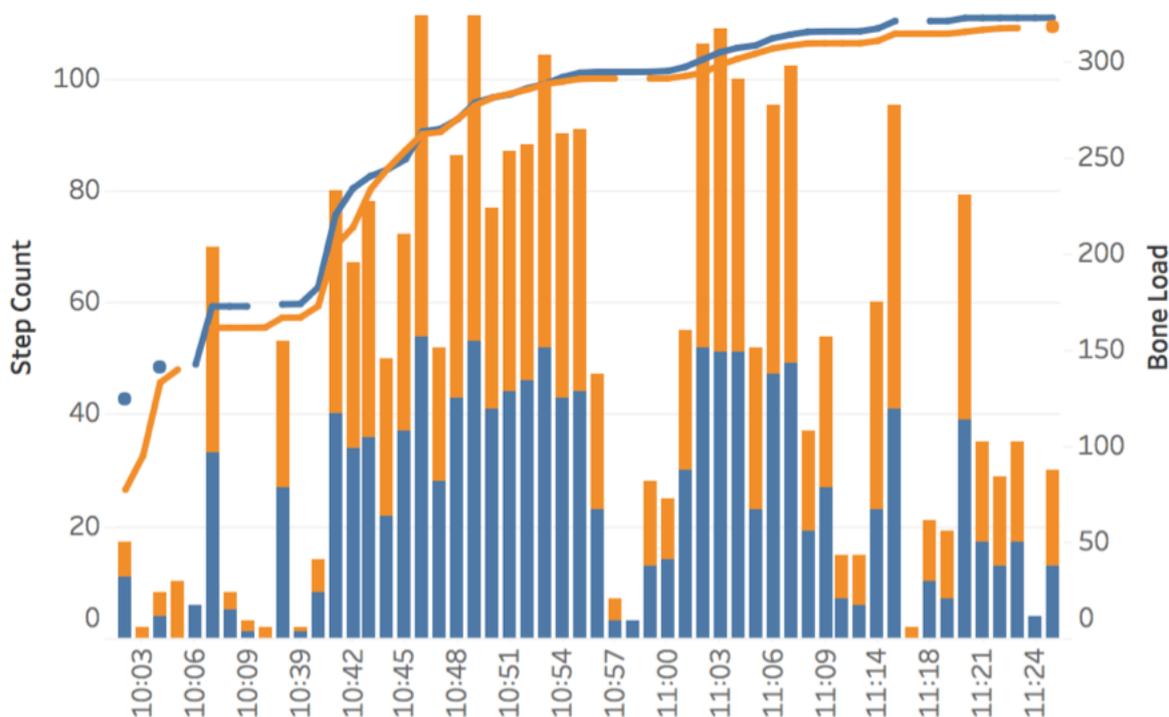


Figure 3: Session Graph showing **a**) the number of steps (left hand axis) that occur at each time interval within the training session and **b**) the Accumulative Bone Load value (right hand axis) at each time interval.

It is possible to change the time resolution of the Session Graph (Figure 3) anywhere from 1-minute periods up to 10-minute periods using the "Step Time (min)" control in the top right hand corner of Step Intensity Dashboard (Figure 2). This allows clusters of data to be viewed at a different resolution e.g. one bar every 10 minutes.

2.1 Accumulative Bone Load

The "Accumulative Bone Load" metric is a scientific based model of loads propagated into the lower limbs. These loads occur from impacts created when the foot strikes the ground at every step taken. The IMU sensor measures each impact created from every step taken, and IMU Step calculates the Bone Load value based on all the recorded impacts. Bone Load is dependent on:

1. The total number of steps taken
2. The size of the impact derived from each individual step.

If there is a large number of total steps, the Bone Load will also be large.

Given the same number of steps, if there is a larger proportion of "High Intensity" steps (heavy steps that experience a larger impact), the Bone Load value will be larger than the previous value. This is because Bone Load is dependent on the total number of steps as well as the size of the impact from each individual step.

Bone Load is more responsive to the size of step impact rather than the number of steps taken. Therefore a "High Intensity" impact may contribute more to the "Accumulative Bone Load" value than several "Low Intensity" impacts.

Bone Load is non-linear. This means that as more steps are taken, the Bone Load vs. Time graph is not a straight line (looks like an inverse square shape). You can see an example of what Bone Load looks like in the line graph of Figure 3.

Although it is directly related to the number of steps and the impacts from those steps, bone changes its response to loading as time goes on during a continuous running activity. This is what introduces the non-linear nature of Bone Load over time.

For more detail on Accumulative Bone load watch this short 5 part [video series](#) by our Chief Scientist Dr Thor Besier - part 3 refers specifically to Bone Load.

2.2 Footnotes

In [Tableau Online](#), if you hover over the Session Graph (Figure 3), you will be able to see what "Footnotes" have been tagged at that particular point in time during the session. Footnotes are tagged sections of data that allow you to indicate certain activities that may happen during the session, e.g. "Shuttles" or "Shooting". Footnotes are attached to the data during the data upload process using the IMU Step Desktop App.

2.3 Comparing Sessions

The "All Sessions" graph (Figure 4) shows all individual sessions that happen over time. Along the bottom you can see the session date, and along the side you can see the total steps taken. Each bar has three sections, with red, yellow and green respectively indicating high, medium and low intensity steps. The taller the bar, the greater the number of steps. This also applies to the intensity areas of the bar – the larger the area, the greater number of steps for that intensity.

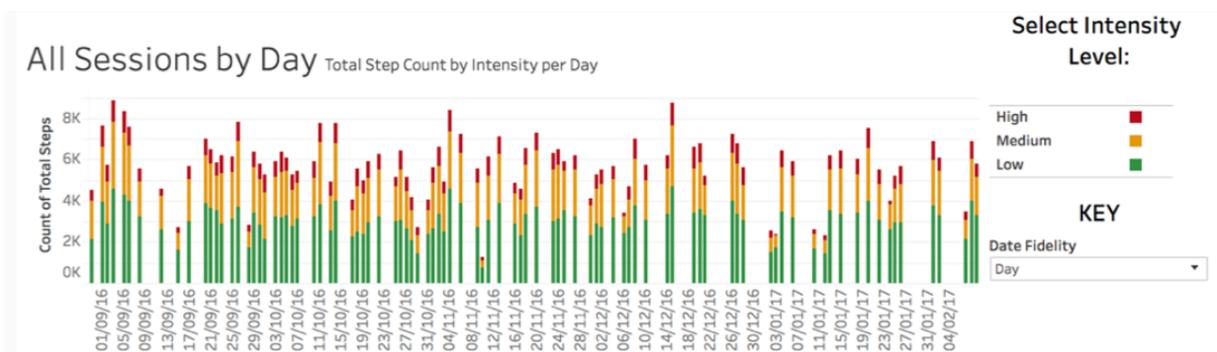


Figure 4: The "All Sessions" graph shows all of the individual sessions for the athlete over time, with gaps showing rest days (i.e. where no data was recorded).

The "All Sessions" graph also allows you to compare and interpret the difference in workload between sessions. One session may have a larger number of steps compared to another session. This may occur because of the difference in intensity of the sessions, i.e. a session with a greater number of steps and/or a great number of high intensity steps indicates a higher workload for that session.

Using this information, you can plan future sessions based on the measured workload from past activities, and combining those activities to create a custom programme for an athlete based on objective workload data.

IMU Step categorises the "intensity" of each foot strike into "Low Intensity" (0g - 6g), "Medium Intensity" (6g - 21.5g) and "High Intensity" (21.5g - 26.7g).

In order to view a specific intensity band (high/medium/low) across both graphs, simply click on either "High", "Medium" or "Low" labels to the right of the "All Sessions" graph (Figure 4). E.g. clicking "High" will filter the Session graph to show only high intensity right and left leg data, and also filter the All Sessions graph to show only high intensity steps per session.

Figure 5 (below) shows an example of the All Sessions graph when only high intensity steps are shown.

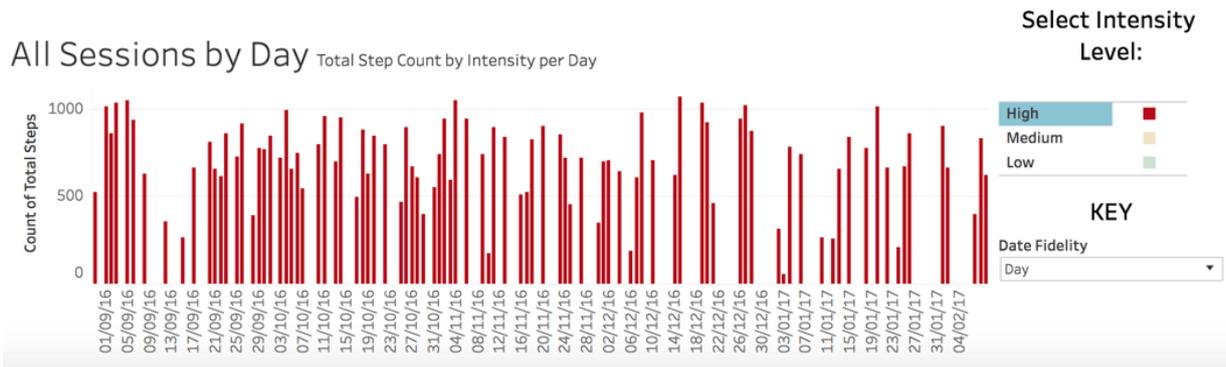


Figure 5: The "All Sessions" graph filtered to show only the number of high intensity strikes for each day.

A larger proportion of "High Intensity" strikes often correlates to a higher intensity session, which in turn indicates a greater athlete workload/energy expenditure for that session.

The session summary metrics, shown in the top left corner of the Step Dashboard view (Figure 2) provide a good overview on the intensity of the session in question.

3 Asymmetry View Summary

The Asymmetry View (Figure 6) looks at the symmetry of intensities between the left and right leg.

There are two important analyses able to be taken from this view:

1. How did the distribution of loads look for a single session, both within each leg as well as compared between legs (e.g. today's training session)
2. How did the asymmetry compare to an athlete's historical "profile" over time.

Full SeasonEx

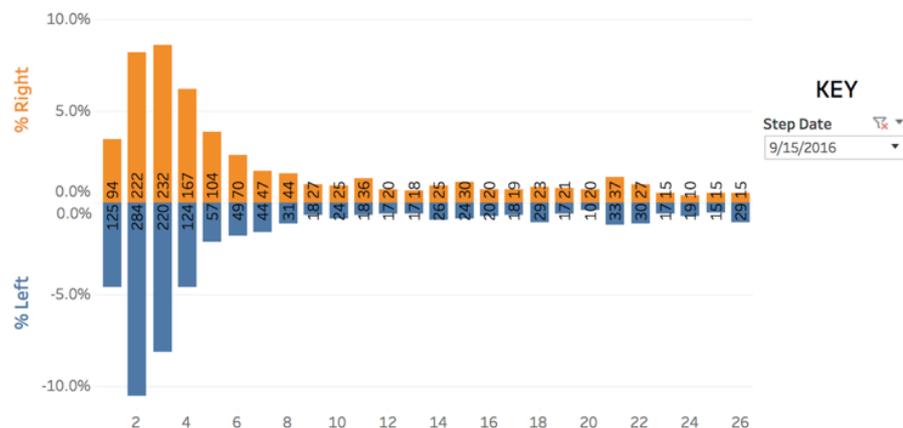
Asymmetry

35



Session 9/15/2016 Left and Right Leg Step Count vs. Intensity Bin (1-26)

Full SeasonEx	
Weight: 119 kg	Height: 215 cm
Position: C	
9/15/2016	
# Total Steps	2,698
# High	262
% High	9.71%
Session Bone Load	323
A:C (Bone Load)	1.00
Session Minutes	85



All Sessions by Day Intensity Bins showing Left Leg and Right Leg Asymmetry Levels vs. All Sessions by Day

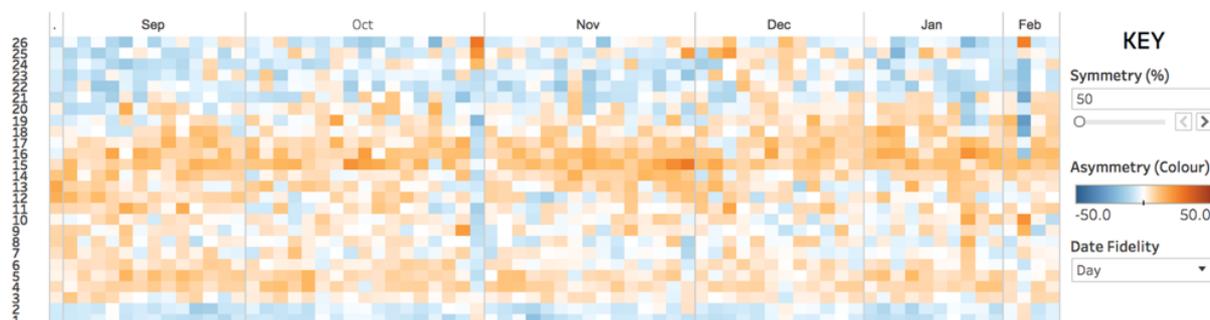


Figure 6: Asymmetry View of the IMU Step dashboard.

3.1 Single Session Asymmetry

Figure 7 shows example data from a single session. Every step that has been measured is categorised by intensity (measured in g's) and tallied into the respective "intensity bin", where 1g is the smallest intensity, and 26g is the largest intensity measured.

IMU Step categorises the "intensity" of each foot strike into "Low Intensity" (0g - 6g), "Medium Intensity" (6g - 21.5g) and "High Intensity" (21.5g - 26.7g).

Each "intensity bin" has a total count for both left and right legs. E.g. looking at Figure 7, the 26g bin has 15 steps measured on the right leg and 29 steps measured on the left leg. Furthermore, bin 25 has 15 steps measured on both the right and left legs.

Using the total count of each intensity bin, you can visualise how high, medium and low intensities were spread over a session.

Asymmetry

Latest Session 15/09/16

(Left and Right Leg Step Count vs. Intensity Bin (1-26))

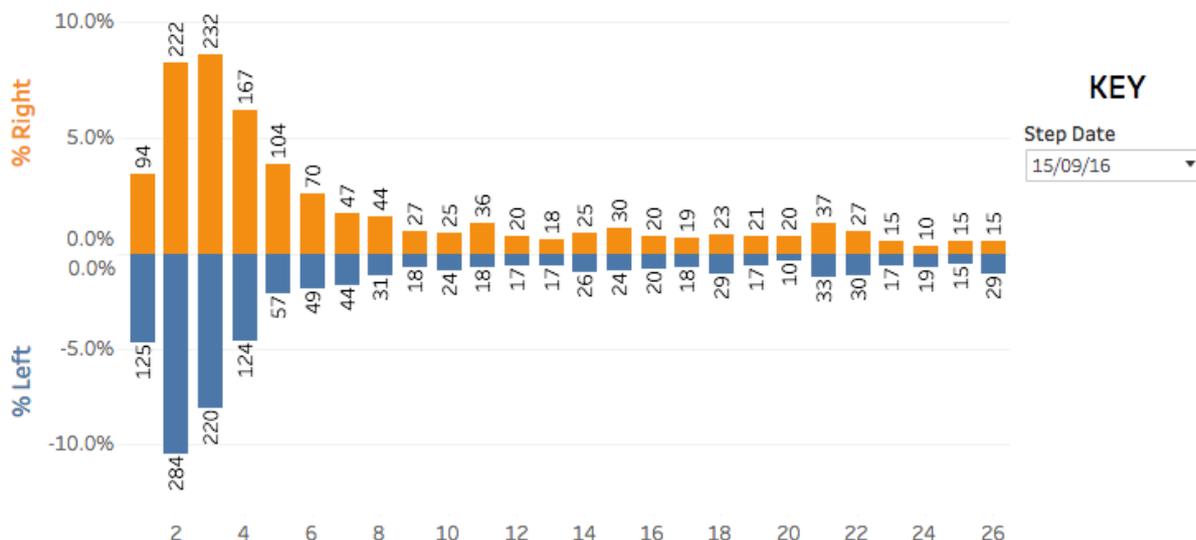


Figure 7: The Asymmetry graph of the selected session; Every step that has been measured is categorised by intensity (measured in g's) and tallied into the respective "intensity bin", where 1g is the smallest intensity, and 26g is the largest intensity measured. Each "intensity bin" has a total count for both left and right legs.

3.2 Multiple Session Asymmetry

Looking at the asymmetry of each day viewed over time (Figure 8), days run along the top with the most recent day on the far right, and "intensity bins" run up the left, with the largest intensity at the top (1g at the bottom, 26g at the top).

All Sessions by Day

(Intensity Bins showing Left Leg and Right Leg Asymmetry Levels vs. All Sessions by Day)

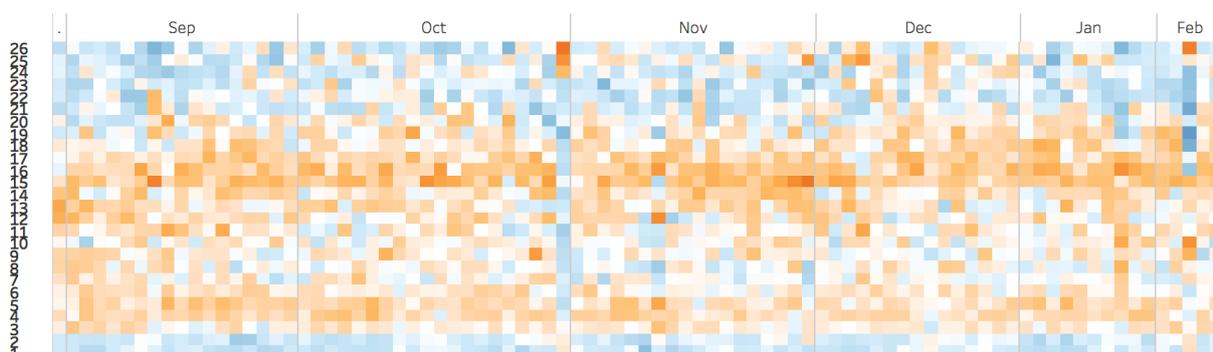


Figure 8: The asymmetry of each day viewed over time. Days run along the top - with the most recent day on the far right, and "intensity bins" run up the left, with the largest intensity at the top (1g at the bottom, 26g at the top). Asymmetry over multiple sessions is visualised by colour grading. I.e. the more right dominant the "intensity bin" is, the darker orange the square will be. The more left dominant the "intensity bin" is, the darker blue the square will be. If there is no asymmetry in the "intensity bin", the square will be white (the same number of strikes on the right compared to the left).

Asymmetry over multiple sessions is visualised by colour grading. I.e. the more right dominant the "intensity bin" is, the darker orange the square will be. The more left dominant the "intensity bin" is, the darker blue the square will be. If there is no asymmetry in the "intensity bin", the square will be white (the same number of strikes on the right compared to the left).

3.3 Asymmetry Calculation Example

Referring to Figure 9 provides a good example of how asymmetry is calculated and displayed. It contains copy of Figure 7 on the right, and a snippet of the same day taken from Figure 8 on the left. The snippet highlights the same day as the single session asymmetry graph (9/15/2016).

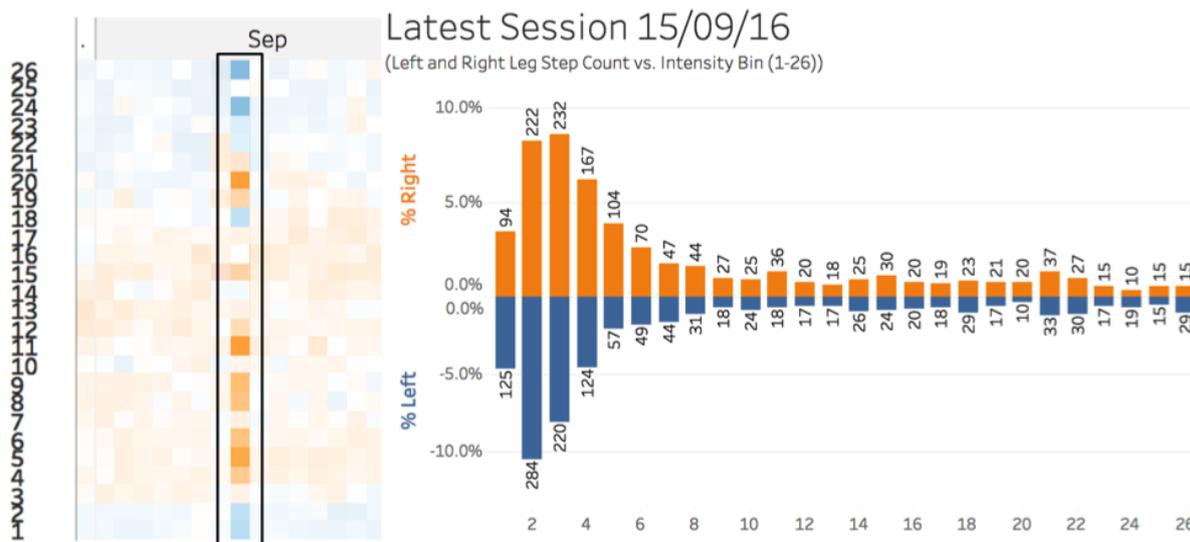


Figure 9: A good example of how asymmetry is calculated and displayed - It contains copy of Figure 7 on the right, and a snippet of the same day taken from Figure 6 on the left. The snippet highlights the same day as the single session asymmetry graph (9/15/2016).

Looking at the single session asymmetry graph on the right, bin 25 has 15 strikes on the right leg and 15 strikes on the left leg. Bin 26 has 15 on the right and 29 on the left.

Looking again at bins 25 and 26 on the left of Figure 9 (Figure 6 snippet):

- bin 26 is a dark shade of blue, indicating the player was left dominant in this bin (i.e. 29 of the 44 total, or 65.91% of steps in this bin were on the left leg)
- bin 25 is white, indicating there was no asymmetry (i.e. there are 15 steps on both the right and left leg).