Assessing Athletic Performance with a Wearable Inertial Measurement Unit

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***Abstract*—With the growth of wearable devices, professional athletes are frequently monitored during training and competition to assess athletic performance and devise improvements. While beneficial to athletes, these measures are often costly and unavailable in amateur sports. A user study was conducted to determine the efficacy of measuring the Reactive Strength Index (RSI) in amateurs by using low-cost off-the-shelf components. While results are favorable to prior work with athletes and custom hardware, additional evaluation is needed to identify error sources between the users and sensor systems within the study.**

I. Introduction

With the growth of the Internet of Things and wearable devices, it is more common than ever to instrument ourselves to monitor daily activity such as step counting, body weight, blood pressure, and sleep patterns. This "quantified self" has even extended to athletes where regular monitoring of performance is common for professional and college-level athletes alike. Typically these measures are conducted using cameras, force plates, or custom inertial measurement systems [1], [2] that may be cost-prohibitive for individuals and smaller organizations. To this end, we will examine whether a common athletic performance measure, the Reactive Strength Index (RSI) [3], can be extended to amateurs using low-cost off-the-shelf hardware by monitoring their performance during a drop jump exercise, and subsequently calculating the RSI value from a body-worn accelerometer and an in-ground force plate.

A drop jump is a common athletic test to assess the strength and performance of an athlete. The jump begins by having a participant step off from an elevated platform, land on the ground, and quickly execute a vertical jump in place. The elements of this drop jump can be seen in Figure 1. Several metrics can be calculated from this jump including jump height power output, and ground contact time. A "good" drop jump is one in which the participant rapidly jumps after landing while achieving a powerful output.

A study was conducted in a biomechanics laboratory with 11 healthy participants comparing the RSI from a body-worn inertial measurement unit to an in-ground force plate during a drop jump exercise. A total of 107 trials were recorded and measures of correlation and error between force plate derived RSI and accelerometer RSI were found. While our results are not as accurate as preceding work with athletes and custom systems, we achieve favorable measures and examine ways in which our results can be improved.

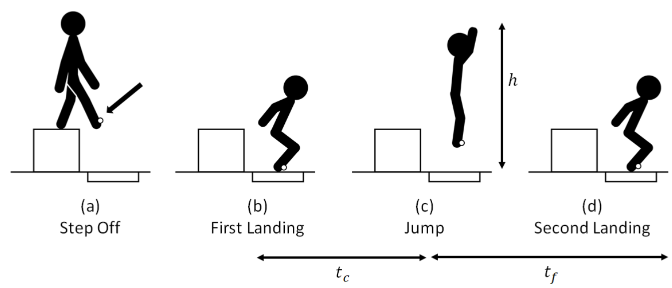

Fig. 1: Steps performed in a drop jump with measurements of time of contact, time of flight, and jump height. A body-worn accelerometer is indicated with an arrow.

II. Background and Methodology

A. Measuring RSI with Accelerometers and Force Plates During Drop Jumps

For our analysis, an important measure is the Reactive Strength Index (RSI) which measures the height of a jump (h) divided by the time of contact on the ground (t_c) during some jumping exercise. If the jump height (h) cannot be measured directly, then it can be calculated from the time of flight (t_f) while the person is in the air. In the context of the drop jump, Figure 1 shows the elements for the time of contact as the time between the first landing and jump, and the time of flight as the time between the jump and second Landing. By measuring these durations the RSI can be found by $RSI = \frac{g{t_f}^2}{8t_c}$ [1].

An example of force plate and accelerometer measurements during a drop jump are shown in Figure 2, with each sub-figure indicating the locations of the first landing, the subsequent jump, and the second landing. While both sensor systems measure the same event, determining timing between the platforms can be challenging. First, it is easier to determine the landing and take-off points with the force plate as that system reports no value when the user is not present. Thus the sudden impact of the user (either from landing or take-off) can be more easily found. These points are more difficult to capture with the accelerometer as it measures the person's whole movement during the drop jump. Second, the accelerometer

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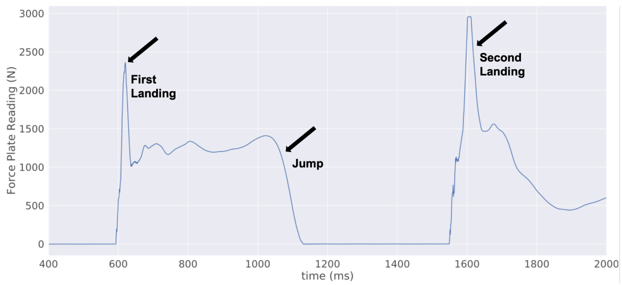
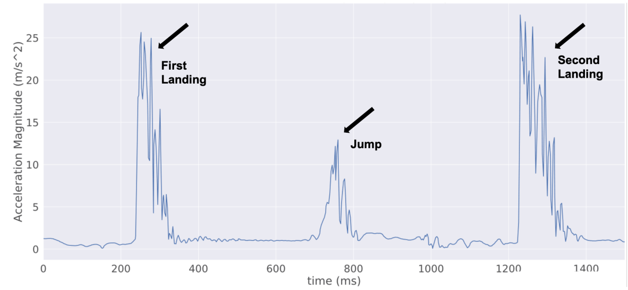


(a) In-ground force plate



(b) Body-worn accelerometer

Fig. 2: Comparison of Drop Jump data collected from force plate in (a) and body worn accelerometer in (b).

was attached to the participant's foot in the user study, and this object would oscillate during motion. These variations cause the "noise" in Figure 2b, whereas the force plate was fixed into the ground and did not have similar challenges.

B. User Study and Protocol

To test the efficacy of our approach a user study was conducted with 11 healthy young adults. Commercially available inertial measurement units (Mbientlab MetaMotionR) were used to calculate RSI in comparison to a force plate (AMTI Force Plate) which was installed in the floor of a biomechanics lab. The participants placed the accelerometer on their dominant foot and practice drop jumps were performed until they felt comfortable with the activity. Later, ten drop jumps were conducted while data was recorded on both the attached accelerometer and the in-ground force plate upon which they landed. The investigators ensured all jumps were performed "correctly"; if a person stumbled, fell, or otherwise did not follow the procedure, they were asked to repeat the jump. Acceleration data was collected in all three axes at 800 Hz and force data from the plate was sampled at 1000 Hz. The dataset was later analyzed by a custom Python script to calculate the RSI for each jump.

III. Results and Conclusion

Data was collected from 11 participants from which 107 trial jumps are reported. Three jumps are excluded as RSI could not be calculated due to high accelerometer noise. For each jump, the calculated force plate and accelerometer RSI values are plotted in Figure 3. The correlation between these measurements (R^2) across all jumps is 0.806. As the force plate and accelerometer measured the same person's motion, both derived RSI values should be similar and the measurements between the two sensors should be highly correlated.

While overall there is a large correlation across all trials, some users exhibited higher variation in their RSI measurement. In comparing the average measurement error between accelerometer and force plate RSI across all trials the average error was 0.107 ± 0.09. Examining individual participants, some had average error values as low as 0.049 ± 0.06 and the highest of which was 0.183 ± 0.10. As all RSI values were calculated in the same manner, this large difference suggests subject-specific factors may have been responsible

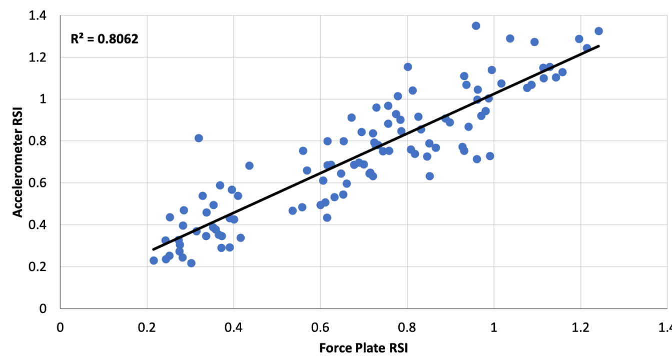


Fig. 3: Comparing RSI values calculated from force plate and accelerometer data for all user trials.

for these errors. One possible source of this error would be the amateur status of the participants recruited for the study. Many participants had never performed a drop jump before and it is possible that variations in drop jump form could have led to incorrect approximations by the accelerometer RSI algorithm.

Overall, our approach shows the potential of calculating athletic performance measures from amateurs using off-the-shelf components. However, our results are less accurate than prior work with research grade hardware that found a higher correlation between RSI values of 0.98 [1] (compared to our value of 0.806) and data collected with athletes and custom hardware found smaller error values for RSI at 0.06 ± 0.05 [2] (compared to our 0.10 ± 0.09). Further investigation is warranted to determine the impacts of improved detection methods for time of contact and time of flight, and to understand what biomechanical performance measures between persons may impact these results.

References

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