# Measurement of striking impact kinetics via inertial modelling and accelerometry

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Striking impact has been explored repeatedly in combat sports. The majority of methods used in the literature require intricate equipment. This study implemented a novel and simple method of measuring impact kinetics using a common, commercially available striking bag. Impulse and peak force of impacts were determined, with reliability and validity statistics obtained from multiple impacts with a custom ballistic pendulum. Test-retest reliability calculations determined that all measures had acceptable reliability (CV$\leq$ 2.4%). Using linear regression modelling, the coefficient of determination scores displayed a good fit for the model ($R^2 \geq 0.96$) when plotted with a spectrum of pendulum masses. This novel method represents a reliable and valid approach to measuring striking impact kinetics which is easily adaptable to any type of hanging striking target.

**KEYWORDS:** combat sports, striking dynamometry, martial arts.

**INTRODUCTION:** Striking impact kinetics are central to performance in full contact combat sports (Lenetsky, Harris, & Brughelli, 2013). Varying methods for measuring impact kinetics include the use of force plates or load cells, fluid filled targets, strain gauges and accelerometers inserted internally in striking targets (Smith, Dyson, Hale, & Janaway, 2000). These dynamometers present acceptable reliability and validity data (Busko et al., 2014), however they are typically very expensive and complicated to use. Such issues have limited the use of striking impact dynamometry (SID) to a lab based measure rarely used by practitioners in the field.

The aim of this study was to develop a novel and simple method to measure impact kinetics that can be used effectively and easily by field practitioners.

**METHODS:** The SID developed for this study was comprised of a commercially available striking bag (NZ Boxer™, Teardrop style, Auckland, New Zealand) and an externally mounted wireless triaxial accelerometer (I Measure U Ltd., Auckland, New Zealand), sampling at 1000Hz. A custom built ballistic pendulum was designed to produce a repeatable and controlled SID measurement. This pendulum was designed to be very ridged and consisted of very light cables fitted to a range of commercial dumbbells (Hammer Strength™, Cincinnati, OH, USA). The pendulum was raised to a height of 2.05m for each test impact, loaded with a range of masses to produce a spectrum of impact forces, seen in Figure 1. The masses tested were, 10.8, 12.46, 14.46, 16.4, 18.34, 26.22, 30.4, and 34.5Kgs. A custom built LabVIEW program (Version 11.0, National Instruments Corp., Austin, TX, USA) was used to analyse the accelerometer data and calculate the force kinetics.

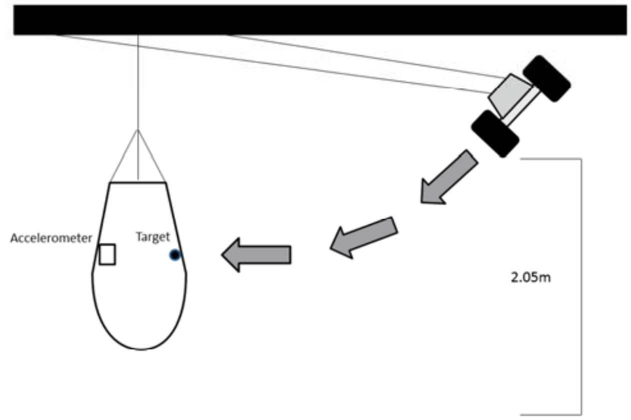


**Figure 1. A non-scale diagramme of the experimental set up.**

**STUDY DESIGN:** The ballistic pendulum was impacted against the equipped striking bag. For each pendulum mass, six repeated trials were performed to calculate test-retest reliability results. In addition, the multiple trials were implemented to explore the compliance of the bag to repeated impacts, the result of which may cause compression of the bag and its contents and hence variability in its response. The bag was adjusted to return the contents to their initial state between each mass change. To establish internal validity of the equipped punching bag the varying masses were compared to the findings of the bag calculated through the custom LabVIEW program.
The independent variables were the spectrum of masses used for the impacts. The consistent acceleration of the pendulum, due to the same drop height used for every test, allowed for validity testing as the increase in pendulum mass was predicted to produce linear increases in the dependant variables. Dependant variables were peak force and impulse. Peak force was included due to common inclusion throughout the literature (Pierce, Reinbold, Lyngard, Goldman, & Pastore, 2006; Smith et al., 2000; Walilko, Viano, & Bir, 2005). Likewise, impulse was included as it has primarily been used in the literature to calculate the effective mass of strikes (Lenetsky, Nates, Brughelli, & Harris, 2015). A threshold of 400N was placed on the ending of the force curve for the calculation of impulse due to signal noise caused by the swing of the equipped bag.

**STATISTICAL ANALYSIS:** Mean and standard deviations (SD) were calculated for all dependent variables. All data were log-transformed for reliability statistics. Coefficient of variation (CV%) was calculated to establish the test-retest reliability of the dependent variables. Between trial percent mean change was calculated to explore the influence of repeated impacts. Reliability findings were calculated using a reliability spreadsheet from Sportsci.org (Hopkins, 2012b). Internal validity was examined using an analysis of validity by linear regression spreadsheet (Hopkins, 2012a), analysing the data via linear regression and coefficient of determination.

**RESULTS:** Impulse ranged between 49-87 N·s and peak force ranged between 2261-3734 N. Between trial percent mean result for the equipped punching bag (Table 1) indicated that there was a levelling off process in the change in mean scores after the first two impacts on the bag in its initial state.

**Table 1. Between trial percent mean change**

| | Trial 2 - 1 | Trial 3 - 2 | Trial 4 - 3 | Trial 5 - 4 | Trial 6 - 5 |
|---|---|---|---|---|---|
| Impulse | 2.9 | 1.4 | 0.3 | -0.2 | -0.2 |
| Peak Force | 10.4 | 3.3 | 0.5 | -0.8 | 0.4 |

Test-retest reliability (Table 2) displays that removing the first two of the impacts results in similar reliability and was within acceptable ranges (Hopkins, 2000).

**Table 2. Test-rest reliability (CV) for the equipped punching bag**

| | 6 Impacts | 4 Impacts |
|---|---|---|
| Impulse | 0.9 | 1.0 |
| Peak Force | 2.5 | 2.4 |

Internal validity testing comparing the dependent variables to the mass of the pendulum was found to have a good fit to linear regression models for all variables. Linear regression figures, coefficient of determination, and regression equations can be found in Figure 2. The last four trials were used for this analysis as they were not influenced by the bag compression. There is a slight spread in the findings in Figure 2 due to variations in the angle of impact. This is caused in part by a minor wobble that was inherent in the design of the ballistic pendulum.

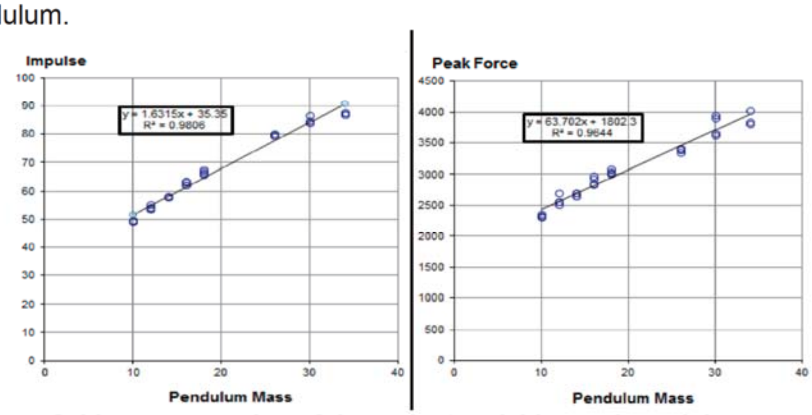


**Figure 2. Linear regression of dependent variables and pendulum masses.**

**DISCUSSION:** The purpose of this study was to develop a novel, and simple method of measuring striking impact kinetics that can be used be practitioners in field. The method developed was successful and requires only a commercial striking bag and a triaxial accelerometer. This SID approach produced a reliable measurement of impulse and peak force across multiple impacts. Change in mean scores were found to appropriately illustrate the compressive nature of the equipped bag. On the specific striking bag used in this study it was found that two impacts were needed to compress the bag to a point where the compliant materials in the bag did not affect the readings. Other bags may require a greater or lesser number of impacts to reach a similar point. After an initial observation of this compression point, any striking bag can use this method. Additionally, this method is internally valid in differentiating magnitudes of impulse and peak force across a spectrum of loads.

This internal validity is specific to SIDs as Pedzich et al. (2006) and Busko et al. (2014) argue that due to the variation of the target size and protective padding on the multitude of SIDs used in the literature, accurate comparisons of findings are difficult. In a review of the literature we were unable to find any studies that did not in some way pad the impact target, the striking limb, or both. This makes instinctive sense; a full strength bare knuckle punch, in this example, against an unpadded target would most likely result in injury. Thus, SIDs have been designed in such a way that, while minimizing injury risk, does not accurately measure the true impact kinetics. Some force will always be absorbed by the protective padding during impact, and the time period of the impact varies due to that absorption. This inherent limitation of SID does not mean that measuring impact kinetics in combat sports is meaningless. Rather, in agreement with Busko et al. (2014), we believe that further research must avoid comparison between SIDs as seen previously in the literature (Lenetsky et al., 2013). We suggest that SID need only be: 1) reliable within the device used; and 2) valid in the ability to differentiate kinetic magnitudes to identify differences between and within participants over time. In summary, a SID must produce reproducible results that should only be compared to other results from that same dynamometer, reliability and internal validity. There exists a multitude of devices to measure striking impact kinetics, and while such diversity in the characteristics of the devices exists comparison is problematic. The method presented in this paper offers the most practical approach to SID developed to-date.

**CONCLUSION:** This study produced a novel method of striking dynamometry that is reliable and internally valid in measuring impulse, and peak force in striking impacts. The method is relatively simple to use, requiring only a striking bag and a triaxial accelerometer. Additionally, this method does not necessitate any major adjustments to either piece of equipment to provide the information needed to analyse striking performance. This method can also be simply applied to any other hanging striking bag.

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