Actual Strike Force Estimation in Combat Sports Using Correlated Sensor Data

Minho Chae[1], Jonghak Hwang[2], Wooseop Han[2], Sangkyoon Park[3], Sihyun Ryu[3], Sukyung Park[1]†
[1]Biomechanics Laboratory, Dept. Mechanical Eng, Korea Advanced Institute of Science & Technology, Daejeon, Korea
[2]Korea Sports Promotion Foundation, Seoul, Korea
[3]Motion Innovation Center, Korea National Sport University, Seoul, Republic of Korea
Email: minho.chae@kaist.ac.kr

Summary

The main aim of this study was to estimate the force in combat sports by compensating for the cushioning effect of the protective gear or cushioning material using the correlation between sensors. A kick simulation machine was developed to measure both striking force and impacted force simultaneously. Based on the compensation equation obtained by using the machine, the force profile of Taekwondo athletes with the cushioning effect compensated has been estimated.

Introduction

Various studies have attempted to measure the striking force in combat sports, but accurate measurement has been challenging due to safety concerns that prevent athletes from directly striking the sensor. In particular, to ensure the safety of athletes, cushioning materials are placed over the sensor, inevitably causing discrepancies between the measured impact force on the sensor and the actual striking force of the athlete, depending on the measurement method of various studies [1]. Therefore, the aim of this study is to estimate the actual force by compensating for the cushioning effect through the correlation between sensors.

Methods

A kick simulation machine that mimics human kicking motions was designed to analyze the differences in impact force profiles between the Taekwondo protector and the striking object, which induces the cushioning effect. The range of maximum force and impact duration encompass most of the maximum force and impact duration reported in previous studies [2]. To measure the force of the impacted object (mannequin) and the cushioning material (electronic protector), a load cell was attached between them, while another load cell was mounted on the fist of the striking object.

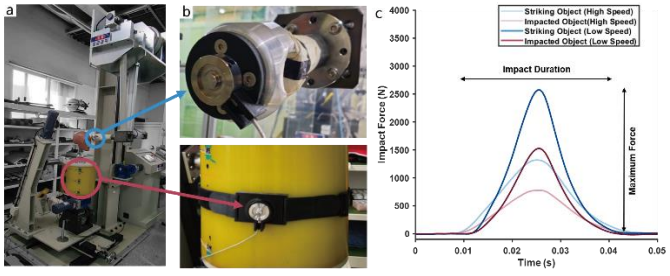

Figure 1: (a) Kick simulation machine, (b) Loadcell attached on striking object and impacted object, (c) Force profile of Striking object and Impacted Object on different striking speed

The derivation of the compensation equation between the impacted and striking objects consists of two steps. First, to analyze only the main peaks of the measured force profiles, both the striking and impacted force profiles are fitted to Gaussian functions, ensuring that each profile contains a single peak. Then, a linear relationship between the Gaussian function parameters of the impacted and striking objects is used to derive the compensation equation. Finally, the Taekwondo athlete's kick was measured by placing a load cell between the mannequin and the electronic protector.

Results and Discussion

The results of this study demonstrate the validity of the compensation equation obtained using a kick simulation machine that simulates human strikes. The Gaussian parameters of impacted and striking objects show a strong linear correlation, with $R^2 = 0.9729$ for amplitude (maximum force) and $R^2 = 0.9993$ for sigma (impact duration). Additionally, the NRMSE error between the overall force profiles of the striking and impacted objects averaged 3.2%. Additionally, the proposed method enables the estimation of a Taekwondo athlete's actual force profile with the cushioning effect compensated. The linear regression results indicate that the maximum force of the striking object was 67% higher than that of the impacted object, whereas the impact duration showed an almost negligible difference of 0.2%. (Figure 2)

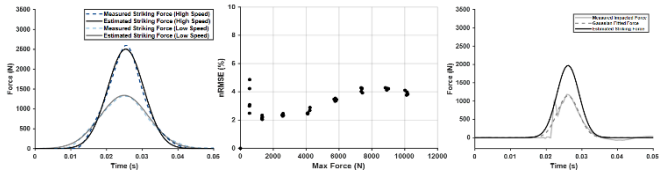

Figure 2: (a) Raw data of Measured Striking force and Estimated Striking force on different striking speed, (b) NRMSE of the overall trajectory according to maximum force, (c) Raw data of an actual Taekwondo athlete's kick with the cushioning effect compensated.

Conclusions

This study contributes by developing a striking machine that simulates human kicks, allowing for the control of specific force and impact duration while ensuring repeatable strikes. Proposed compensation could allow researchers to measure actual striking force of combat sports by eliminating the cushioning effect, which varies across different studies and propose a method for indirectly measuring force.

Acknowledgments

This research was supported by the Korea National Sport University in 2023. (N06230140)

References

[1] Lenetsky S et al. (2021). SCJ, Publish Ahead of Print
[2] Buśko K et al. (2016). Acta Bioeng Biomech, 18: 47-5