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Original article

Resultant linear acceleration of an instrumented head form does not differ between junior and collegiate taekwondo athletes' kicks

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Abstract

Objective: The purpose of this study was to compare the effects of various taekwondo kicks and age (school level) in absolute terms and relative body mass on the resultant linear acceleration (RLA) of an instrumented head form.
Methods: Forty-eight male (middle school: 16; high school: 16; university: 16) taekwondo athletes were recruited for this study. Subjects performed 10 turning, 10 jump spinning hook, and 10 jump back kicks on a Hybrid II head mounted on a height-adjustable frame.
Results: A 2-way (School × Kick) MANOVA was used to determine the differences in RLA between schools (age groups) by type of kick. There was no univariate School main effect for absolute RLA ($\eta^2 = 0.06$) and RLA relative to body mass ($\eta^2 = 0.06$). No univariate Kick main effects were found for absolute ($\eta^2 = 0.06$) and relative RLA ($\eta^2 = 0.06$).
Conclusion: It is of concern that RLA did not significantly differ between school levels, implying that young taekwondo athletes generate similar forces to their adult counterparts, possibly exposing young athletes to an increased risk for head injuries.

Keywords: Biomechanics; Concussion; Injury; Martial arts; Taekwondo

1. Introduction

The World Taekwondo Federation (WTF) is one of the largest sport governing bodies with practitioners in over 206 countries.[1] Although the exact number of junior athletes participating is unclear, there are 4.3 million and 3.8 million registered adult and junior black belts (an advanced rank), respectively.[2] The latest head injury studies demonstrate the concussion incidence in taekwondo over a 15-year period to be 4 times higher than in American football.[3] In young taekwondo athletes (6–16 years), cerebral concussions constitute 28% of all injuries.[4] Compared to their adult counterparts, boys were more likely to sustain a cerebral concussion: relative risk (RR) = 1.9 (95% confidence interval (CI): 1.5–2.6) and girls were likewise at a higher risk: RR = 3.6 (95%CI: 2.1–6.2).[3]

The severity of brain injury among young athletes is reported to be due to multi-factorial components, such as biomechanical characteristics, pathophysiological responses, neurobehavioral outcome, and contextual complications.[5] It is reported that the material properties of developing and mature rat skulls and the brain are different and so the specific effects of the applied forces may be age-dependent.[6] The full effect of developmental factors on the biomechanical response of the brain, such as its water content, cerebral blood volume, level of myelination, skull geometry, and suture elasticity remains unknown.[5,7] Age-specific concussion mechanisms in sport are complex and remain unclear,[8] although recent attempts to understand them among adults in taekwondo provide a window of insight into head injury in this sport.[9,10]

Fife et al.[10] reported head injury measures, such as resultant linear acceleration (RLA) and head injury criterion (HIC) measures associated with the 5 most frequently used head kicks in taekwondo. Alarmingly, the turning kick elicited the highest magnitudes (RLA: 130.1 ± 51.7 *g*; HIC: 672.7 ± 540.9).[9]

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Furthermore, the axe kick, associated with lower values (RLA: 34.5 ± 17.9 *g*, HIC: 56.9 ± 54.9),[9] caused traumatic subarachnoid hemorrhage in a healthy 23-year-old male in another case study.[11] Moreover, 2 deaths were reported[12,13] with one 17-year-old male losing his life due to brain hemorrhage resulting from a kick to the neck by a 15-year-old opponent during a taekwondo competition.[12] For these reasons, it is important for the effects of the biomechanical forces on the pre-mature brain to be investigated in this sport.

With the lack of data regarding impact forces to the head in competition taekwondo for juniors, the purpose of this study was to determine the difference in RLA, as a measure of possible head injury severity, between 3 age groups, middle school, high school, and university students in absolute terms and relative body mass on the resultant linear acceleration of an instrumented head form.

2. Methods

2.1. Participants

A total of 48 subjects, including middle school (n = 16, 14.8 ± 0.6 years, 166.1 ± 11.3 cm, 57.0 ± 13.2 kg), high school, (n = 16, 17.4 ± 0.6 years, 177.1 ± 5.9 cm, 69.2 ± 7.4 kg) as well as those from 1 university (n = 16, 20.2 ± 1.3 years, 178.5 ± 7.1 cm, 73.3 ± 10.9 kg) in the Seoul area, Korea, were recruited for this study. All subjects were elite athletes (mean years experience ± SD: middle school: 4.6 ± 1.2 years, high school: 7.0 ± 1.6 years, and university: 9.6 ± 2.0 years) and members of either a school or university taekwondo competition team. Pre-participation screening consisted of completing informed consent (university athletes) or assent (junior athletes) forms by the subjects or their parent/guardian depending on their age. Prior to the commencement of the testing, all subjects were orally briefed on testing procedures then gave their written consent (guardian's signature for the minors), with height, weight, and age recorded. Prior to data collection, this study was given approval by the Seoul National University Institutional Review Board on Human Ethics (IRB #:1104/001-002).

2.2. Testing apparatus: anthropometric test dummy

To simulate head impact in taekwondo, the target consisted of a Hybrid II head and neck (fitted with a large Adidas taekwondo head guard) secured to an aluminum support frame with locations for peg bolts to be fastened at pre-determined increments (Fig. 1), which allowed adjustment of the Hybrid II head and neck to comply with average weight category standing heights of Olympic male taekwondo participants from the Athens 2004 Olympic Games[14] for the university athletes. Similarly for middle and high school athletes, the pre-determined increment heights were collected from average standing heights of athletes supplied by 3 middle and high schools (in Korea) as well as the junior Greek national team (Willy Pieter, unpublished data, 2010).

2.3. Testing procedures

Subjects wore lightweight athletic clothing during testing and performed individualized warm-up routines followed by a series of light kicking techniques for specific preparation. The athletes were then given time to practice kicking the Hybrid II by performing the high turning kick, jump back kick, and the jump spinning hook kick to the head to become familiar with the target. Research on head blows and head injury variables in taekwondo have shown these kicks to record the highest RLA and HIC values.[9] Following the familiarization and a brief rest period, subjects were asked to perform 10 repetitions of each kick aimed at the Hybrid II head. To ensure a standard criterion was used for successful kicking trials, the technical description was used when awarding points during full-contact competition was adopted.[15] This criterion stipulates that all kicks which make contact with the head causing visible head movement are to be awarded a point. Adhering to this criterion ensured that only successful (potentially point-scoring kicks) were used for data analysis. All participants wore a protective footpad that is commonly used during competition and were asked to kick as if in competition (i.e., with maximum effort).

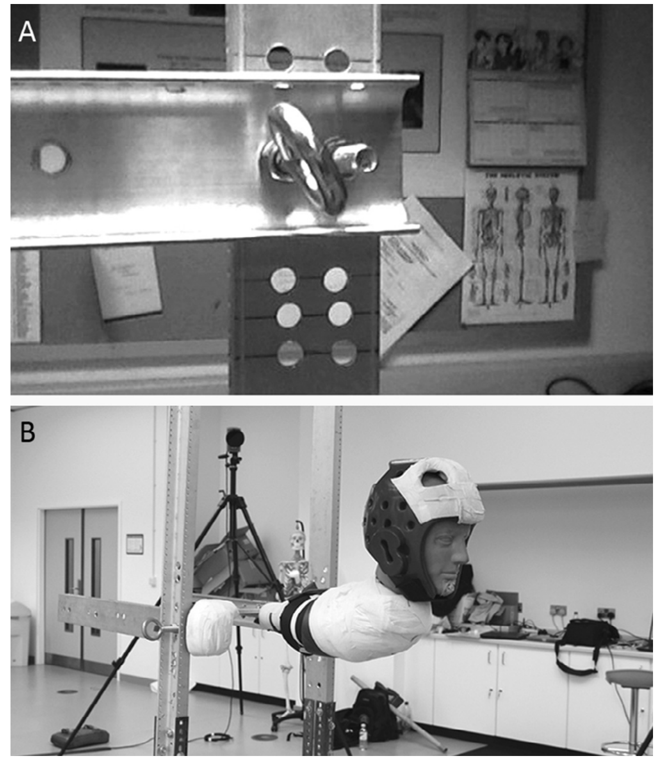

Fig. 1. Peg bolt height adjustment (A) and height adjustable Hybrid II (B).

2.4. Data acquisition

The Hybrid II head form was instrumented with a 500 *g* tri-axial accelerometer (Model 356A66; PCB Piezotronics, Depew, NY, USA) mounted at the head center of gravity to obtain RLA. The accelerometer was attached inside the Hybrid II head on a 4.0 × 4.0 cm aluminum plate secured to the head base by 4 socket head cap screws. Furthermore, a plastic mounting base (manufacturer provided) that allows for the sensor to be mechanically grounded was glued to the aluminum plate to ensure no movement of the accelerometer occurred during each trial (Fig. 2).