RISK OF HEAD INJURY FROM FALLS ON TAEKWONDO MATS

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The aim of this project was to determine the risk of head injury from falls without protective headgear onto 5 different taekwondo mats. In addition, the combined shock absorption of the headgear and mats adopted by the Australian taekwondo team was assessed. An artificial headform with accelerometers was dropped from a height of 1.5 m onto the mats. The acceleration data were used to calculate the Head Injury Criterion (HIC). Results revealed that only one mat had sufficient shock absorption to generate a HIC value below the threshold for head injury for drops with the unprotected headform. The combination of the protective headgear and mats adopted by the Australian taekwondo team produced HIC values below the injury threshold. It is recommended that taekwondo athletes wear protective headgear at all times when training.

KEY WORDS: head injury, taekwondo, mats, falls.

INTRODUCTION: The prevention of injuries in sport is a major priority for a number of organisations, particularly in the combat sports. Taekwondo is a martial art with such popularity that it will be included as a medal sport at the Sydney 2000 Olympics. Mats have only recently been introduced to taekwondo (Pieter and Lufting, 1994). Protective headgear is mandatory during competition but not always worn during training. Despite the introduction of these countermeasures, serious injuries are still being reported (Menard, 1994). Biomechanical techniques such as the determination of the deceleration of body segments during impacts can be used to assess the protection afforded by various equipment (Mertz, 1985). This information may be used as an aid in the selection of the most appropriate equipment. Artificial humanoid headforms have been developed for this purpose. In the United States, the Hodgson-Wayne State University (WSU) headform was originally designed as part of a helmet test system for the National Operating Committee on Standards for Athletic Equipment (NOCSAE). Its application can extend to the assessment of sports surfaces and mats. The headform comprises of a glycerin "brain" in a sealed cranium with silicon rubber skin and a rubber covered neck. The biofidelity of the headform has been assessed and it was shown that the static load deflection, striking point impedance and impact acceleration responses were similar to those observed on cadaver heads (Hodgson, 1975).

A head injury tolerance level has been derived from an acceleration-time curve known as the Wayne State Tolerance Curve (Gurdjian, Lissner, & Patrick, 1962). It was based on linear accelerations from frontal impacts on a flat hard surface producing fractures in adult cadaver skulls and concussion in experimental animals. The HIC has been derived from the curve. It is in the form of a weighted-impulse and specifies the limit of tolerance in terms of the acceleration pulse sustained by the head during impact. It does not account for rotational motion or stress waves as injury mechanisms. The HIC is commonly used in automotive crash research (Prasad and Mertz, 1993) as well as in standards for playground surfaces (e.g. Australian/New Zealand Standard 4422: 1996). The signal from accelerometers within the headforrn is used to calculate the HIC. The aim of this project was to use the Hodgson-WSU head form and HIC to determine the risk of head injury from fall onto different taekwondo mats.

METHOD: A medium size Hodgson-WSU headform (NOCSAE, Kansas) with three orthogonally arranged PCB® ICP® 303A piezoelectric accelerometers (Piezotronics Inc., New York) at the centre of gravity of the headform were used. Calibration of the accelerometers was checked prior to use via the back-to-back method with a reference accelerometer (Semdge and Licht, 1987). The headform was manually raised to a height of 1.5 m with a pulley and cable attached to the neck region. A drop height of 1.5 rn was chosen to approximate the distance covered when an individual of average stature falls to the ground. This is also the distance used in the NOCSAE gridiron helmet tests (NOCSAE, 1997). The headform was aligned such that the impact point was the rear of the head. The mats were positioned on a piece of carpet over a concrete floor directly under the headform. Three drops were performed on different locations of each mat. Data capture was triggered externally by a photocell positioned at approximately 0.5m above the mats. The high level conditioned acceleration signals were AID converted at a sampling rate of 10 kHz. LabVIEW® (National Instruments, Texas) custom written software was used to calculate a resultant acceleration signal from the three low-pass filtered (1650Hz), digitised acceleration signals. From the resultant acceleration signal, HIC for the duration of the impact was calculated as described by Chou and Nyquist (1974). A HIC value of 1000 has been used as the concussive threshold (Slobodnik, 1979) and was adopted as the injury threshold. Five mats were assessed: Pinetree green, Pinetree orange, Jigsaw red, Jigsaw blue and Jigsaw white. The Pinetree green was the mat adopted by the Australian taekwondo team. The same manufacturer (Pinetree) provided the headgear which comprised of 19mm thick NBR sponge. All mats were constructed from closed-cell foam. The thickness of the mats was measured with an anthropometer. The mass of the mats along with their volume determined by water displacement method (Miller and Nelson, 1973) was used to calculate the density. A one-way ANOVA along with Tukey HSD post hoc test were conducted to detect significant differences ($p<0.05$) in HIC values.

RESULTS: Representative acceleration-time curves for each of the three accelerometers are displayed in Figure 1. The accelerometer registering the greatest deceleration was the one orientated mostly in the vertical plane. The least deceleration was detected by the accelerometer aligned in the mediolateral plane. Impact lasted between 30 and 45 ms.

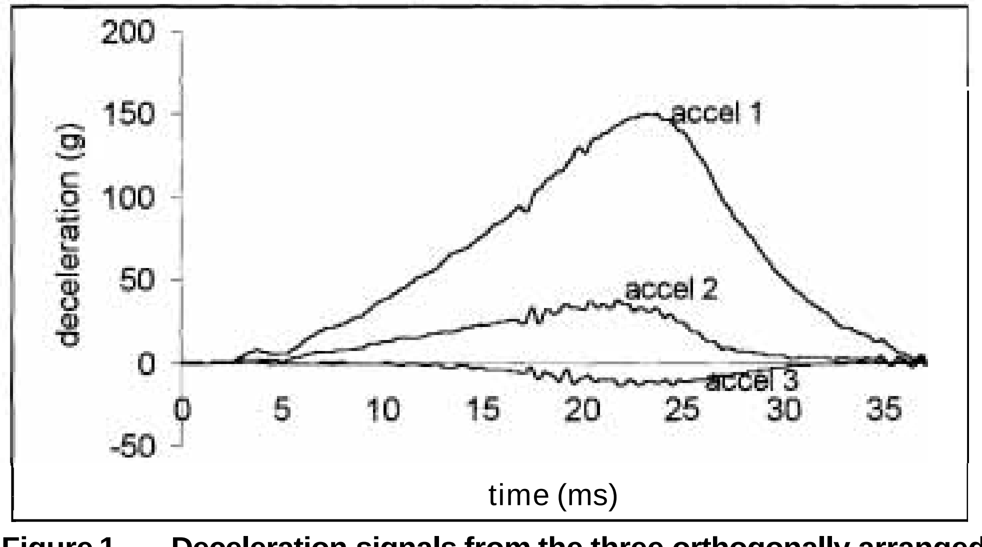

Figure 1- Deceleration signals from the three orthogonally arranged accelerometers (accel 1, 2, 3) from a drop on the Pinetree green mat.

The characteristics of the mats along with HIC values are depicted in Table 1. Three mats were of similar thickness (≈ 23mm) while the other two mats were notably thicker (30 and 33mm). The density ranged from 0.09 to 0.19 g/ml. Only the Jigsaw red mat produced a mean HIC values below the injury threshold value. When the headform was dressed with the Pinetree headgear and dropped onto the Pinetree green mat the mean HIC value (666) was well below the injury threshold. The coefficient of variation (CV) for the HIC values ranged from 1 to 11 %, with an average value of 5 %. All HIC values were significantly different from each other apart from Pinetree orange and Jigsaw white.

Table 1 Thickness, Density and HIC Values

Mat (+ headgear)	Thickness (mm)	Density (g/ml)	HIC (mean ± SD)
Pinetree green	23	0.16	1192 ± 67
Pinetree green + headgear			666 ± 72
Jigsaw red	33	0.09	853 ± 70
Jigsaw blue	30	0.09	1028 ± 14
Pinetree orange	22	0.18	1413 ± 51
Jigsaw white	23	0.19	1560 ± 49

DISCUSSION: The relatively low (average 5 %) CV for the HIC values indicate that the results were consistent. The highest CV (11 %) was for drops with the headgear. The Jigsaw red mat had the greatest thickness and least density and produced the lowest HIC value. Conversely, the thinnest mats with the greatest densities produced the highest HIC values. When comparing the Jigsaw red to blue, a decrease in thickness of only 3mm resulted in significantly greater HIC values and the mat exceeding the injury threshold. There was no significant difference between the Pinetree orange and Jigsaw white mats which may be attributed to the similarity in their thickness and density. The mat adopted by the Australian taekwondo team (Pinetree green) did not display the greatest shock absorption. When selecting equipment, there are a number of considerations. Reducing the likelihood of one type of injury may increase the incidence of another. This may be the case when there is drastic imbalance between cushioning and other properties. Although, the Jigsaw red produced the lowest HIC value, previous tests (Hrysomallis, 1997) revealed that it displayed the greatest compression. Anecdotal evidence suggested that the excessive compressive contributed to lower limb injuries when the foot sank into the mat and became fixed while attempting to rotate the body. Lower limb injuries appeared more common than head injuries and this prompted the change from the Jigsaw red to the Pinetree green mat. Despite head injuries being less common than lower limb injuries, measures must be taken to reduce their occurrence and severity. The combination of the Pinetree green mat and headgear produced HIC values well below the injury threshold, indicating that the risk of head injury was minimal. It should be noted that there still is a small risk of injury. A goal of biomechanical assessment of protective equipment is to control specific injuries caused by a particular mechanism. Total elimination of the injuries may be the goal but is at times unattainable. Risk minimisation appears to be the realistic outcome.

CONCLUSION: Using the HIC values from drop tests, this project determined that there was a considerable risk of head injury for the unprotected head from falls onto four of the five taekwondo mats tested. When tests were conducted with the headgear and mat adopted by the Australian taekwondo team, the HIC value was below the injury threshold, thus minimising injury likelihood. It is strongly recommended that taekwondo practitioners wear protective headgear while training.

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