KARATE AND BOXING GLOVE IMPACT

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Karate, an oriental art of self defense which has been adapted to sport form, has gained considerable popularity since the development of sparring and tournament competition. The sport form, one aspect of the martial art, has three distinct sparring divisions: controlled or non-contact, limited contact, and full-contact competition. In non-contact competition the blows are delivered with "full power". Opponent injury is avoided by focusing the blow just prior to contact. The match is awarded on points by judges for probable injury occurance. In limited contact sparring, light and moderate contact is required, however emphasis is on demonstrating a successful blow has been delivered rather than damaging the oponent. A point system is also used for this division. In full-contact karate the object is to knock out the opponent with a hand or foot technique and in this respect it is similar to boxing. In the absence of a knockout, the match is awarded on points.

Forces sufficient to cause head accelerations of 80 g (784 N at about 8 msec) have been established as the concussive or knockout level via the Wayne State Tolerance Curve (WSTC) by Hodgson and Thomas (1981). Comparable forces applied to the body can cause ruptures, contusions, and other injury to organs of the trunk, depending on the blow site.

Newtonian principles of momentum and energy conservation and force-time apparatus have been employed to estimate force levels for punches. Peak forces up to 12,143 N (2,730 lbs.) have been recorded from karate punches (Melton, 1981) measured on force sensing devices. Walker (1975) estimated about 3,200 N would be required to break a brick, which is a common practice in karate demonstrations. Average forces, from cinematographic studies, range from about 1,666 N to 6,860 N (Nakayama, 1966; Smith, 1975; Cavanagh and Landa, 1976; Feld, McNair & Wilk, 1979) under various punching conditions. This is a considerable amount of force since only about 1,100 N is required to fracture a mandible (Patrick and Sato, 1970).

In none of these studies did karate punchers wear gloves nor was the effective momentum transferred to an object of comparable size to the human body measured. The purpose of this study was, therefore, to compare low, intermediate, and high skilled subjects wearing no glove, the karate glove, and the boxing glove on fist impact velocity (FV) and momentum (M) transferred to a heavy bag.

METHOD

High speed cinematographic recordings of subjects punching a heavy bag were used to determine fist velocities immediately prior to impact and bag momentum following the impact. Five low skilled (white belt), five intermediate skilled (green belt), and five high skilled (black belt) subjects were used for the study. Randomly selected from a list of volunteers, subjects were from karate clubs in and around Southern Illinois. A person of white belt rank is considered a novice and having less than 9 months experience in karate but is familiar with the basic punching techniques. Intermediate skilled green belt subjects have about one to one and one half years of karate experience and subjects with black belt rank are considered skilled in karate punching, having more than three years training. Informed consent forms were signed by subjects previous to data collection. Subject characteristics are presented in Table I.

TABLE I.
MEANS AND STANDARD DEVIATIONS FOR SUBJECT DESCRIPTIVE INFORMATION BY SKILL LEVEL.

Skill Level	Age (yrs)		Years Training		Height (cm)		Weight (kg)	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
High	30.40	9.71	10.70 [a]	6.08	172.60	6.40	72.50	12.34
Intermediate	23.60	7.13	1.20 [b]	0.50	168.42	6.83	65.06	9.26
Low	20.80	2.38	.34 [b]	0.15	176.52	10.02	81.00	16.07

*Means with the same superscripts are not significantly different ($p < .05$)

The hands of the subjects were not taped for this study. Hand protection devices (HPD) were the Everlast brand Model 2210 Official A.A.U. boxing glove and the Pro brand karate glove. Padding in the boxing glove was a combination of hair and open cell foam. It was approximately 4 cm in thickness at the impact surface. The karate glove was manufactured from Uniroyal's Type MLC Ensolite (R) molded foam with a density of 3 - 4.5 lb-cu ft and a 25% compression-resistance of 1.5 - 3 lb/cu ft. At the impact surface the karate glove was 3 cm thick.

A 33.45 kg punching bag, 109 cm high and 34.5 cm wide, was suspended by a rope from a gymnasium ceiling support a distance of approximately 10 m. The bag was firmly packed and its center

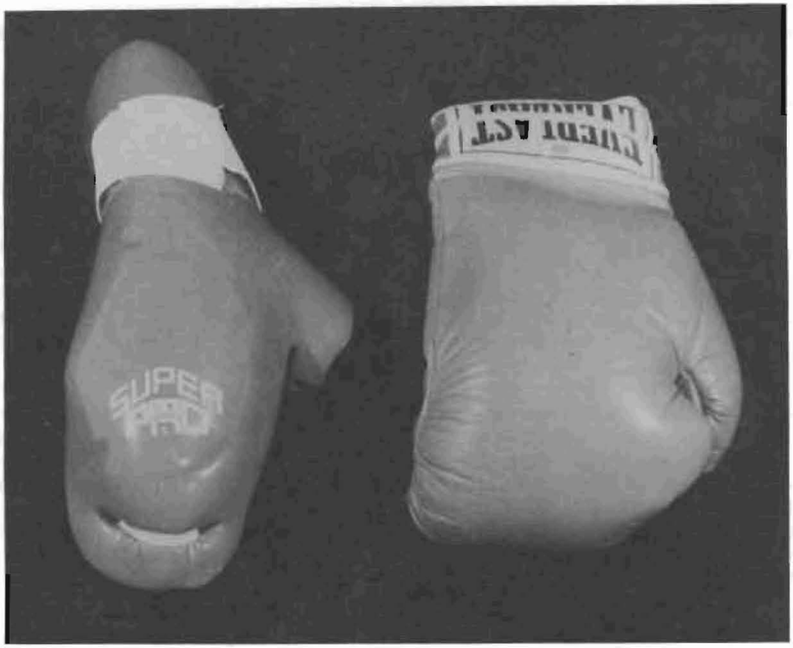

Figure 1. Karate glove and boxing glove.

of gravity level marked for easy identification and to serve as a target level. The target was adjusted to the height preferred by each puncher.

A LOCAM 16 mm motor driven camera operating at 100 frames/s was used to record the study protocol using Kodak Tri-X Reversal film with an ASA rating of 160. The camera was positioned perpendicular to the subjects such that a lateral view of the punching event was recorded.

Subjects were dressed only in shorts, had joint centers marked, and had anthropometric measures taken. Joint centers were marked at the distal ends of the second and fifth metacarpals, medial and lateral styloid processes, medial and lateral epicondyles of the humerus, the head of the humerus, the greater trochanter of the femur, the lateral epicondyles of the femur and the lateral malleolus. A felt-tipped pen was used to mark joint centers. Anthropometric measures taken were limb and body segment lengths as well as height and weight information. Sufficient practice was allowed for subjects to become accustomed to punching the heavy bag. This procedure occurred with each HPD and the bare fist condition. When the subject signified he was ready the camera was started and the subject punched the bag on command from the investigator. Three trials were recorded of each subject punching the bag with each glove type and the bare fist.

Data were reduced and analysed with a Vanguard projection head, Numonics 1224 digitizer interfaced with an Apple II plus microcomputer and an IBM 360 mainframe computer. Fist positions at the impact side and bag positions at the opposite side from impact at the center of gravity level were digitized for each of 10 frames before through 10 frames after impact. Twenty-one total frames were digitized for each trial. Using the finite differences method, fist velocities were calculated 0.01 s prior to impact and bag momentum was calculated 0.1 s following the impact frame. The average fist velocity and bag momentum for the three recorded trials with each glove condition were used for analysis.

A skill by glove type (3 X 3) factorial design with skill level nested in glove type was used to analyse the data. Independent variables were the three skill levels; low, intermediate, and high, and the glove types; boxing glove, karate glove, and bare fist. Dependent variables were momentum (M) of the bag after impact, and fist velocity (FV) just prior to impact.

A Multivariate Analysis of Variance (MANOVA) was used to detect possible differences among the main effects on the two dependent variables; M and FV. Duncan's Multiple Range Test was used to detect differences between levels of possible significant main effect means.

RESULTS

Analysis of Variance (ANOVA) and Duncan's Multiple Range Tests revealed the high skilled group to have significantly more years training experience than intermediate and low skill subjects, $F\ (2,12) = 13.32$, $p < .05$. No other statistical differences were found among skill levels on subject descriptive information.

Bare fist, karate, and boxing glove conditions were compared on fist velocity (FV) 0.01 s prior to impact and bag momentum (BM) 0.10 s following impact for five high, five intermediate, and five low skilled subjects. Fist velocity and bag momentum descriptive information by skill level and glove type are presented on Table II.

Multivariate analysis of variance was used to compare glove type and skill level for FV and BM dependent variables. Since all possible sources of variability were accounted for in the model, specific skill level-glove type tests were made to determine differences between skill levels, glove type, and their interaction. No differences were found between skill level, $F\ (2,12) = 1.06$, $p > .05$; glove type, $F\ (2,24) = 3.30$, $p > .05$; nor their interaction, $F\ (4,24) = 0.47$, $p > .05$) on the FV dependent variable.

With BM as the criterion, similar non-significant results were found for the skill level-glove type interaction (See Tables II and III). However, differences were found for skill level and glove type with the BM dependent measure. The Duncan tests revealed the high skilled group to differ from the low skill group and the intermediate skill group . Using the same statistical procedure for glove type, the boxing glove differed from the bare fist but neither condition was different from the karate glove. These findings indicate the higher skill level imparted more momentum to the bag than both other skill levels with no differences between the lower two categories. In addition, more momentum was transferred with the boxing glove than the bare fist, but no differences were present between the karate glove and the glove type with higher (boxing glove) and lower (bare fist) mean scores.

TABLE II.
FIST VELOCITY (FV) AND BAG MOMENTUM (BM) MEANS AND STANDARD DEVIATIONS BY GLOVE TYPE.

	FV (m/s)		BM (N.s)	
Skill Level	$\bar{X}$	SD	$\bar{X}$	SD
High	12.34	1.37	60.79[a]	17.27
Intermediate	11.67	2.45	38.98[b]	15.26
Low	10.48	2.19	42.34[b]	11.62
Glove Type				
Bare fist	11.03	1.96	42.01[a]	18.66
Karate glove	11.89	2.10	46.38[ab]	17.40
Boxing glove	11.57	2.43	53.73[b]	15.35

* Means with the same superscripts are not significantly different ($p < .05$).

Results of the three studies, designed to determine selected impact characteristics of karate and boxing gloves, indicate definitive differences in glove performance. With similar fist velocities, high skill subjects were able to impart more momentum to the bag than intermediate or low skilled subjects. When boxing gloves were worn, the subjects transferred more momentum than when bare fisted, yet no difference was detected between mean scores of karate glove and bare fist or boxing glove conditions (See Table II).

DISCUSSION

This project was carried out to determine selected impact characteristics of karate and boxing gloves under conditions of subjects punching a bag. Subjects were comparable on height, weight, and age but the high skilled group had more years in training. The three skill levels were therefore comparable on the descriptive variables of age, height, and weight (See Table I.) such that these factors would not affect the results of the study.

No FV differences were found between skill levels or glove types. Nakayama's (1966) contention that velocity would increase as a function of skill level was not supported. These data agree with Smith (1977) who found an absence of velocity difference in relation to skill. Nakayama's (1966) highest skilled subjects nad higher fist velocities, 5.16 m/s, than intermediate and low skilled subjects when punching boards. Since Nakayama´s subjects were punching boards, high velocities would have been expected.

The type of punch used can make a difference in fist velocity. Subjects in this study used the counter punch as opposed to the straight punch and the stepping punch used by Nakayama (1966). He hypothesized that the stepping punch, by virtue of larger distance being covered, would have potentially higher velocites than other punch types. Again this contention was not supported. Mean values for the reverse punch was 11.5 m/s, somewhat higher than the average maximum stepping punch velocity, 10.4 m/s, of Nakayama´s (1966) subjects. The difference between the two punch types being hip rotation in the reverse punch versus the forward stepping action of the stepping punch would indicate subjects are able to rotate their hips faster than they step and thereby achieve comparable fist velocities. It was not surprising that fist velocity was higher, 11.5 m/s, in this study than reported by Walker (1975), 7 m/s, or Smith (1975), about 6 m/s, due to the number of degrees of freedom used in the respective punch types.

Bag momentum after impact did differ according to skill level and glove type. The high skilled group imparted more momentum to the bag than the lower two skill levels which did not differ. The boxing glove imparted more momentum to the bag than the bare fist, but not the karate glove, which imparted similar momentum levels to the bare fist condition.

Since BM was higher for the skilled punchers with no difference in punching velocities among skill levels, evidence exists that the high skilled subjects were better able to coordinate body momentum applied to the bag than intermediate

Table III
ANALYSIS OF VARIANCE FOR BAG MOMENTUM CRITERION

Source	df	SS	MS	F	p
Skill	2	4140.43	2070.22	4.34	0.038*
Subject (Skill)	12	5722.38	476.83		
Glove Type	2	1058.12	526.50	5.36	0.012*
Skill * Glove Type	4	189.91	47.48	0.48	0.748
Subjects * Glove Type (Skill)	24	2359.87	98.33		

*p < .05.

and low skilled subjects. This particular finding supports the concepts of focus and force summation such that body momentum concentrated at the fist can be learned in order to generate larger forces.

It was surprising to find the boxing glove transmitted more momentum to the bag than the bare fist. Possibly the cushioning effect of the gloves allowed subjects to punch harder since impact would be less painful to the puncher. Without the impending pain from impact as a constraint, the subject could feel freer to apply more momentum to the bag.

Assuming impact force for all glove conditions to be similar, another possible explanation for more momentum transfer would be that energy absorbed by the glove could be translated to the bag by an elastic effect. Force imparted to the glove would compress the materials in the glove which would tend to regain its original shape and, in that process, displace the bag in the same direction as the applied compression force from the fist.

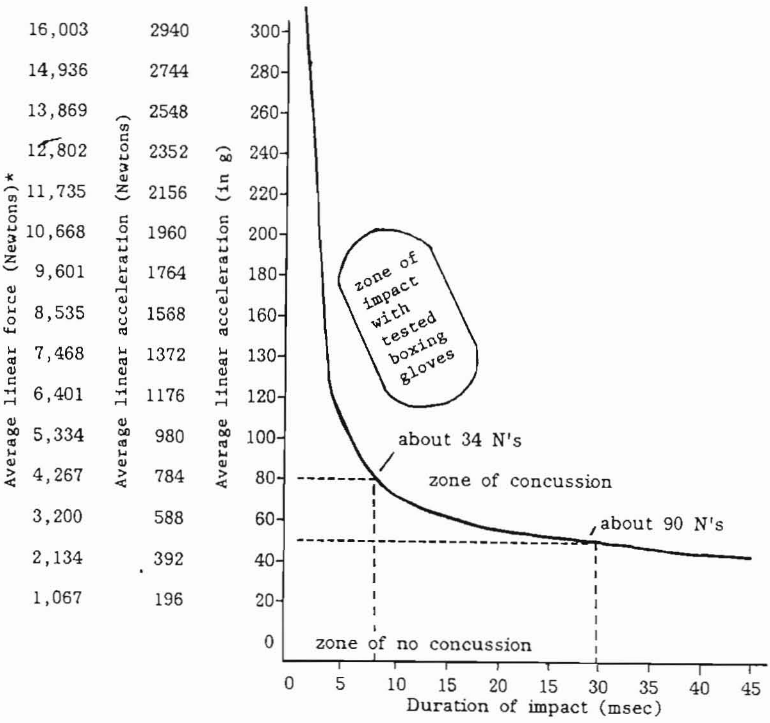

Figure 2. Human tolerance of concussion. Developed at Wayne State University by Hodgson and Thomas. (Courtesy of V.R. Hodgson)

* Adjusted for 5.44 kg mass.

Because BM was greater for high skilled subjects and for those with the boxing glove, with no interaction effect, either condition could potentially be more dangerous to a victim (See Figure 2.). The higher velocity of the bag is indicative of higher acceleration which is directly linked to brain and tissue injury (Kroell, et al., 1982; Hodgson and Thomas, 1981).

Punch velocities were similar to hammer fist strike velocities reported by Feld, McNair, and Wilk (1979) and higher than those estimated by Walker (1975) for the straight punch. Though Walker's (1975) 7 m/s punch was about average compared to Feld's, et al. (1979) range of 5.7 - 9.8 m/s, the present study revealed an overall average of 11.5 m/s -- 1.7 m/s faster than the highest score of that range. It is likely the values reported here are representative of the general population of karate reverse punches due to the hip's contribution to the movement.

That punch velocities were in the range of striking actions was not expected. The strike involves an angular line of force application similar to that of a baseball throw, whereas the punch, a thrusting action, applies force along a straight line of action. Higher velocities would be expected from the strike due to the longer moment arm and circular follow through characteristics.

The overall BM mean of 47.37 N-s was found to be similar to that calculated by Walker (1975). Using a 7 kg arm mass at 7 m/s, 49 N-s momentum was reported and with a 10 ms contact time, an average force of 4900 N was computed. Realistic contact times were not determined in the present study due to the compressions of the gloves and bag. However, overall BM average was comparable to that reported by Walker (1975).

Considering Walker's (1975) lower velocity value, either subjects in the present test used less mass than the 7 kg suggested or the calculated momentum levels would not be comparable. His results are based on the assertion that the mass of the arm, forearm, and hand be used in the kinetic calculations. With fist velocity at 11.5 m/s immediately prior to impact and resultant BM at 47.37 N-s, the mass striking the bag would be 4.1 kg. This is considerably less striking mass than that estimated by Walker (1975).

Hodgson and Thomas's (1981) statement that less mass would be involved in high energy impacts due to soft tissue distortion appears tenable. However, no other data is available to support this argument. The "distortion" hypothesis involves soft tissue being distorted in the opposite direction of the moving segment during a punch and, at impact, taking more time to travel toward the target than the halting effect of the impact. The resultant effect would be that the soft tissue mass would not be totally connected to the rigid skeletal force imparting structure and therefore would not be considered as part of the impacting mass.

Velocity and force ranges from the present study agreed with related literature on punching. Striking mass ranges were similar to those found by Smith (1977), 4 - 5 kg, and Plagenhoef (1971), 4.5 kg, though different from the 7 kg total arm mass suggested by Walker (1975). Subjects did not differ on FV at impact, but high skilled subjects transferred more momentum to the bag than intermediate and low skilled groups. In addition, more momentum was transferred with the boxing glove than bare fist condition. The karate glove did not differ from the other glove conditions.

In general, neither glove can be called "safe" for boxing or full-contact karate. With human punching capabilities, neither glove would prevent an opponent from being knocked out. However, the karate glove would have more effect in reducing breakage of bones and cartilage, especially after the first impact.

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