KARATE AND BOXING GLOVE IMPACT CHARACTERISTICS AS FUNCTIONS OF VELOCITY AND REPEATED IMPACT

Paul K. Smith
Department of Physical Education, Sport and Leisure Studies
Washington State University
Pullman, Washington 99164-1410

Joseph Hamill
Department of Physical Education
Southern Illinois University
Carbondale, Illinois 62901

The use of safety equipment in boxing dates back to the late 1800's and karate to the 1930's when efforts were made to offer safety to contestants, allow freedom of movement and allow participants to adhere to training and philosophical principles (Hassell, 1982).

Rules and procedures designed to avoid injuries and keep excitement in the activities have been established by various karate associations, boxing commissions, and sanctioning organizations. This concern for participant safety has resulted in the general use of foam karate gloves in non-contact and limited contact karate matches (Young, 1974) and the use of "professional quality" gloves in contact karate. "Professional quality", however is not defined. In boxing the type and weight of gloves used depends on the sanctioning organization and event (Dessureault and Therrien, 1981).

No studies are available on impact characteristics of foam karate gloves and few have addressed boxing gloves. Hodgson and Thomas (1981) compared the conventional boxing glove with the "thumbless" glove at sub-concussion and concussion levels of impact. They found considerable differences in acceleration and Severity Index values generated by boxers and mechanical impactors. At the lower force levels a 55% (129 to 58 S. I.) difference between the "Thumbless" and conventional boxing gloves was found favoring the "Thumbless" glove. This difference was reduced to 19% (1650 to 1340 S. I.) at the concussive level. If both gloves bottomed out, their energy absorption would be essentially the same. Differences in response characteristics were found with respect to repeated impacts of these glove types.

Dessureault and Therrien's (1981) findings did not support those of Hodgson and Thomas (1981) when gloves of differential weights were compared. In a report to the Canadian government they noted a wide disparity of response and weight characteristics for conventional gloves of several "supposedly" specific weight classifications. When tested for repeated impact these researchers found substantial impact attenuation decrements. This study further related that gloves have been used for up to 100 matches.

Foam karate gloves are used extensively by millions of karate students and little is known about their safety characteristics. Two studies were therefore designed to compare the foam Karate Glove and the conventional Boxing Glove on the selected impact characteristics of peak force, time to peak force, average force, and impulse at differential velocities and with repeated impacts.

METHOD: STUDY 1

STUDY 1 was designed to determine the effect on selected kinetic parameters of impact with the Karate Glove and Boxing Glove at specific velocities using a mechanical impactor to eliminate mass variations due to human physical interactions. A 2 X 5 design with Multivariate Analysis of Variance and Duncan's Range Test followup procedure was used to analyse data.

The gloves (See Figure 1) used for comparison were an Everlast brand Model 2210 Official A.A.U. boxing glove and a Pro brand karate glove. Padding in the boxing glove consisted of a layer of hair sandwiched between two layers of open cell foam covered with a leather sheath. At the impact area the glove was approximately 4 cm thick. 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 to 3 lb/cu ft. At the impact surface the karate glove was 3 cm thick.

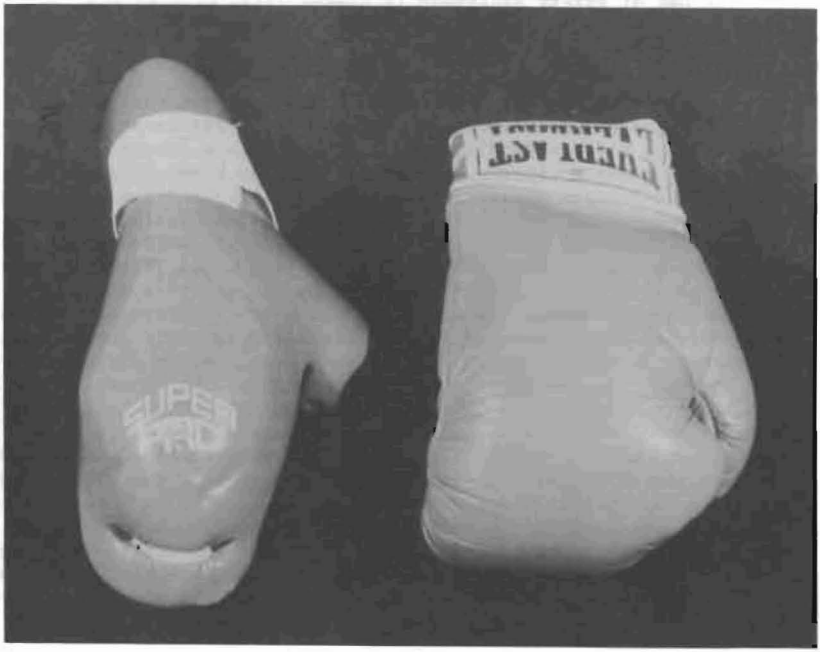

Figure 1. Karate glove and boxing glove.

Gloves were fitted over a Red Oak Fist with an 8.98 sq cm surface area which was mounted on a specailly built impact device (See Figure 2.).

Figure 2. Glove testing apparatus.

The impactor consisted of a total mass of 4.71 kg and was directed perpendicular onto a computerized AMTI force plate by sleeves on the vertical guides. Velocity was changed by changing the height of release of the gloves. Gloves were dropped in random order at 0.5, 1.0, 1.5, 2.0, and 2.5 m/s velocities; the range of which yielded impulses on the force plate approximating the lower range of momentum generated by karate punchers (Smith, 1984). Three trials for each Glove Type and Velocity condition were recorded and averaged for the analysis.

RESULTS AND DISCUSSION: STUDY 1

Significant effects were found for Glove Type, Velocity, and the Glove Type-Velocity interaction. Table I. presents the means and standard deviations of the kinetic parameters by Glove Type. The Boxing Glove had higher peak forces, longer time to peak force, and lower impulse scores than the karate glove. There was no difference in average forces. The significant interaction effects are discussed as the graphed scores are presented.

Table I.

MEANS AND STANDARD DEVIATIONS OF KINETIC PARAMETERS BY GLOVE TYPE

Variable		Karate Glove	Boxing Glove	F-ratio
Peak Force (N)	$\overline{X}$	1212.977[a]	1530.499[b]	29.73*
	SD	962.823	1345.079	
Time to peak (s)	$\overline{X}$	0.016[a]	0.019[b]	10.17*
	SD	0.003	0.006	
Average force (N)	$\overline{X}$	426.900	440.296	0.29
	SD	242.348	340.493	
Impulse (N's)	$\overline{X}$	25.251[a]	23.984[b]	20.22*
	SD	9.741	8.595	

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

Table II.

MEANS AND STANDARD DEVIATIONS OF KINETIC PARAMETERS BY VELOCITY

Variables		0.5 m/s	1.0 m/s	1.5 m/s	2.0 m/s	2.5 m/s	F-ratio
Peak Force (N)	$\overline{X}$	369.928	379.140[a]	1007.663[b]	1767.273[c]	3334.675[d]	361.63*
	SD	21.927	63.705	162.752	286.908	585.012	
Time to Peak Force (s)	$\overline{X}$	0.021	0.022[a]	0.016[b]	0.014[b]	0.012[c]	61.89*
	SD	0.001	0.005	0.001	0.001	0.001	
Average Force (N)	$\overline{X}$	165.617	176.737[a]	360.412[b]	563.008[c]	902.217[d]	120.62*
	SD	13.885	41.774	18.276	32.447	174.980	
Impulse (N's)	$\overline{X}$	14.932	15.867[b]	23.550[c]	30.590[d]	38.148[e]	983.58*
	SD	0.152	1.484	0.794	1.238	1.492	

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

Table II. presents means and standard deviations of the kinetic parameters by velocity. Peak and average forces were not different at the lower two velocity levels and were different thereafter. Time to peak force differences were present between the 1.0 to 1.5 m/s level and between the 2.0 and 2.5 m.s velocities. Impulse displayed significant differences among all velocity levels. It should be stressed that the higher impact levels from this study were equivalent to the lower momentum extimates from the punch studies, which was about 40 N-s. Values from this study must therefore be consisered conservative in terms of actual forces that could be applied by higher skill evel punchers.

Figure 3. displays peak force as a function of velocity. The significant interaction effect can be noted as the Boxing Glove and Karate Glove curves diverge with the increase in velocity. After the 1.5 m/s velocity the Boxing Glove had increasingly larger peak force values than the Karate Glove.

Time to peak forces generally dropped with the initial velocity increase and then leveled off.

Time to peak force as a function of velocity is presented in Figure 4. and it is clear that the Karate Glove had a smoother reduction in time to peak force than the erratic Boxing Glove values.

Average forces over the total contact time were higher for the Karate Glove through the 2.0 m/s velocity (See Figure 5.). After this point the Boxing Glove values surpass those of the Karate Glove.

From Figure 6. it can be seen that impulse displayed different patterns than peak force and average force as demonstrated by the Karate Glove having higher values than the Boxing Glove. The Boxing Glove generally had higher values on the force variables. With impulse the Karate Glove had increasingly higher values with the increase of velocity.

Foam, as opposed to hair padding in the boxing glove, has the ability to trap air within the cells and hold it under higher loads. Hair must rely on resistance to compression and density as the force absorption factor, whereas the foam in the Karate Glove would have these qualities plus a bubble effect. The cushioning effect of an inflated versus a deflated automobile tire would be a comparable analogy of this principle and would help explain the value differences between the two peak force curves.

Because peak force for the boxing glove was higher, it would tend to cause more danger to hard tissues such as bone or cartilage found in the hand, nose, and jaw. The erratic time to peak force values for the Boxing Glove at the 1.0 m/s velocity was probably caused by irregular collapsing of the hair materials during the loading process and air escaping the leather sheath of the glove. Multiple interaction effects are demonstrated by the divergence and convergence of scores for the gloves with the increase of velocity.

Since these values are conservative with respect to actual punch forces, the continuation of this trend of the Boxing Glove to progressively demonstrate higher average forces than the Karate Glove would indicate the Boxing Glove to present greater danger of injury because of the greater forces transmitted. These high forces would be particularly injurious to hard tissues. For less rigid surfaces such as the abdomen, it is not clear exactly what the effects would be since the area of impact has considerable effect injury outcome. Birrer and Birrer (1981) and Schmidt (1975) did find severe and critical injuries from punches to the abdomen.

At higher velocities the Karate Glove spread the forces over a longer time period. Average force would tend to be higher for short contact time durations and impulse would tend to be higher for longer contact times. While the Boxing Glove transfers less momentum, it transmitted higher peak forces. This finding indicates the Boxing Glove to be more likely to damage hard tissues where less contact time is needed, but the Karate Glove would tend to cause a greater acceleration of an impacted object.

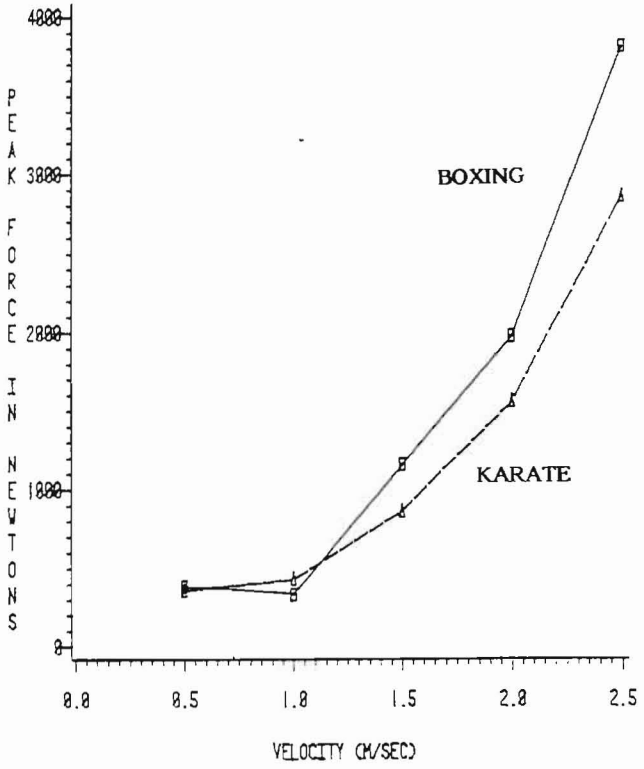

Figure 3. Peak force as a function of impact velocity.

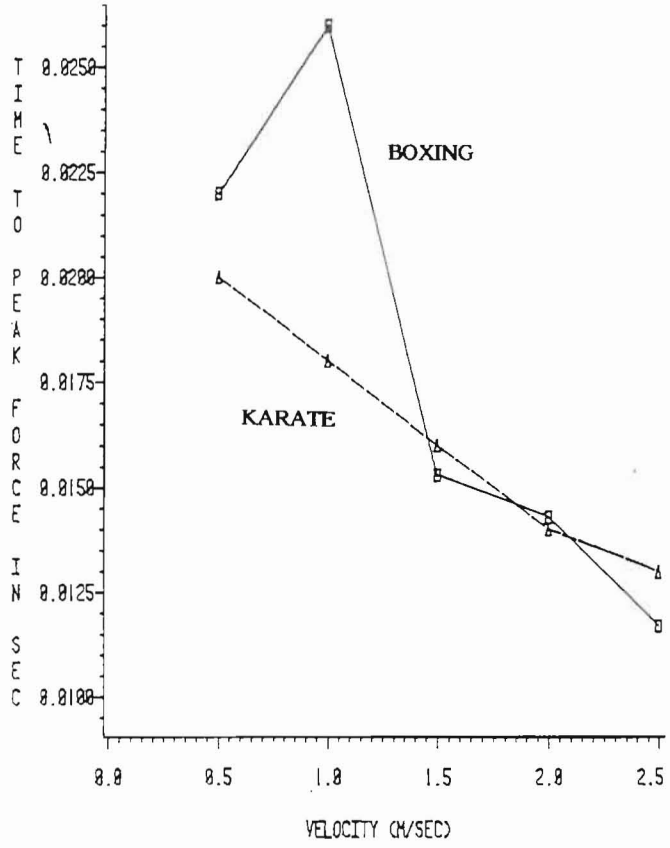

Figure 4. Time to peak force as a function of impact velocity.

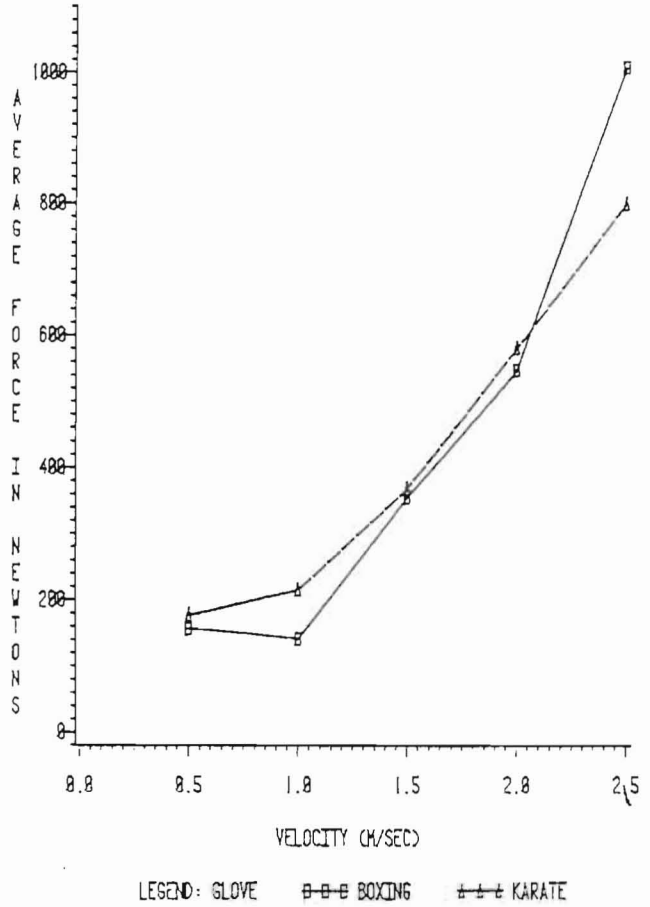

Figure 5. Mean force as a function of impact velocity.

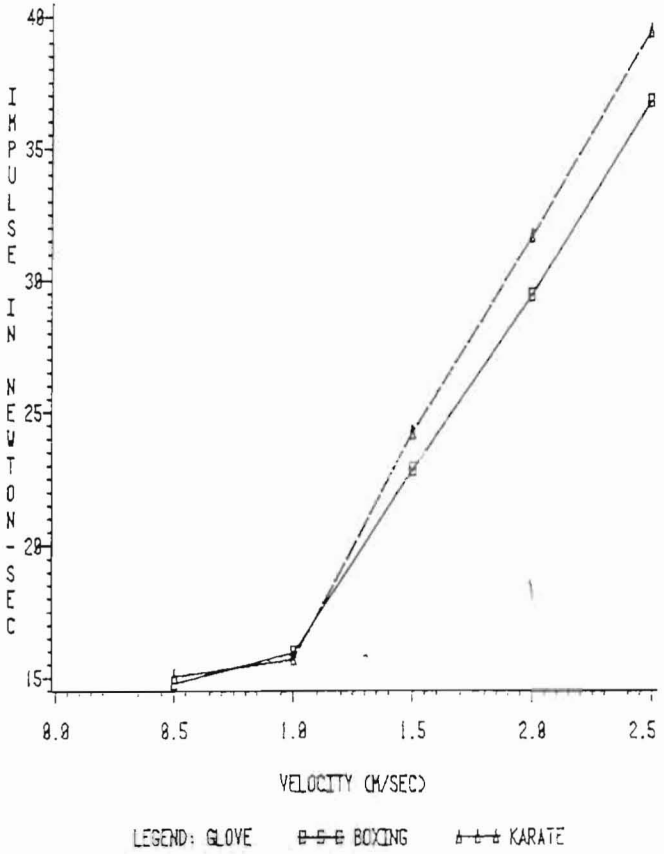

Figure 6. Impulse as a function of impact velocity.

METHOD: STUDY 2

STUDY 2 was designed to determine the general trends of the kinetic parameters across 50 impact trials using a virgin glove. The apparatus used in the previous study was used in this analysis. Fifty impact trials were administered to each glove type at 2.0 m/s velocity and data were recorded the first and every fifth trial thereafter such that 11 trials were analysed. Fifty impact trials is the approximate number of blows in one round of boxing. Trend Analysis for simple linear, quadratic, and cubic effects were used to detect the presence of gross trends across the 50 impact trials.

RESULTS AND DISCUSSION: STUDY 2

For peak force, as represented in Figure 7., the R^2 was .78 for the Boxing Glove and .70 for the Karate Glove. The slope for the Boxing Glove was 3 times that of the Karate Glove (108.43 to 36.44 N, respectively). The sharp rise from the 1st to the 5th trial indicates the initial collapsing and air escapement from the materials. With the Boxing Glove this effect was greater as forces rose much quicker for that number of impacts. Both glove types began to level at the 15th impact, but by the 50th trial the Boxing Glove peak force had risen 96% from 1,483.95 to 2,913 N. The consistency of the Ensolite was evidenced by the Karate Glove's values rising only 27%, from 1,626 to 2,078.74 N.

Time to peak force decreased for both glove types to the 15th trial and stabilized with 1 ms difference (See Figure 8.). The linear R^2 was .60 for the Karate Glove and .41 for the Boxing Glove. The initial sudden drops for both glove types, especially the Boxing Glove indicate a rapid decrease in the ability to distribute forces over time. For the Boxing Glove this drop may also indicate a collapse of the hair and expulsion of air from the leather sheath.

For average force values (See Figure 9.) the Boxing Glove R^2 was .81 and it was .68 for the Karate Glove. The slope for the Boxing Glove was 6 times that of the Karate Glove (39.16 to 5.73 N, respectively). The Boxing Glove started out at just over half the average force of the Karate Glove, but by the 20th trial had surpassed the highest Karate Glove average force level. By the 50th trial the Boxing Glove average force had risen 118%, from 370.20 to 806.33 N, while the Karate Glove force had risen only 12%, from 579.79 to 649.40 N. With impact forces from this test, the Boxing Glove would attenate forces below the concussion level only on the first few impacts. After the first 5 blows, impacts using either glove type would be within the zone of concussion which is about 588 N with a 26 ms contact time. However, the Boxing Glove would be 'further inside the zone. It should be remembered that these are very conservative applied loads in relation to those of capable punchers. Mechanical impact velocities in these studies ranged from about 8 to 21 percent of velocities generated by human punchers. The 4.71 kg mass of the impactor corresponds to both the striking mass levels used in previous studies and the mass of the human head (Smith, 1984; Plagenhoef, 1971).

Because the forces had rising functions and the impulse was constant, the contact time relationship was important. Since average force rose for the Boxing Glove, the chance of hard tissue damage would be greater for the Boxing Glove with repeated impacts. Because impulse was constant, the acceleration of an impacted object such as the head would be within a comparatively stable range for specific impact levels with the Karate Glove. This data 'does not support the findings of Hodgson and Thomas (1981), who found no trends for repeated impact with boxing gloves for kinetic energy, acceleration, or the Severity Index.

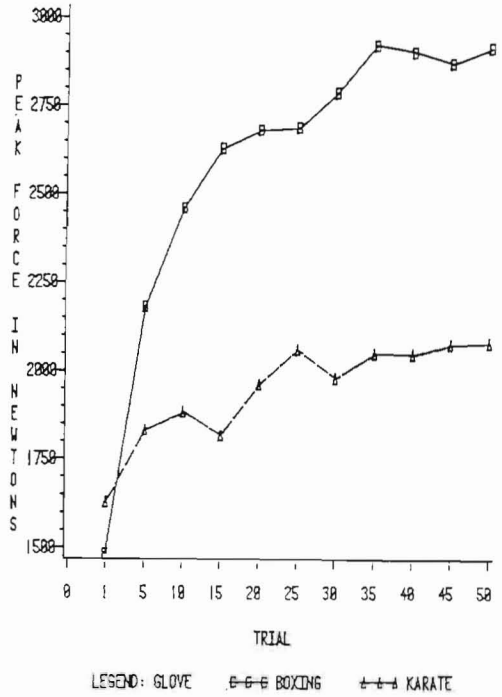

Figure 7. Peak force as a function of repeated impact.

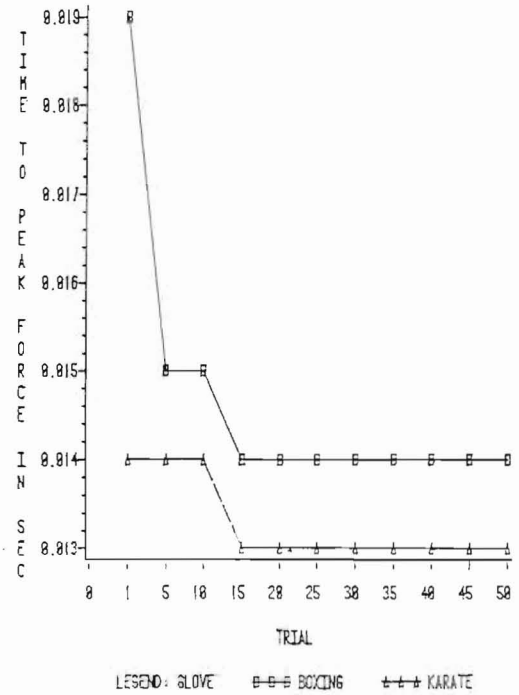

Figure 8. Time to peak force as a function of repeated impact.

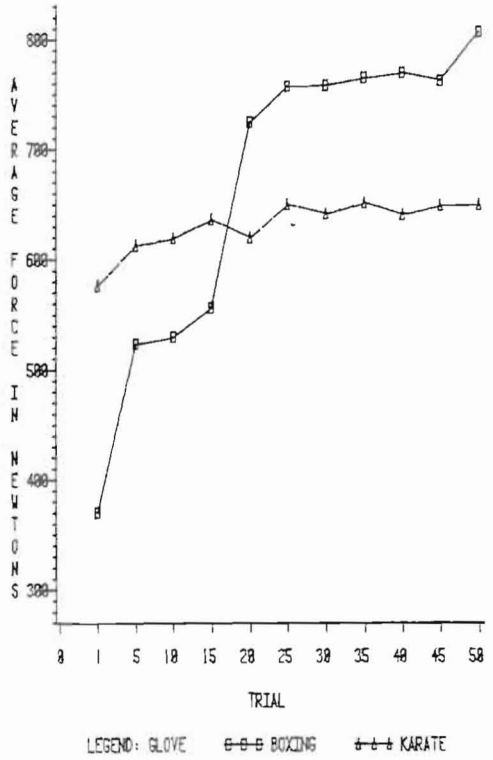

Figure 9. Average force as a function of repeated impact.

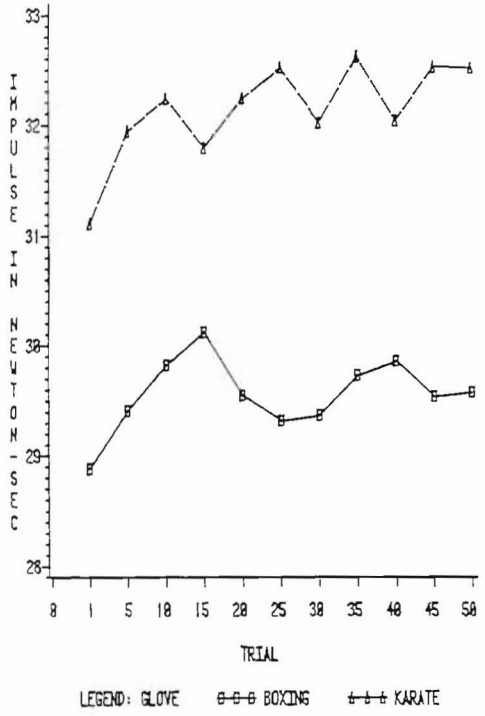

Figure 10. Impulse as a function of repeated impact.

Considering the lowest time to peak force was greater than 10 ms and the curves were fairly symmetrical, the contact time would be on the order of 26 to 28 ms, minimum. Forces greater than about 588 N applied for 26 to 28 ms would be within the zone of concussion. In the first study, only the 2.0 and 2.5 m/s velocity impacts would be comparable to the force ranges generated by the lowest skilled punchers. Average forces crossed the demarcation line at about 2.0 m/s velocity to indicate concusssion level impacts could easily be generated. From the latter study this level of force, 588 N, was surpassed between the 1st and 5th impacts for both glaove types though the Boxing Glove forces rose much higher across the 50 trials.

Data from this project infers that very low skilled punchers could readily deliver concussion level blows while wearing either the Boxing or Karate Glove and that even with blows of comparatively low forces the gloves would offer little protecton after the first few impacts. Neither the Boxing Glove or the Karate Glove can be considered "safe" in terms of protection from concussion. The Boxing Glove is more likely to permit hard tissue damage by virtue of its higher forces transmitted and the Karate Glove would more likely permit concussions as determined from the higher impulse levels.

REFERENCES

Birrer, R.B. & Birrer, C.D. (1985, June). Martial arts injuries. Physician and Sportsmedicine. 10(6), 103-104.

Hassell, R.G. (1982). Conversations with the master; Masatoshi Nakayama. St. Louis: Focus Publications.

Hodgson, V.R. (1981, November). Boxing gloves compared using dummy head acceleration response. (Report to the New York Athletic Commissioner).

Dessureault, J. &Therrien, R.G. (1981). Energy absorption and force transmission characteristics of boxing gloves. In Regie de la securite dans les sports. Professional Boxing in Quebec: a study. (pp 86-99). Quebec: Government of Quebec.

Moore, M. (1983, January). A pall over boxing. Physician and Sportsmedicine, 11(1),21.

Plagenhoef, S. (1971). Patterns of human motion: a cinematographical analysis. Englewood Cliffs, N.J.: Prentice-Hall.

Schmidt, R.J. (1975, Spring). Fatal anterior chest trauma in karate training. Medicine and Science in Sport, 7, 59-61.

Smith, P.K. (1984). Selected impact characteristics of karate and boxing gloves. Doctoral dissertation, Southern Illinois Univaersity, Carbondale, Illinois.

Young, J. (1974, February). Contact karate tournaments: will they separate the fighters from the actors. Black Belt Magazine, 12(2), 14-19.