TRANSMISSION OF FORCE THROUGH THE KARATE, BOXING, AND THUMBLESS BOXING GLOVE AS A FUNCTION OF VELOCITY

Paul K. SMITH

Department of Physical Education
West Chester University
West Chester PA 19383

Two studies were designed, using Smith and Hamill's (1985) protocol, to compare the foam Karate Glove, the conventional Boxing Glove, and the Thumbless Glove on 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 to determine the effect on selected kinetic parameters of impact with the Karate Glove, the Boxing Glove, and the Thumbless Glove at specific velocities using a mechanical impactor to eliminate mass variations due to human physical interactions.

A 3 * 5 design with Multivariate Analysis of Variance and Duncan's Range Test followup procedure was used to analyse the data. Gloves were fitted over a Red Oak fist with an 8.98 sq cm surface area which was mounted on a specially built impact device.

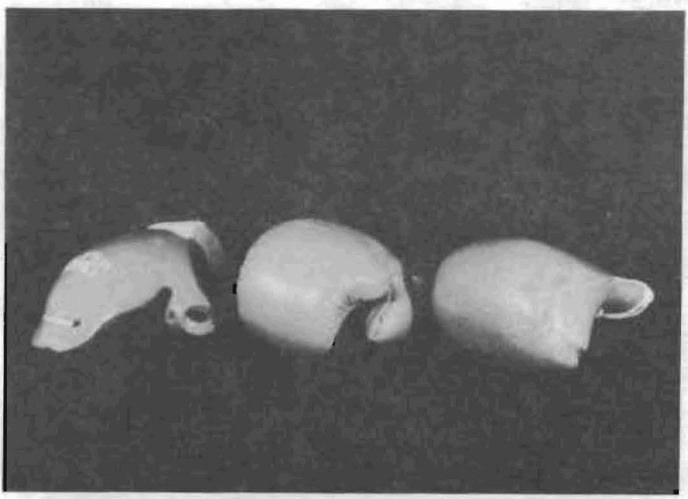


Figure 1. Karate, boxing, and thumbless glove.

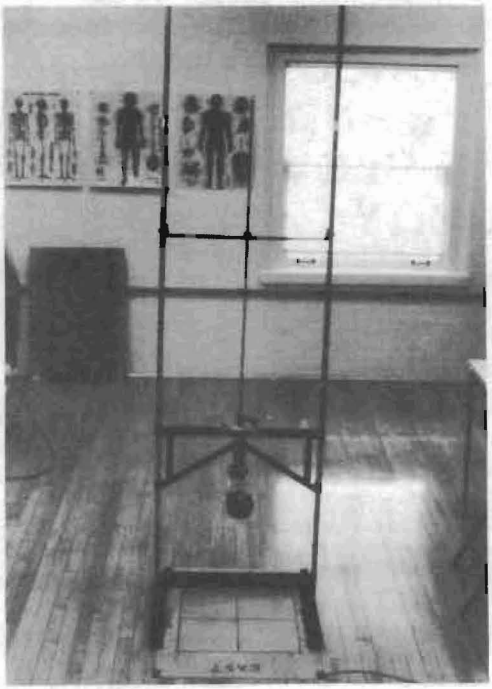


Figure 2. Apparatus layout for Study 1.

RESULTS AND DISCUSSION: STUDY 1

Significant effects were found for Glove Type, velocity, and the Glove Type-Velocity interaction.

TABLE I
MEANS AND STANDARD DEVIATIONS OF KINETIC PARAMETERS BY GLOVE TYPE

Variable		Karate Glove	Boxing Glove	Thumbless Glove	F-ratio
Peak Force (N)	X	1212.977[b]	1530.499[a]	1180.711[b]	22.35*
	SD	962.823	1345.079	1020.128	
Time to Peak Force (s)	X	0.016[b]	0.019[a]	0.018[a]	8.38*
	SD	0.003	0.006	0.004	
Average Force (N)	X	426.900[a,b]	440.296[a]	385.893[b]	3.67*
	SD	242.379	340.493	247.455	
Impulse (N-s)	X	25.251[a]	23.984[b]	23.818[b]	20.59*
	SD	9.741	8.585	8.652	

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

The Boxing Glove had higher peak force, longer time to peak force, and lower impulse scores than the Karate Glove. There was no difference between the Boxing Glove and Karate Glove with respect to average force.

Peak and average forces were not different at the lower two velocities but 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 estimates from the punch studies, which was about 40 N-s. Values from this study must therefore be considered conservative in terms of actual forces that could be applied by higher skill level punchers.

TABLE II
MEANS AND STANDARDS OF KINETIC PARAMETERS BY VELOCITY

Variable		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)	X	355.221[a]	391.786[a]	926.353[b]	1651.137[c]	3215.810[d]	506.84*
	SD	28.945	54.274	179.626	292.586	520.990	
Time to Peak Force (s)	X	0.021[a]	0.021[a]	0.016[b]	0.015[c]	0.012[d]	105.20*
	SD	0.002	0.004	0.001	0.001	0.001	
Average Force (N)	X	156.047[a]	178.881[a]	341.650[b]	550.500[c]	861.404[d]	237.13*
	SD	18.826	33.43	32.790	34.787	151.891	
Impulse (N-s)	X	14.786[a]	16.034[b]	23.061[c]	30.081[d]	37.792[e]	1890.54*
	SD	0.254	1.203	0.982	1.260	1.333	

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

The significant interaction effects were noted as the peak force curves diverge with the increase of velocity (Figure 3.). After the 1.5 m/s velocity the Boxing Glove had increasingly larger peak force values than the Karate Glove and Thumbless Glove.

At higher velocities the Karate and Thumbless Gloves 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 Gloves would tend to cause a greater acceleration of an object at the tested impact levels. It is important to keep in mind that only relatively low impact forces were used in this study.

METHOD: STUDY 2

STUDY 2 was to determine the general trends of the kinetic parameters across 50 trials using virgin gloves. The apparatus use 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 impacts is the approximate number of blows in one round of boxing. Trend analysis for linear, quadratic, and cubic effects were used to detect the best fit across the 50 impact trails.

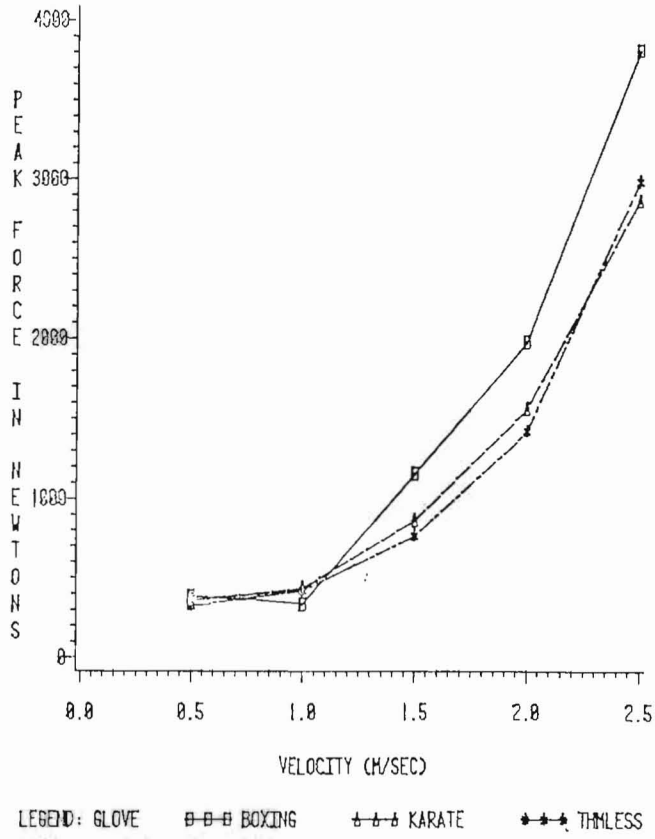


Figure 3: Peak force as a function of velocity for karate, boxing, and thumbless gloves.

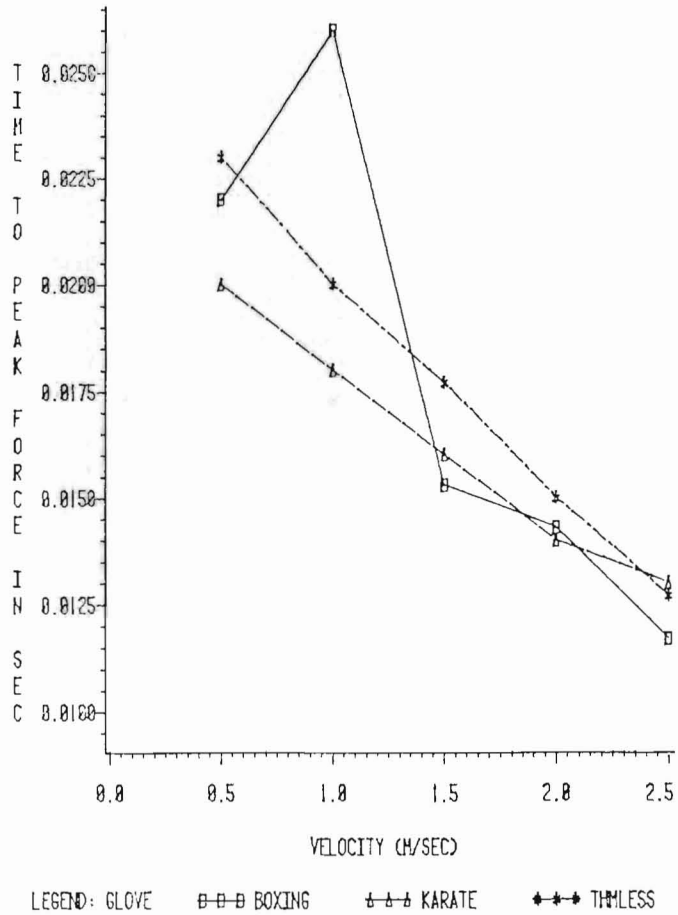


Figure 4: Time to peak force as a function of velocity for karate, boxing, and thumbless gloves.

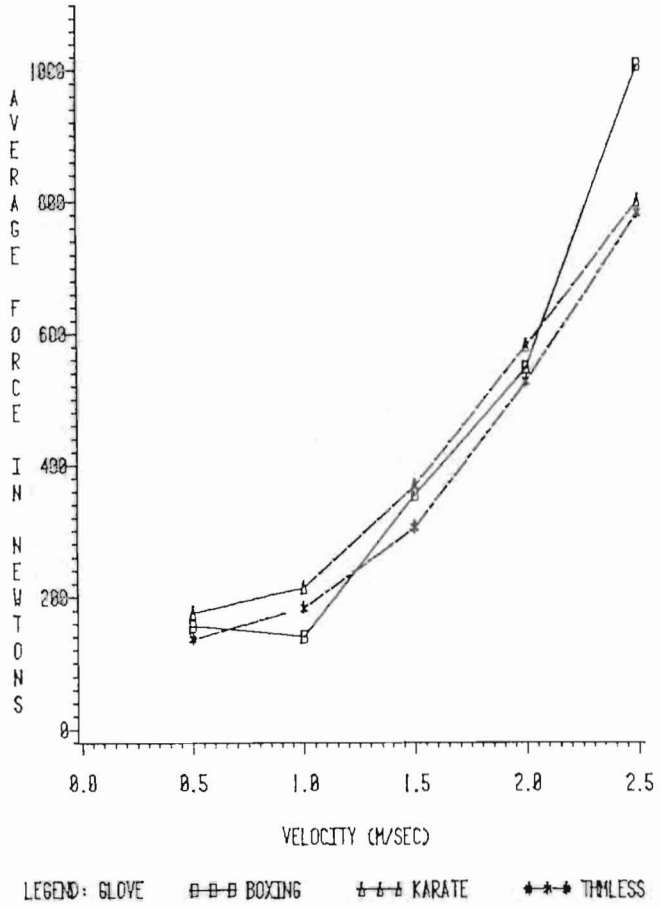


Figure 5: Average force as a function of velocity for karate, boxing, and thumbless gloves.

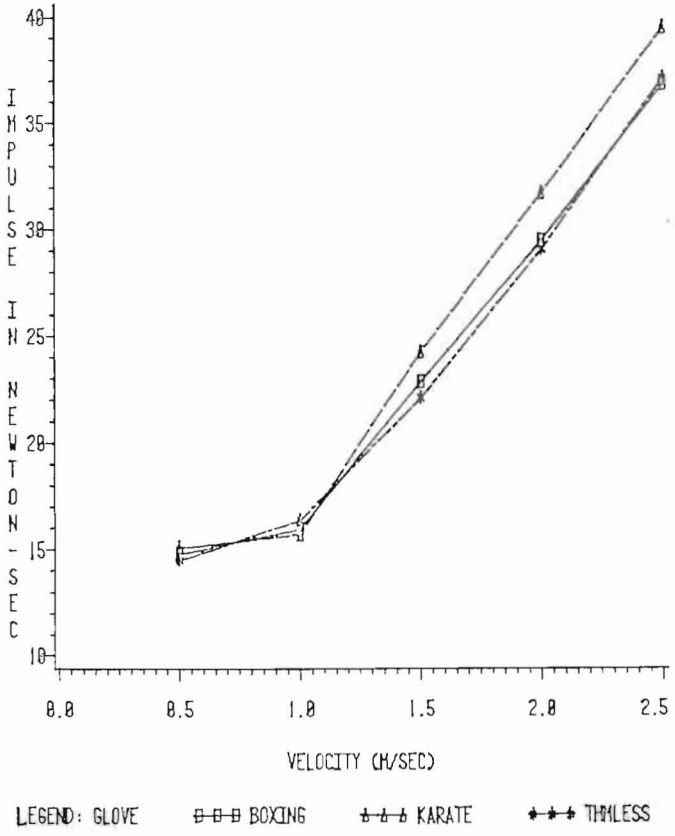


Figure 6: Impulse as a function of velocity for karate, boxing, and thumbless gloves.

RESULTS AND DISCUSSION: STUDY 2

Peak force, time to peak force, average force, and impulse variances were accounted for better with the linear function than quadratic or cubic functions. An exception was the impulse variable for the Boxing Glove in which no significant trend was found. The presence of higher order trends indicated a complex phenomena took place. However, since only one glove of each type was tested, results will be reviewed from a more practical than statistical perspective.

For peak force the R^2 was .81 for the Thumbless Glove, .78 for the Karate Glove, and .70 for the Boxing Glove. The slope for the Boxing Glove was 3 times that of the Karate Glove, which in turn was about 3 times that of the Thumbless Glove (108, 36, and 13, respectively). A sharp rise from the 1st to the 5th trial probably indicated the initial collapsing and air escapment from the materials. With the Boxing Glove this effect was greater as forces rose much quicker for that number of impacts. All glove types had leveled at the 15th impact, but by the 50th trial the Boxing Glove had risen 96%, from 1,484 to 2,913 N. The consistency of the Ensolite was evidenced by the Karate Glove rising only 27%, from 1,626 to 2,078 N. The hair-foam composition of the Thumbless Glove was even more consistent rising only 12%, from 1,069 to 1,196 N.

For average force R^2 values were .81 for the Boxing Glove, .73 for the Thumbless Glove, and .68 for the Karate Glove. The slopes were 39.16, 5.73, and 5.15 respectively for the Boxing, Karate, and Thumbless Gloves. While the Boxing Glove started at just over half the average force transmitted by the Karate glove, it had surpassed the foam glove by the 20th trial. The Thumbless Glove values remained consistent at a level of about 450 N.

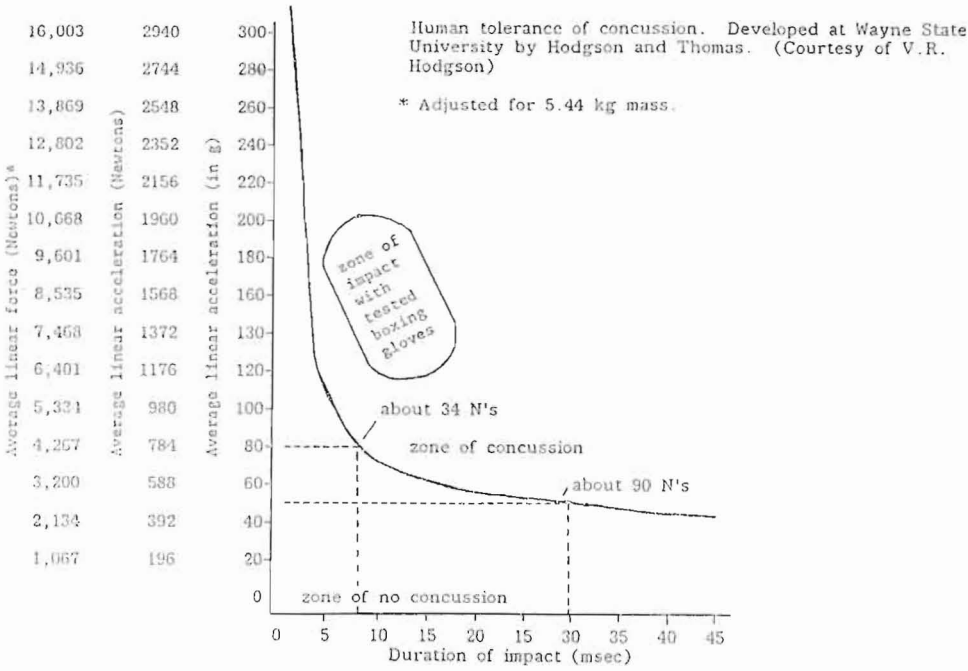
By the 50th trial the Boxing Glove average force had risen 118%, from 370.20 to 806.33 N, while the Karate Glove values rose only 12%, from 579.79 to 649.40 N. The Thumbless Glove average force increased 14%, from 422.11 to 479.45 N.

Impulse slopes for all glove types were practically horizontal 0.03, 0.09, and 0.11, respectively, for the Boxing, Karate, and Thumbless Gloves. Thumbless Glove impulse rose 4%, from 27.88 to a maximum of 28.98 N-s. The Karate Glove values only rose 4%, from 31.22 to 32.22 N-s and the Boxing Glove values only 2%, from 28.88 to 29.58 N-s.

With impact forces from this test, the Boxing Glove would attenuate forces below the concussion level only on the first few impacts. After the first 5 blows, impacts using either the Karate or Boxing Gloves would be within the zone of concussion, which is about 588 N with a 26 ms contact time for a unit mass. However, the Boxing Glove would be further inside the zone. The Thumbless Glove would be just barely below the concussion cutoff level.

Again, 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 the velocities generated by human punchers. The 4.71 kg mass of the impactor corresponds to both the striking masses used in previous studies and the mass of the human head (Smith and Hamill, 1985).

None of the glove types tested could be considered "safe" in terms of protection from concussion, though the Thumbless Glove appears to offer more of a safety factor than the others and should be employed for both partner training and competition. 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, whereas the Thumbless Glove seems to combine the advantages of force and impulse attenuation at the impact levels tested.



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