A Pilot Study of Kinetic Energy Transfer Based Upon Police Baton Designs

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Introduction

For the past several decades, law enforcement technology has seen major advances. Technology such as the advent of the radio has shaped the very nature of how police respond to calls for service. The introduction of high-powered ammunition, rifle rounds, and large capacity magazines that are available to the public has resulted in law enforcement reacting with more advanced bullet-resistant vests, which are lighter and created from technologically superior materials. Chemical agents, once available only to the military, are now standard issue to almost all law enforcement officers in the United States. Although the chemical composition, strength, and propellants have changed, the basic principle of a chemical weapon remains the same.

Another very recent technological advancement has been the almost universal adoption of conducted energy weapons (CEWs) which are also referred to as electro-muscular disruption devices (EMDs). These less-than-lethal tools include the popular TASER®, which functions by discharging two probes that are connected to the weapon by thin wire tethers which allow a current to pass from the TASER® to the subject. This current disrupts the body's ability to pass electrical impulses and is therefore incapacitating.

However, despite these advances in technology and in many other areas, law enforcement officers still have much more rudimentary tools on their duty belt. The most simple, and likely the most archaic, is the police baton. Modern styles of police batons are significantly different when examined closely, including major differences in composition, size, weight, feel, and grip. These differences, when taken into consideration with all the potential physical and biological differences that can occur between law enforcement officers, can result in a significantly different level of police use of force despite the attempt at standardization. Little research into these differences has been conduced, and any research into this phenomenon is certainly dated. The following is a review of the literature on police batons, and the mathematics of force and force transfer.

Literature Review

Impact weapons, such as clubs, sticks, and stones, are perhaps the earliest and most simplistic form of weaponry. Man has used clubs as defensive as well as offensive weapons to kill not only game and prey but other humans as well. Archeologists have discovered clubs dating back as far as 35,000 BC that were predominantly used as hunting tools (Dupuy, 1990). Traditionally, clubs were crafted from a single piece of wood and were designed to be maneuvered and controlled with a single hand. Throughout history, they have been some of the most employed weapons.

Not only has prehistoric man used clubs effectively, but, historically, they have also been employed by law enforcement. Billy clubs, truncheons, and straight wood batons have been utilized for hundreds of years by police officers around the world. Military and law enforcement applications of these simplistic weapons have remained virtually unchanged. The most modern advancement in the field of baton design came in the early 1990s with the introduction of new composite materials as well as telescopic and side-handled batons. Expandable batons are designed to be collapsible for storage and extended as the user needs. The PR24 side-handled baton is simply a composite straight baton with a perpendicular grip on one side creating a 90-degree angle to the straight baton.

The science of law enforcement has shaped the tools and procedures used to serve and protect populations all around the world. As technology has evolved, we have seen the introduction of weapons that were considered fiction a decade ago. However, some literature suggests that these advances have come at a price. According to the Potomac Institute for Policy Study (2005), there exists statistical evidence demonstrating that as a result of the introduction of CEWs, such as a TASER®, law enforcement officers are becoming complacent and lack the skills to effectively conduct close quarters defensive and offensive tactical moves.

While there are an immeasurable number of potential use-of-force scenarios, it is clear that there are instances in which an impact weapon may serve an officer better than the latest electronic weapons technology. This is especially true when a risk of hitting innocent bystanders exists or the subject is wearing clothing that would resist the penetrating barbs of a CEW. In addition, an increasing phenomenon encountered by police and law enforcement is subjects wearing body armor. In these situations, a CEW would not be effective; however, blunt force to an exposed area of these individuals may be.

Mathematically, there are several factors which influence a baton's level of force transfer and, therefore, its resulting effectiveness. The kinetic energy potential of a baton depends on its weight and speed of swing. However, heavy objects tend to move slower than light ones and are more cumbersome to deploy. To calculate the force of a baton strike, the velocity of the impacting end of the baton is multiplied in proportion to the increase in its distance from the pivoting body parts such as the pelvis, shoulder, elbow, and wrist (Crosby, 2002).

Highly visible nightsticks and side-handled batons carried on the police officer's belt seem to have gone out of style and have been replaced with smaller, expandable batons which have a more positive public perception and are easier to carry (Johnson, 1996). The new structure of these common impact weapons may also have increased the baton's effectiveness. Gervais, Baudin, Cruikshank, and Dahlstedt (1997) found that a 26-inch ASP® expandable baton created more impact pressure than a traditional full-size baton. The study futher indicated that the ASP® expandable baton is much lighter and easier to carry than the traditional baton. Research conducted by Mesloh, Henych, Hougland, and Thompson (2005) found that the newest generation of batons has now added an enlarged plastic tip, which creates a larger amount of kinetic energy in the strike, consequently making the weapon more effective.

Due to advances in medical knowledge concerning the human body, law enforcement officers now have increased access to information on pressure points, nerve clusters, and fluid shock from strikes. Therefore, when properly trained, law enforcement officers are more cognizant of how these factors influence the body's weaknesses and thus have a better understanding of how to control a person. Consequently, batons are now designed to be extremely effective and a more precise tool for law enforcement officers. One recent change to the modern baton is its basic construction as they are no longer fashioned from a single piece of hard wood. New materials such as aluminum, nickel, and hard plastics comprise a majority of these less-than-lethal weapons. Varying the materials of the baton directly impacts the key issue of weight.

In addition to weight reduction, the ability to reduce size has also become a key feature of the newer batons. This reduction is accomplished by collapsing two or three inner shafts that lock into place when expanded. Traditional batons and truncheons are between 21 and 26 inches in length, while modern collapsible batons expand to that length from 7 to 10 inches in their collapsed state. An examination of the existing and anecdotal literature suggests that while it may appear docile and underpowered in the collapsed state, it commands respect and often gains psychological compliance when expanded, even before it is ever utilized.

Law enforcement personnel commonly cite weight and size as negative factors that influence their decision to carry a baton on their duty belt. While 10% of officers reported carrying the heavy wooden baton or truncheon at all times, 95% of officers surveyed reported that they carried a lighter and collapsible ASP® baton at all times (Johnston, 1990). Manufacturers such as ASP® and Monadnock® market their batons to the general policing population; however, the more modern collapsible batons have become an effective alternative less-lethal weapon to undercover officers or those who do not wear traditional police uniforms (Gervais et al., 1997).

While impact weapons have become lighter and easier to carry, they still have the ability to deliver an effective amount of force. In a study conducted to determine the impact characteristics of modern batons, it was concluded that the amount of energy exerted by the ASP® and ESHB (expandable side-handled baton) were relative to the amount of energy produced by the traditional wooden truncheon (Gervais et al., 1997). However, Roberts, Nokes, Leadbeatter, and Pike (1994) found that the peak pressure of modern batons, obtained by calculating the impact size area, were considerably higher than traditional batons. This study compared the standard wooden truncheon that was being used in the United Kingdom with the baton that was being used in the United States and other European countries. The study found that the traditional truncheon's impact area was nearly double (196%)

that of the expandable ASP® baton. The data set showed a greater tendency toward extended areas of bruising with the traditional truncheon or baton upon impact, while the impact area of the ASP® was smaller and thus produced less bruising.

This research conducted by Roberts et al. (1994) also claimed that the average traditional police baton produced 3,513 newtons (N) of energy while the new ASP® batons only produced 3,230 N of energy. While the traditional baton produced over 1.096 times the energy, it did not sustain that maximum amount of force for the same length of time. The newer ASP® models were found to exert their pressure on a continuous level for longer periods of time, thus allowing for a higher amount of kinetic energy transfer.

Currently, many agencies choose to take a "one size fits all" approach in issuing impact weapons to their officers. However, the researchers of this current study originally hypothesized that it is an individual science to determine which baton best fits each officer. This is accomplished by determining which baton generates the greatest amount of energy and assigning that particular baton to the officer. Most law enforcement agencies dictate that the primary approved target areas are large muscle masses. The ability of an officer to hit these targets is directly related to their success in an encounter (Gervais et al., 1997). This has forced agencies to discontinue their use of some impact weapons, including saps and blackjacks, due to their size and potential reach as well as the propensity of the officer to strike the head of the suspect. Consequently, serious injuries are a likely result if the head is targeted for an impact weapon strike (Cox, Buchholz, & Wolf, 1987), which still limits the officer's deployment of a baton.

To study the effect of baton type, weight, and size, the researchers designed an experimental pilot study. In this study of baton force potential, the researchers sought to conduct tests with the various types of batons and compare their resultant kinetic levels of force by utilizing a standardized group of research volunteers. A force sensor was used to capture the G-Force (G) of transferred energy to a training target, and the results were reported. The following section addresses the methodology employed in this study.

Methodology

The current study examined the effect of length and weight on the kinetic energy output of impact weapons. A number of batons were utilized in an attempt to create a model for matching an individual with the impact weapon that generates the greatest amount of force. The batons tested consisted of three straight batons and six expandable batons of varying lengths and weights. A baseball bat was also included for comparison purposes.

The field study utilized nine participants who were, prior to the data collection, trained in an impact weapon training course. Participants were taught the proper form and accepted law enforcement approved methods for delivering the strongest strikes possible, while instructors corrected deficiencies. At the conclusion of training, participants were invited to participate in data collection for this pilot study.

Each participant was given a score sheet, which they maintained throughout the study. After being randomly assigned to a testing order, each participant would strike a testing target three times using a forward swing from their dominant side. To reduce the effect of fatigue, participants would move to the end of the rotation after each set of baton strikes. This created a rest period of five to six minutes between batons. Practice swings with each new baton were permitted to allow the user to become accustomed to the baton. The testing target was a training dummy with two accelerometers (force sensors) attached that measured the amount of G from the baton strikes. The force sensor provided measurements of maximum power through an LED readout, which allowed the researchers to create a rank order of impact weapon force. The data was collected into *SPSS 15* (*Statistical Package for the Social Sciences*), and basic analysis was conducted. The following tables reflect the mean scores of the strikes by the test volunteers.

Findings

As shown below in Table 1, baton force loads from the test subjects are presented with length, weight, and features of the batons under examination. Initially, the authors hypothesized that impact weapon performance would be based upon a range of factors, which would require precise matching of the baton with the user. Surprisingly, this was not the case. In both male and female test groups, an identical rank order of baton force was observed.

Table 1. Baton Force Loads and Baton Features

	Force	Length Closed	Length Open	Weight
Bat	14.17	n/a	33.25	1,122 g
Composite thick	11.28	n/a	26.50	566 g
Composite thin	9.44	n/a	25.75	378 g
Wood	9.22	n/a	26.25	346 g
Expandable 1[AB]	8.89	10.25	21.75	658 g
Expandable 2[B]	8.44	10.00	25.75	598 g
Expandable 3[A]	8.39	9.50	22.25	538 g
Expandable 4	8.28	9.75	26.00	576 g
Expandable 5[B]	7.61	8.00	20.50	504 g
Expandable 6	6.28	6.25	15.50	380 g
Expandable 7	6.11	6.25	15.25	242 g

Note: A = enlarged striking tip; B = enlarged end cap

In a review of Table 1, it is clear that expandable batons 1 through 4 were very similar in performance across the test subjects. This is of interest as these batons vary significantly in length, although with less variation in weight. It appears from this finding that expandable batons 1 through 4 generate a very similar force and, as such, would allow an agency some discretion in the particular model to be assigned to individual officers. This would also allow individual officers some choice if agency policy permitted.

In almost every case, it was clear that the force generated was directly related to the length and weight of the baton, regardless of the size of the user. Clearly, larger test subjects were capable of generating larger force loads, but the individual performance from even the smallest users indicated that they proportionately had better results with longer, heavier batons.

Table 2. Force Loads by Gender

	Male			Female		
	Mean	**N**	**SD**	**Mean**	**N**	**SD**
Baseball bat	18.3	5	2.28	9.00	4	1.08
Composite thick	13.3	5	1.65	8.75	4	0.65
Composite thin	10.7	5	1.44	7.88	4	0.48
Wood	10.2	5	2.51	8.00	4	0.58
Expandable 1	10.2	5	1.89	7.25	4	0.50
Expandable 2	9.7	5	1.44	6.88	4	0.48
Expandable 3	9.9	5	1.64	6.50	4	1.29
Expandable 4	9.4	5	1.02	6.88	4	1.03
Expandable 5	8.8	5	1.40	6.13	4	0.48
Expandable 6	7.3	5	1.57	5.00	4	0.82
Expandable 7	7.1	5	0.90	4.88	4	0.25

In comparing the sampled respondents by gender, male test subjects' mean scores were higher than those of the female participants. However, the "composite thick" baton when examined in the female score group produced a mean score of 8.75, which is very comparable to the amount of force generated by the male testers with expandable batons 5 and 6. From this initial study, it may be hypothesized that the heavier straight baton allows for some equalization of force between genders and may offer officers with less strength the competitive advantage needed to be effective in a use-of-force confrontation with a baton. Additionally, straight batons, regardless of their composition and weight, outperformed all of the expandable batons.

Although the majority of the baton performance can be explained by the length and weight, additional baton characteristics and features certainly impacted the results. First, several of the batons were equipped with an enlarged end-cap on the grip, which prevents the baton from slipping from the user's hand. With these batons, participants tended to grip the baton much further down the grip. Hand placement on batons without this feature tended to be much higher as participants "choked-up" on the grip. Second, several batons were equipped with an enlarged striking tip, which appeared to improve performance. It is unclear if this is a result of a mathematical factor of force transfer (increased mass on the end thereby generating higher speed and force transfer coefficients) or the users simply were more efficient striking the center of the target with the tip rather than the side of the baton.

Third, the comfort and ease of use for each baton appeared to be a factor as well. A number of test subjects commented that the smaller batons were harder to grip and were uncomfortable to use. It was not unexpected that the scores for these batons were substantially lower. Conversely, when a test subject determined that a baton had a comfortable grip, scores tended to be higher.

Conclusions

Law enforcement's decision to transition away from the straight baton and adopt expandable batons was viewed as a significant evolution in law enforcement technology. However, critics complained that many of the control techniques, once possible with straight and side-handled batons, were difficult to perform with the new, smaller expandable batons. Further, there was a perceived loss in force transfer, which unfortunately was only anecdotally documented. This pilot study tends to support those claims as all of the straight batons outperformed expandable batons in generating force.

However, the value of the expandable baton is still compelling. Officers have access to an impact weapon on their duty belt when they need it most, whereas many straight and side-handled batons remained on the front seat of the police car and are not available for immediate deployment. This research also shows that collapsible batons can be used to strike with an effective amount of force if they have sufficient mass and length. On the other hand, if a smaller, lighter baton is chosen, it may lack the potential energy potential to be effective against active suspect resistance.

Issues of ergonomics greatly affect the force that could be produced by those batons. Many of the testers mentioned that it was difficult to grip the smallest batons tested and, as a result, these batons generated considerably less force. Frequently, the user was able to predict the performance of the baton by simply gripping it. Although this was not a scientific measure, it was worthy of mention and of potential examination in future research.

Finally, the rank order of performance is almost identical between genders. This has direct application to law enforcement as some agencies have a practice of issuing smaller batons to smaller officers. Although the smaller batons may be easier to handle, these lighter batons simply cannot generate the force of larger, heavier batons. Consequently, this practice actually works against the smaller officers by reducing the force that they are capable of delivering. A baton that is too light or too small may cause an officer to strike a subject repeatedly to effectively control a suspect, which is perceived badly by both the media and the public. While a heavier baton is more likely to cause injury, this risk is reduced when strikes are properly delivered to an approved target area on the body and is more likely to be effective in a single strike. The most practical, less-than-lethal force option is one that incapacitates with the least number of applications.

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