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ORIGINAL ARTICLE

The influence of striking object characteristics on the impact energy

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Abstract A common form of violence investigated in legal medicine is blunt trauma caused by striking with different objects. The injuries and medical consequences have been widely examined, whereas the forces and especially the energies acting on impact have rarely been analyzed. This study focuses on how the impact energy of different striking objects depends on their characteristics. A total of 1170 measurements of horizontal strikes against a static and relatively heavy pendulum have been acquired with 13 volunteers. The main focus was laid on how the weight, the length, and the center of mass of the different striking objects influenced the striking energy. The results show average impact energies in the range of 67.3 up to 311.5 J for men with an optimum weight of about 1.3 kg with its center of mass in the far end quarter for a 1-m-long striking object. The average values for women range from 30 to 202.6 J, with an optimum weight between 1.65 and 2.2 kg and similar settings for the center of mass as the men. Also, the impact energies are getting higher with shorter object lengths and reach a maximum at a length of about 0.3 to 0.4 m. The male volunteers' impact energy was on average by 84.2 % higher than the values of the female volunteers, where the impact masses were very similar and the impact velocities played the key role.

Keywords Blunt trauma · Impact energy · Horizontal striking · Hitting zone · Center of mass

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Introduction

A considerable part of the daily casework in legal medicine is the analysis of blunt trauma. A significant amount of such cases are strikes with a great variety of longish rigid objects as weapons, which can cause injuries ranging from mild to potentially deadly.

In one particular case found in the literature, "[…] a youth of 18 years was (deliberately) struck a single blow across the chest with a golf club and collapsed dead on the spot. […] The heart showed multiple internal ruptures and there was a laceration of the lingula of the lung" [1]. Not only golf clubs, but several other pieces of sports equipment, such as baseball bats or ice hockey sticks, as well as objects for the daily use such as shovels, broomsticks, or pipes, can be potentially harmful when used to hit other individuals. The use of a baseball bat as such an assault weapon is especially popular and dangerous because of its characteristics as a tool constructed for batting. It can be swung from a distance with tremendous force and can induce severe injuries in the victims such as comminuted and displaced fractures of the radius and ulnar diaphysis or open fractures of the tibia, in some cases resulting in amputation [2, 3]. One internally processed case reports murder by three strikes with a baseball bat to the head. Another recent case reports of a 9-year-old boy being struck by a bat during a baseball game, who died of the sustained injuries despite wearing a helmet [4].

All objects used for hitting differ in their characteristics and therefore their usefulness as a striking tool varies greatly, resulting in different impact energies.

There have been a number of studies presenting cases where a specific weapon was used and describing the injury it caused [5–8]. But if one wants to analyze and compare different hitting instruments, their injury potential has to be examined. The injury potential of a weapon is determined by many different parameters. First, the object is accelerated by the hitter leading to a certain impact energy. The ability of an object to accelerate depends on the object's mass, length, and center of gravity, among other parameters. The resulting energy then will be transferred to the target. Depending on the geometric properties of the hitting instrument and the target, the area and thus the energy density of the impact change. The last factor determining the injury potential is the distance over which the energy is delivered and thus the force-time curve. Soft striking objects or yielding target materials (for example the human skin and fat tissue) tend to deform and hence the energy is transferred more slowly in comparison to rigid striking objects or solid targets (such as a human bone). In this study, solely the first aspect, the ability of a person to accelerate an object, will be examined.

The impact energy is chosen because of its independence of the target, which makes it possible to solely compare the striking objects' characteristics that have generally not been analyzed yet. The effective impact masses and the acting forces have been studied [5, 9–11], but the impact energies have barely been examined [2] and data is therefore rare.

The intention of this study is to determine the impact energies and how they are influenced by the striking object's characteristics (hitting zone, mass, and center of mass) by measuring the striking energy of several volunteers. Only horizontal strikes will be analyzed because of their relevance in recent casework. A basis for the analysis of blunt trauma cases in legal medicine is thereby acquired.

Materials and methods

To evaluate the influence of the characteristics of the impactor on the impact energy, the different striking objects were divided into three groups. The first group included a total of three sticks and pipes with the length of 1.00 m and the center of mass at 50 % of the total length, but with different masses. The length and center of mass were identical in all the striking objects to isolate the influence of the mass on the impact energy. The target had to be hit with the far end of the striking object. A wooden stick (0.452 kg), an aluminum pipe (0.690 kg), and a steel pipe (1.279 kg) were used.

The second group consisted of an aluminum pipe with different hitting zones, with which the target was struck. These zones were located at 0.94 m (0.87–1.00 m), 0.68 m (0.62–0.74 m), and 0.44 m (0.38–0.50 m) of the total length of 1.00 m. The mass of 0.296 kg (0.290–0.303 kg) and the center of mass remained unchanged.

For the wooden stick and the light aluminum pipe, the masses varied due to the inhomogeneity of wood and the small variations, which can occur in the production process. Several of them had to be used due to wear out during the measurements.

The third group of objects was a steel pipe with a relocatable mass to evaluate the influence of the center of mass on the impact energy. In this group, the mass and the length were not changed throughout the measurements. The pipe weighed 1.279 kg and the additional mass was 0.371 kg, which resulted in a total mass of 1.650 kg. The different settings of the relocatable mass correlated with centers of mass at 0.49, 0.55, and 0.61 m of the total length of 1.00 m, measured from the end, where the steel pipe was held. The target was struck again with the far end of the pipe for all the settings.

All the characteristics of the striking objects are summarized in Table 1.

For this study, seven male and six female volunteers in the range of 21 to 39 years of age have been recruited. Physically well-trained as well as non-trained individuals with different professions and leisure activities, varying from students and desk workers to martial artists and police instructors, participated. Neither the profession nor the training level have been used to in- or exclude volunteers from the study.

To measure the striking energies, the volunteers had to horizontally hit a pendulum as hard as they could. The target was located 0.98 m above ground and had a diameter of 0.18 m. The mass of the pendulum was 13.643 kg. A test series for one volunteer included 10 strikes with each object, resulting in 90 measurements per volunteer. A total of 1170 measurements have been acquired.

The target on the pendulum consisted of modelling clay covered in a layer of Kevlar® and fabric to get an inelastic collision, which is important for later calculations. The angular movement of the pendulum was measured with an oscilloscope (PicoScope 5203 PC oscilloscope). To determine the striking velocity, each strike was filmed with a high-speed camera (Casio Exilim High Speed EX-FC 100) at 420 fps vertically from below the pendulum. For better visibility, the striking objects were contrasty marked. A video with a ruler was made to gain a scale for the distance for later analysis of the high-speed videos.

The last four frames prior to the impact were saved as JPEG files. These pictures were then evaluated with the program K-bit Image Analyzer, where the picture with the ruler was used. Thereby, the covered distance of a striking object could be measured frame by frame. At a frame rate of 420 fps, a time of $1\ s/420 = 2.381$ ms passes between two frames. The average of the three measured distances and the time between two frames were then calculated to obtain the striking velocity.

The curves of the oscilloscope were processed with MATLAB, where the relevant section of the curve was determined. The values prior to the impact were cut off and a damped sinusoidal wave was fitted over the curve to obtain a curve without white noise. The greatest gradient was then calculated with the first derivative of the sinus curve, which corresponds to the greatest angular velocity

Table 1 Properties of the three groups of the striking objects

Object	m_o (kg)	l_o (m)	COM (m)
Wooden stick	*0.452* (0.413–0.475)	1.00	0.50
Aluminum pipe	*0.670*	1.00	0.50
Steel pipe	*1.279*	1.00	0.50
Light aluminum pipe, *hitting zone at 0.94 m* (1.00–0.87)	0.296 (0.290–0.303)	1.00	0.50
Light aluminum pipe, *hitting zone at 0.68 m* (0.74–0.62)	0.296 (0.290–0.303)	1.00	0.50
Light aluminum pipe, *hitting zone at 0.44 m* (0.50–0.37)	0.296 (0.290–0.303)	1.00	0.50
Steel pipe with relocatable mass at 0.44 m	1.650	1.01	*0.49*
Steel pipe with relocatable mass at 0.70 m	1.650	1.01	*0.55*
Steel pipe with relocatable mass at 0.95 m	1.650	1.01	*0.61*

Emphasized in italics are the relevant properties of each of the three analyzed groups, respectively. m_o mass of the striking object, l_o length of the striking object, *COM* center of mass measured from the end of the striking object, where it is held

of the pendulum. The conversion of the angular velocity to the trajectory velocity of the pendulum was done with the formula

$$v = \omega \cdot r$$

where v denotes the trajectory velocity, ω the angular velocity, and r the distance from the suspension of the pendulum to its center of mass.

The striking energy is pure kinetic energy, which cannot be directly measured in the setting of an inelastic collision. It depends on the impact velocity of the striking object onto the pendulum and the fictive impact mass (defined as the point mass that would produce the same impact energy as the striking object, acting in the moment of impact). This impact mass consists of a part of the mass of the striking object and parts of the arm and upper body of the volunteer, which is why it cannot be directly measured. That is why there is only the detour of the following calculation.

Impact tests performed on a pendulum allowed using the law of conservation of momentum with the formula

$$m_s \cdot v_s = \left(m_p + m_s\right) \cdot v$$

where m_s denotes the impact mass, v_s the impact velocity of the striking object, m_p the mass of the pendulum, and v the trajectory velocity of the pendulum. The formula was then transposed to

$$m_s = \frac{m_p \cdot v}{v_s - v}$$

to calculate the impact mass. To obtain the impact energy, the formula

$$E_i = \frac{1}{2} \cdot m_s \cdot {v_s}^2$$

was used, where E_i denotes the impact energy, m_s the impact mass, and v_s the impact velocity of the striking object.

Table 2 Average values of the male volunteers

Men	E_i (J)	v_s (m/s)	m_s (kg)
Light aluminum pipe	*92.7* (67.3–144.2)	*34.89* (29.77–46.06)	*0.151* (0.136–0.168)
Wooden stick	*109.9* (78.2–151.0)	*31.56* (25.14–41.64)	*0.233* (0.176–0.286)
Aluminum pipe	*145.4* (102.8–182.1)	*30.02* (24.92–39.60)	*0.326* (0.232–0.356)
Steel pipe	*194.0* (134.7–269.0)	*26.48* (20.68–46.06)	*0.563* (0.401–0.632)
Steel pipe with relocatable mass at 0.44 m	*168.2* (113.8–251.3)	*23.00* (17.69–32.50)	*0.645* (0.478–0.770)
Aluminum pipe, hitting zone at 0.94 m	*92.7* (67.3–144.2)	*34.89* (29.77–46.06)	*0.151* (0.136–0.168)
Aluminum pipe, hitting zone at 0.68 m	*92.4* (70.8–127.9)	*25.78* (22.28–30.28)	*0.278* (0.247–0.317)
Aluminum pipe, hitting zone at 0.44 m	*107.4* (91.6–125.2)	*18.43* (15.48–20.79)	*0.647* (0.554–0.778)
Steel pipe with relocatable mass at 0.44 m	*168.2* (113.8–251.3)	*23.00* (17.69–32.50)	*0.645* (0.478–0.770)
Steel pipe with relocatable mass at 0.70 m	*196.0* (129.1–282.6)	*22.16* (16.56–30.95)	*0.811* (0.591–0.942)
Steel pipe with relocatable mass at 0.95 m	*208.4* (143.6–311.5)	*21.42* (16.34–30.82)	*0.930* (0.656–1.099)

Average values (in *italics*) of all measurements of the male volunteers with the range of the individual averages in brackets

E_i impact energy, v_s impact velocity of the striking object, m_s impact mass of the striking object

Table 3 Average values of the female volunteers

Women	E_i (J)	v_s (m/s)	m_s (kg)
Light aluminum pipe	*51.6* (30.0–89.9)	*25.93* (20.80–38.46)	*0.149* (0.121–0.216)
Wooden stick	*61.8* (41.3–110.7)	*23.63* (19.22–34.24)	*0.215* (0.189–0.271)
Aluminum pipe	*75.4* (49.5–141.0)	*21.36* (17.39–30.49)	*0.319* (0.271–0.425)
Steel pipe	*86.1* (51.2–156.4)	*17.28* (13.85–24.23)	*0.561* (0.439–0.682)
Weighted steel pipe	*94.8* (49.9–159.8)	*16.46* (12.45–23.57)	*0.673* (0.505–0.951)
Aluminum pipe, hitting zone at 0.94 m	*51.6* (30.0–89.9)	*25.93* (20.82–38.46)	*0.149* (0.121–0.216)
Aluminum pipe, hitting zone at 0.68 m	*59.1* (31.6–111.5)	*19.49* (14.22–27.39)	*0.295* (0.211–0.354)
Aluminum pipe, hitting zone at 0.44 m	*75.3* (49.7–125.4)	*15.37* (11.77–20.60)	*0.627* (0.509–0.789)
Steel pipe with relocatable mass at 0.44 m	*94.8* (49.9–159.8)	*16.46* (12.45–23.57)	*0.673* (0.505–0.951)
Steel pipe with relocatable mass at 0.70 m	*100.3* (63.4–183.7)	*15.56* (12.50–23.11)	*0.793* (0.619–1.111)
Steel pipe with relocatable mass at 0.95 m	*111.4* (61.6–202.6)	*15.14* (11.93–21.98)	*0.926* (0.666–1.143)

Average values (in *italics*) of all measurements of the female volunteers with the range of the individual averages in brackets

E_i impact energy, v_s impact velocity of the striking object, m_s impact mass of the striking object

Results

The results of the male volunteers are shown in Table 2 and the results of the female volunteers in Table 3. Because of their properties (the lengths and the centers of mass are practically identical and only the mass varies), the values of the light aluminum pipe with the hitting zone at 0.94 m (0.296 kg) from the second group and the steel pipe with the relocatable mass at 0.44 m (1.650 kg) from the third group are included in the first group to be compared to the others and thereby extend the spectrum of analyzed masses. The average values for the male and the female volunteers as well as the overall averages are indicated in Figs. 1, 2, and 3.

The overall highest impact energy reached by a male volunteer is 339.4 J and by a female volunteer 222.5 J, both with the steel pipe with the relocatable mass at 0.95 m.

Figure 1 shows the curves of the impact energies depending on the striking object's mass of every volunteer. For almost all the stronger individuals as well as the overall average, the maximum values are reached at a mass of about 1.3 kg.

In Fig. 2, the curves of the influence of the striking object's hitting zone are shown. Except for one outlier (police officer; trainer in baton techniques), the tendency for all energy curves is decreasing with increasing distance between the end where the pipe is held and the hitting zone of the striking object.

Figure 3 displays the energy curves of all participants for the different center of mass configurations of the third striking object group. For a few exceptions, the curves are almost linear with a gently inclining tendency. With increasing energy levels of different individuals, this effect seems to get stronger.

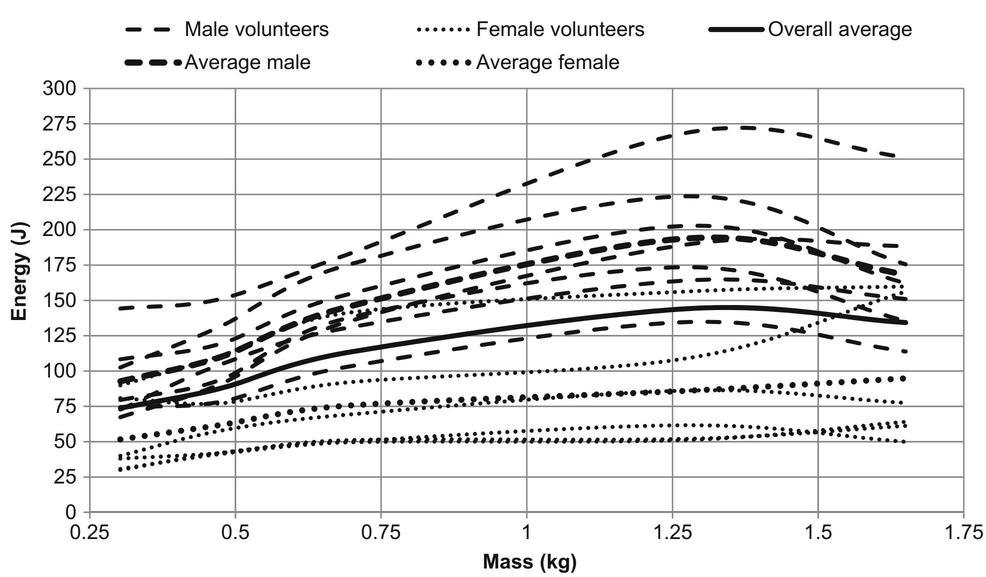

Fig. 1 Impact energy depending on the striking object's mass. Each *dashed line* indicates the average impact energy values for the five striking objects with varying masses of one male volunteer. The average values of all male volunteers are shown in a *bold dashed line*. The values of the female volunteers are shown in *dotted lines*. The *solid line* indicates the overall average

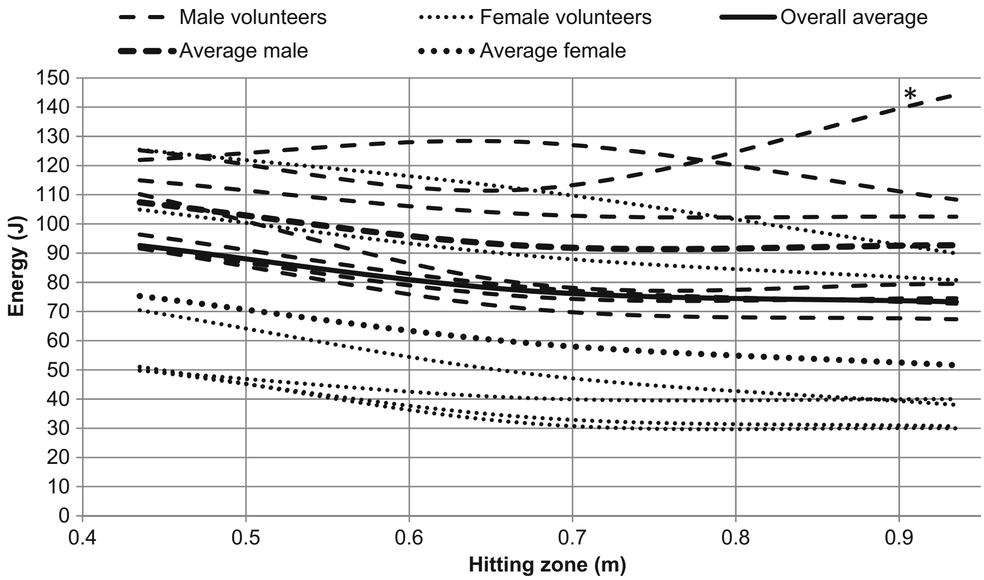

Fig. 2 Impact energy depending on the hitting zone of the striking object. Each *dashed line* indicates the average impact energy values for the striking object with varying hitting zones of one male volunteer. The average values of all male volunteers are shown in a *bold dashed line*. The values of the female volunteers are shown in *dotted lines*. The *solid line* indicates the overall average. The *asterisk* indicates the police officer, trained in baton techniques

In Figs. 4, 5, 6, 7, 8, and 9 the frequency distributions of the different striking objects are shown. The graphs display the distribution for the striking objects for male and female participants separately for different masses (Figs. 4 and 5), different hitting zones (Figs. 6 and 7), as well as the different centers of mass configurations (Figs. 8 and 9).

Discussion

The energy curve for the heavier striking objects is slowly plateauing and the maximum energy is reached at a striking object mass of about 1.3 kg. This can be observed in every male volunteer, regardless of the maximum striking energy. Even the stronger female volunteers reach their maximum at a similar point. Therefore, the mass of a striking object of about 1.3 kg seems to allow the highest impact energies. For weaker individuals, the maximum energy seems to be reached with heavier objects, because the impact mass keeps rising disproportionately in comparison with the striking velocity and the turning point is still not reached with a mass of 1.65 kg. Earlier measurements have shown that a mass of 2.2 kg exceeds the physical abilities of weaker individuals to strike the object to the full extent onto the target. As a conclusion, the optimal mass for weaker volunteers lies somewhere in between these two values, but is definitely higher than the mass for the stronger individuals.

The impact mass tends to decrease with increasing distance between the point of grip and the hitting zone [1], while the impact energy rises inversely proportional to the changing

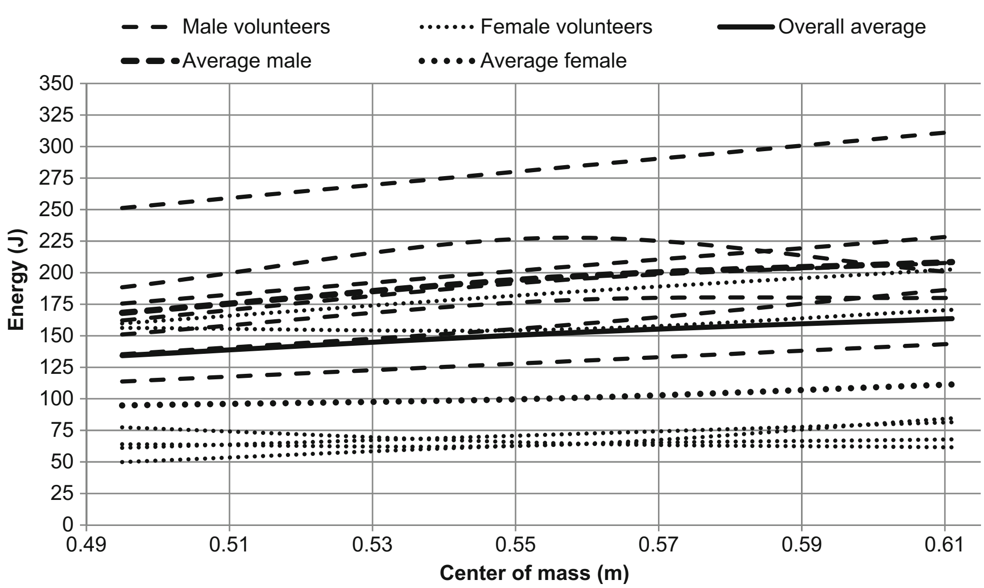

Fig. 3 Impact energy depending on the striking object's center of mass. Each *dashed line* indicates the average impact energy values for the weighted steel pipe with varying center of mass of one male volunteer. The average values of all male volunteers are shown in a *bold dashed line*. The values of the female volunteers are shown in *dotted lines*. The *solid line* indicates the overall average

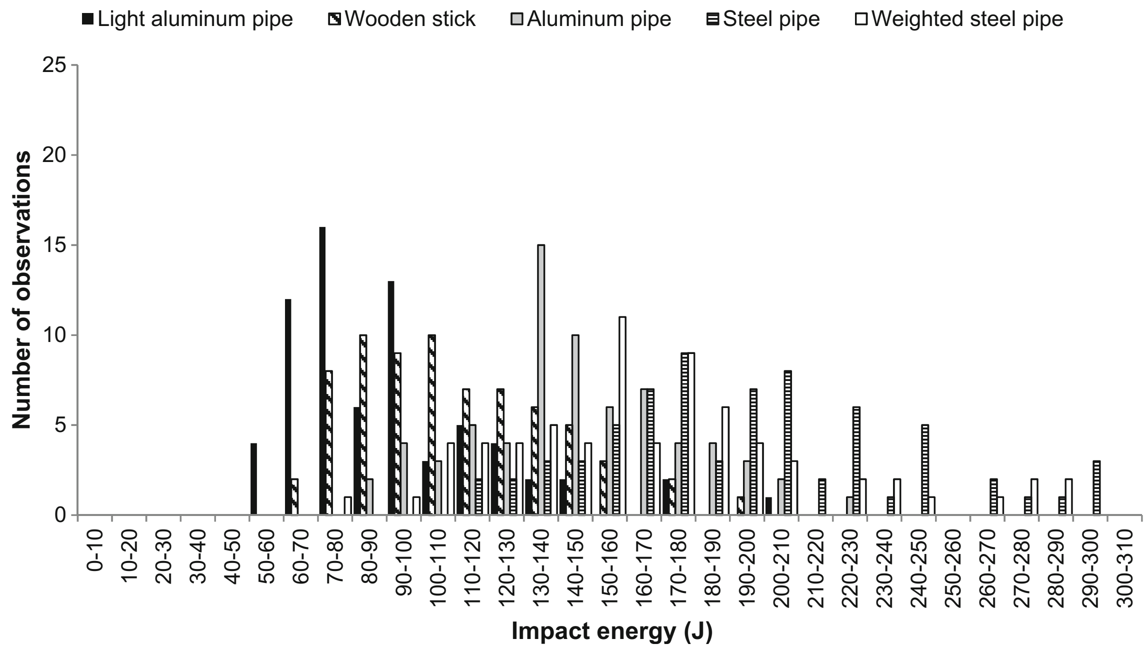

Fig. 4 Frequency distribution of the male subjects for the striking objects with varying masses. Frequency distribution of all measurements of the male volunteers. The 350 values of the five striking objects with varying masses are shown. The impact energies are divided in intervals of 10 J. No energies higher than 300 J have been measured for these objects

distance. The maximum impact energy is reached, before the hitting zone gets too close to the point of grip to be properly hit on the target. This distance is almost reached with 0.44 m. The results suggest that the energy will rise up, until a distance of about 0.3 m is reached to then drop rapidly with shorter distances. This can be observed in both male and female volunteers equally, even on different energy levels. The value of 0.3 m is an assumption, as a striking object with this distance between the point of grip and the hitting zone has not been tested in this study.

The impact energy rises as the center of mass moves closer to the far end of the striking object. The energy curve is approximating its maximum value when the center of mass is located at about 75 % or further of the total 1-m length. Male

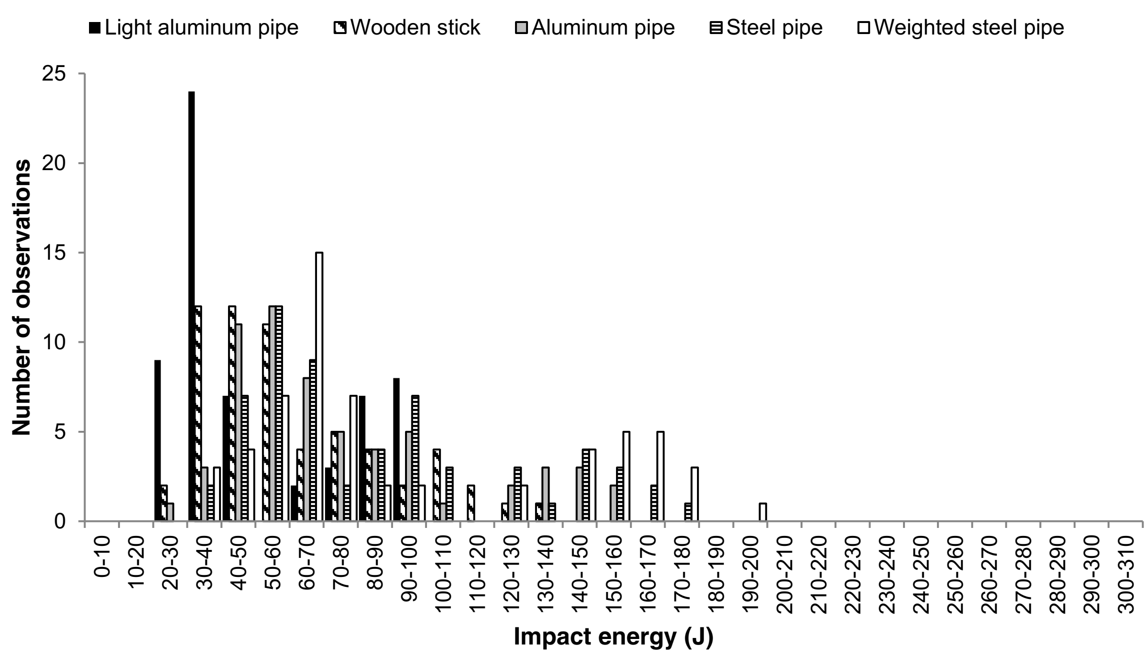

Fig. 5 Frequency distribution of the female subjects for the striking objects with varying masses. Frequency distribution of all measurements of the female volunteers. The 300 values of the five striking objects with varying masses are shown. The impact energies are divided in intervals of 10 J. No energies higher than 200 J have been measured for these objects

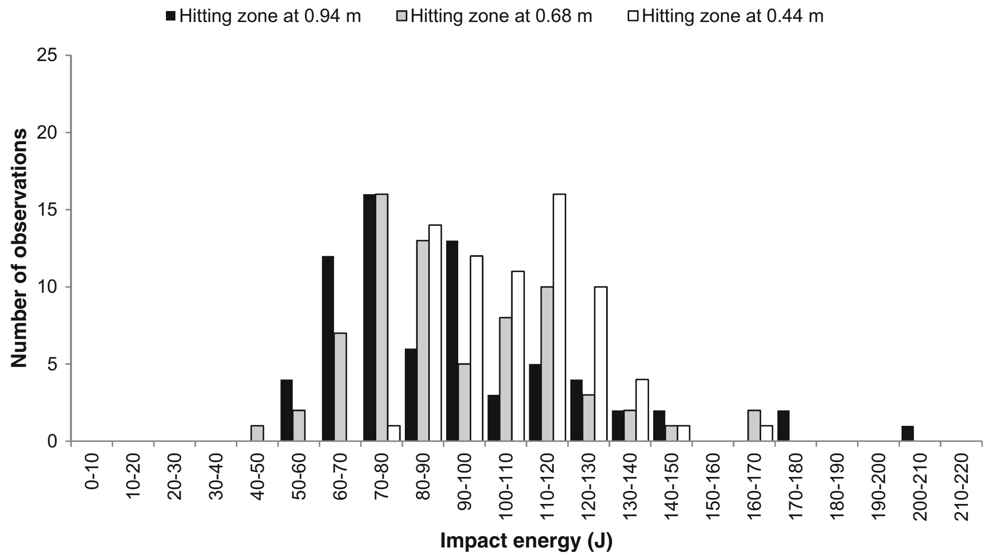

Fig. 6 Frequency distribution of the male subjects for the striking object with varying hitting zones. Frequency distribution of all measurements of the male volunteers. The 210 values of the striking object with varying hitting zones are shown. The impact energies are divided in intervals of 10 J. No energies higher than 210 J have been measured for these objects

volunteers reach the maximum energy a little earlier than the female volunteers, where the center of mass is even further towards the end of the striking object. The center of mass setting for maximum energy has not been reached in the setting of this study.

As expected, every value of the male volunteers is significantly higher than that of the female volunteers. On average, the energy of the males is 66.5 J or 84.2 % higher than that of the females. The difference is smaller with lighter objects (58.9 J or 78.8 %) and gets greater with the heavier objects (88.7 J or 86.6 %). The biggest difference was measured with the steel pipe with a mass of 1.279 kg (energies of males higher by 107.9 J or 125.3 %).

The impact masses for male and female volunteers are on average very similar, but the impact velocities differ considerably. On average, the impact velocity of the males is higher by 7.06 m/s or 37.5 %. The biggest difference was again measured with the steel pipe (9.20 m/s or 53.2 %), and the smallest difference was measured with the aluminum pipe with the hitting zone at 0.44 m (3.06 m/s or 19.9 %) which was the shortest distance between the point of grip and the hitting zone in this study.

Some of the frequency distributions have two peaks, which is more obvious in the graphs for the female participants. A Gaussian distribution cannot be observed. This is due to a greater variability in the strength of the different individuals and a relatively small sample size. The energies of the strongest woman in this study are on average 2.97 times higher in comparison to the lowest values of the weakest volunteers. In men, this difference is with a factor of 1.93 clearly smaller. In general, the impact energy values of the lighter objects are much closer together and are spreading further apart with increasing mass.

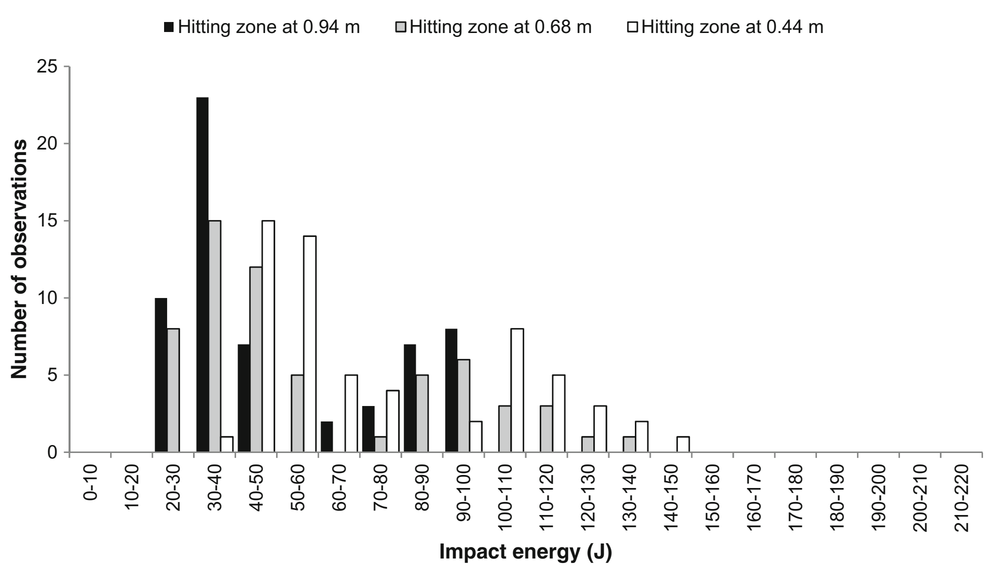

Fig. 7 Frequency distribution of the female subjects for the striking object with varying hitting zones. Frequency distribution of all measurements of the female volunteers. The 180 values of the striking object with varying hitting zones are shown. The impact energies are divided in intervals of 10 J. No energies higher than 150 J have been measured for these objects

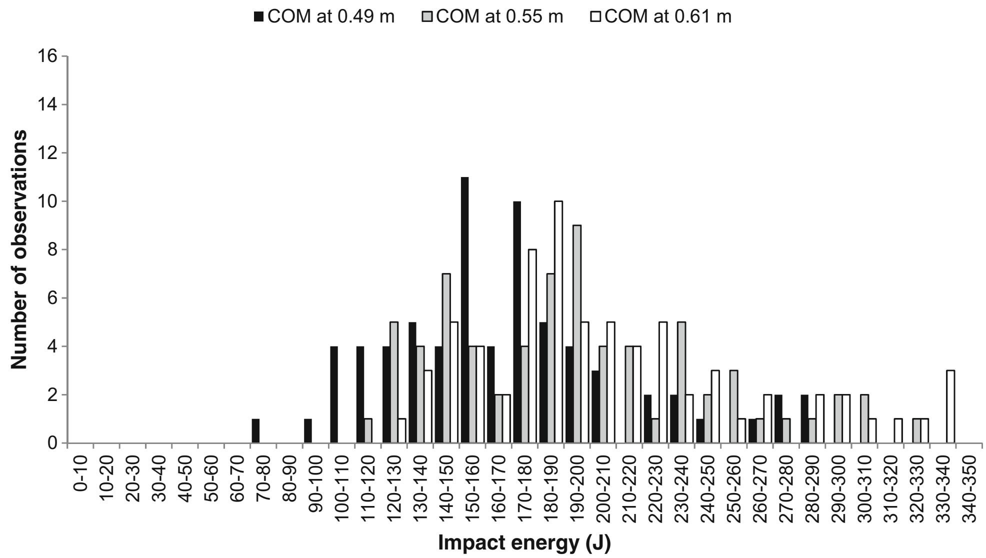

Fig. 8 Frequency distribution of the male subjects for the striking objects with varying center of mass. Frequency distribution of all measurements of the male volunteers. The 210 values of the three striking objects with varying center of mass are shown. The impact energies are divided in intervals of 10 J. No energies higher than 340 J have been measured for these objects. *COM* is the center of mass

The maximum impact velocity varies from one participant to another. All participants can strike to a full extent with the light objects, but as the objects get heavier, the strength of the weaker individuals is insufficient to reach the maximum possible impact velocity (16.34–17.69 m/s for weaker men, 12.83–13.46 m/s for weaker women) and therefore falls behind the stronger volunteers (30.82–32.50 m/s for men, 21.98–23.57 m/s for women). This could explain the bigger variance for heavier striking objects, as the impact energy is a function of the impact velocity squared. So the influence of the impact velocity is much bigger compared to the impact mass, where the values are much closer together (0.856–1.099 kg for weaker male volunteers compared to 0.478–0.656 kg for strong male volunteers; 0.505–0.666 kg for weaker female volunteers compared to 0.576–1.143 kg for stronger female volunteers). Strong male participants compensate lower impact masses with much higher impact velocities. For strong female volunteers, both values are higher than in weaker individuals.

To put these measured impact energies in relation to potential injuries, a number of studies can be consulted. For example, rubber projectiles weighing 140 g were shot at the thorax and abdomen of anesthetized pigs with speeds ranging from 30 to 64 m/s resulting in energies from 63.0 to 286.7 J. Cardiac compression and contusion, rib fractures, as well as vessel ruptures were observed [12]. A different study tested energies resulting in fractures of the neurocranium with an electrohydraulic device and unembalmed intact human cadaver heads. The failure loads were depending on the anatomical localization and ranged from 14.1 to 68.5 J [13]. The values of the impact energies elaborated in this study show that all the male volunteers and stronger female volunteers would be able to inflict severe injuries such as rib fractures and organ or vessel lacerations. Commotio cordis, ventricular fibrillation,

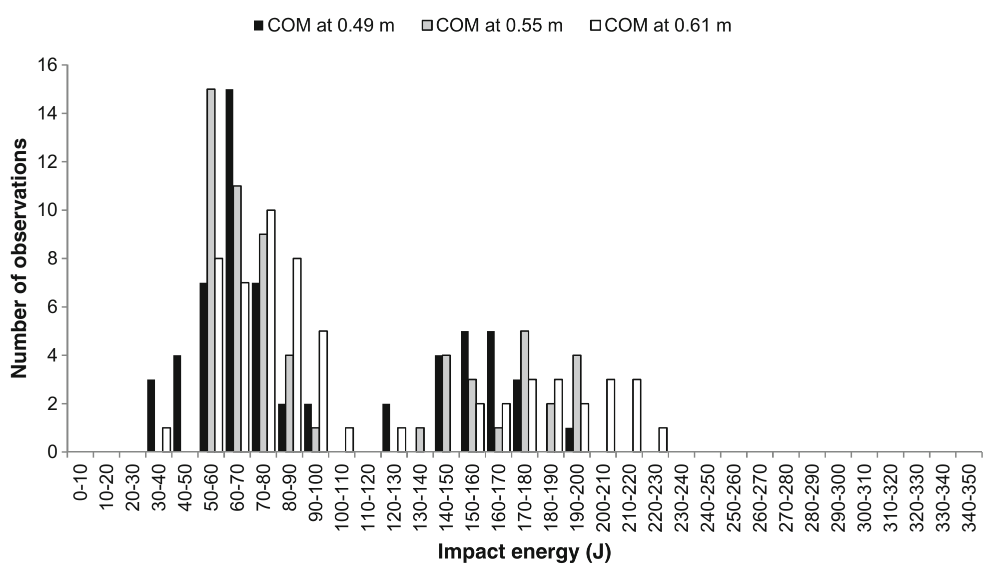

Fig. 9 Frequency distribution of the female subjects for the striking objects with varying center of mass. Frequency distribution of all measurements of the female volunteers. The 180 values of the three striking objects with varying center of mass are shown. The impact energies are divided in intervals of 10 J. No energies higher than 230 J have been measured for these objects. *COM* is the center of mass

or an overstimulation of the vagal nerve with a potentially deadly outcome caused by cardiac arrest has to be considered as well [8, 14–18]. Depending on the localization on the head, fractures of the neurocranium are possible even with relatively light striking objects used by weaker individuals. A threshold value for potential deadly impact energies caused by a striking object is not determined so far.

Limitations

The results of this study are subject to some uncertainties due to the measuring techniques. If the target is not hit right in the center, some of the energy is lost in vibration of the pendulum and therefore excluded from the measurement with the oscilloscope. Another small fraction of the impact energy is lost in deformation of the striking object. The deformation tendency may vary for impactors with the same characteristics, which has not been measured. The calculations assume an absolute inelastic collision, which in reality can just be approximately reached, affecting the results.

Another factor is the reliability of the strikes, which gets better during the measurements. Most of the volunteers were not used to horizontal strikes as demanded in this study. The precision of the strikes increased and the volunteers could strike harder without missing the target and higher values were measured in the process. A different design of the pendulum, which could measure the impact energy independent of the striking direction or a target, could decrease this influence. Furthermore, weaker individuals became exhausted faster, because they were not used to such a physical effort as it was demanded for the study. This factor could be eliminated by using more participants and measuring fewer strikes per volunteer. A larger group of volunteers would also allow the comparison of individual factors (e.g., age or occupation), which influence the performance.

An additional source of errors is the analysis of the high-speed videos. At a frame rate of 420 fps, the resolution of the pictures is limited and light effects could overlay the markings on the striking objects, which could complicate the exact processing, and small inaccuracies could occur in the evaluation process of the pictures. The distance of the impactor from the camera slightly differed in each strike and therefore the scale, which has been centered on the target, was not perfectly accurate for every hit.

In this study, only horizontal strikes have been analyzed. It is possible that vertical or diagonal strikes would lead to different results.

Conclusion

For horizontal strikes with a 1-m-long rigid object, such as a stick or a pipe, the optimum configuration to achieve the highest impact energy seems to be a weight of about 1.3 kg and a center of mass in the far end quarter of the total length of the object at a relatively short distance between the point of grip and the hitting zone of about 0.3 to 0.4 m.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethics approval and consent to participate All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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