Journal of Forensic and Legal Medicine 16 (2009) 138–142

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/jflm

Original Communication

Are full or empty beer bottles sturdier and does their fracture-threshold suffice to break the human skull?

Stephan A. Bolliger MD (Senior Forensic Pathologist) *, Steffen Ross MD (Radiologist), Lars Oesterhelweg MD (Forensic Pathologist), Michael J. Thali MD (Professor, Director, Forensic Pathologist), Beat P. Kneubuehl PhD (Physicist)

Centre for Forensic Imaging and Virtopsy, Institute of Forensic Medicine, University of Bern, IRM, Buehlstrasse 20, CH-3012 Bern, Switzerland

ARTICLE INFO

Article history:
Received 20 June 2008
Accepted 8 July 2008
Available online 7 November 2008

Keywords:
Breaking energy threshold
Beer bottles
Blunt head trauma

ABSTRACT

Beer bottles are often used in physical disputes. If the bottles break, they may give rise to sharp trauma. However, if the bottles remain intact, they may cause blunt injuries. In order to investigate whether full or empty standard half-litre beer bottles are sturdier and if the necessary breaking energy surpasses the minimum fracture-threshold of the human skull, we tested the fracture properties of such beer bottles in a drop-tower.

Full bottles broke at 30 J impact energy, empty bottles at 40 J. These breaking energies surpass the minimum fracture-threshold of the human neurocranium. Beer bottles may therefore fracture the human skull and therefore serve as dangerous instruments in a physical dispute.

© 2008 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.

1. Introduction

The examination of living or deceased victims of bar fights is not uncommon in routine forensic practice. These fights are commonly carried out with fists, feet, furniture, and drinking vessels.

Depending on the state of the drinking vessels, namely intact or broken, different trauma forms are to be expected. According to a British group,[1] readily available one pint beer glasses such as straight-sided glasses, referred to as nonik, and tankards display a mean impact resistance of up to 1.7 Joule (J). The glass shards of shattered beer glasses may give rise to stab and cut wounds, which may sever blood vessels or other vital structures of the body. Indeed, glasses with lower impact resistance cause more injuries,[2] for which reason toughened glassware has been advocated.

On the other hand, if the drinking vessels remain intact, they may serve as clubs. In Switzerland and various other countries, refillable (and therefore sturdy) beer bottles are commonly encountered in pubs and at festivals. In Switzerland, the half-litre, refillable beer bottle is, according to the authors' own experience, a commonly utilized instrument in physical disputes.

The authors have been asked at court whether hitting a human on the head with such intact bottles suffices to break a skull and whether full or empty bottles are more likely to cause such injuries. Obviously, this depends on the breaking properties of the bottle. If the bottle (full or empty) breaks at a minimal energy, no skull fracture is to be expected. On the other hand, should the stability of the bottle surpass that of the head, severe, even life-threatening injuries may be inflicted.

We therefore tested the breaking energy of such beer bottles in a drop-tower as described below in order to estimate at which energies the bottles break and if this amount of energy exceeds the energy necessary to inflict serious injuries to a victim.

2. Methods and materials

Ten (six empty and four full) standard 0.5 l beer bottles (Feldschlösschen Brewery, Rheinfelden, Switzerland, Fig. 1) were examined. The full bottles weighed 898 g, the empty ones 391 g. With multislice computed tomography (Somatom Emotion 6, Siemens Medical Solutions, D-91301 Forchheim, Germany) the wall thickness was measured. The minimal thickness was 0.2 cm and maximal thickness 0.36 cm (Fig. 2).

To one side of the beer bottles, a 7.5 × 1.2 × 5 cm pinewood board was fixed using a thin layer of modelling clay (Fig. 3a). The wood board served to distribute the very small impact point of the steel ball to a more realistic situation concerning the impact area of a beer bottle against a cranium. The modelling clay not only served as a fixing material, but also as a substitute for the soft tissues of the scalp. The bottles were then fixed horizontally to the bottom of a baby-bath tub with a thin layer of modelling clay (Fig. 3b).

A 1 kg heavy steel ball was dropped from different heights (minimum 2 m, maximum 4 m) onto the beer bottles in a drop-tower specifically designed for the testing of materials (Figs. 4 and 5).

* Corresponding author. Tel.: +41 31 631 84 11; fax: +41 31 631 38 33.
E-mail address: stephan.bolliger@irm.unibe.ch (S.A. Bolliger).

1752-928X/$ - see front matter © 2008 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.
doi:10.1016/j.jflm.2008.07.013

Fig. 1. Photograph of the full half-litre beer bottle.

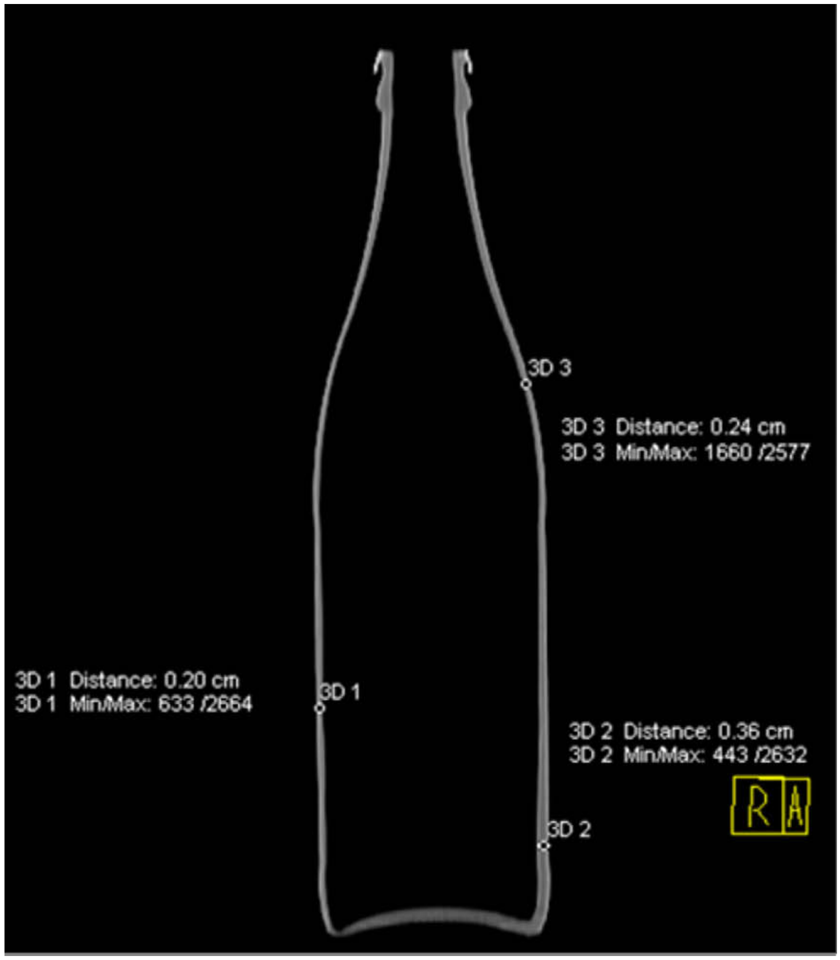

Fig. 2. MSCT, 2D sagittal reconstruction of the bottle. The minimal wall thickness is 0.2 cm, the maximal thickness is 0.36 cm.

Depending on the region of the beer bottle, the wall thickness, curvature, and therefore the expected stability vary. As our aim was to assess the *minimum* breaking threshold, we let the ball strike the weakest part of the bottle, namely the bottom third of the shaft.

3. Results

The full beer bottles tolerated energies of up to 25 J ($N = 2$), but burst at 30 J ($N = 2$), whereas the empty beer bottles shattered at energies of 40 J ($N = 4$) but not below this threshold ($N = 2$). Thus, the empty beer bottles withstood about 10 J more than the full beer bottles before breaking.

4. Discussion

Although the sample size in our experiment is very small, and therefore eludes statistical analysis, a certain trend is clearly deducible, namely that full beer bottles tend to break at considerably lesser energies.

The full beer bottles broke at 30 J, whereas the empty bottles shattered at 10 J more, namely at 40 J. As shown in this experiment, the standard 0.5 l beer bottles are undoubtedly – regardless of whether they are full or empty – more suitable clubs than common beer glasses[1] which break at energies of as little as 1.7 J.

The phenomenon of empty beer bottles breaking at higher energies than full ones is explainable by two factors. Firstly, beer is an almost incompressible fluid. Even a slight deformation of the bottle due to the impact of the steel ball leads to an increase of the pressure within the bottle and its destruction. Another, possibly major additional factor may be that beer is carbonated. This gas is under a certain amount of pressure, and may in adequate amounts – as every incautious home-brewer knows – even suffice in causing the bottle to explode. This gas pressure within the bottle gives rise to an additional strain on the bottle which an empty bottle obviously does not possess. An externally induced, additional strain on the bottle walls will therefore lead to the bottle bursting.

In this experiment, a fixed bottle was struck by an object, namely the steel ball. However, the opposite is true in real life: the moving bottle strikes a more or less static target.

The energy in the real life situation can be assessed using the following formula:

$$E = (M_N/(M_T + M_N)) \times W$$

E is the energy, M_N is the mass of the bottle, M_T is the mass of body part moving the bottle, i.e. the arm and shoulder (which can be as-

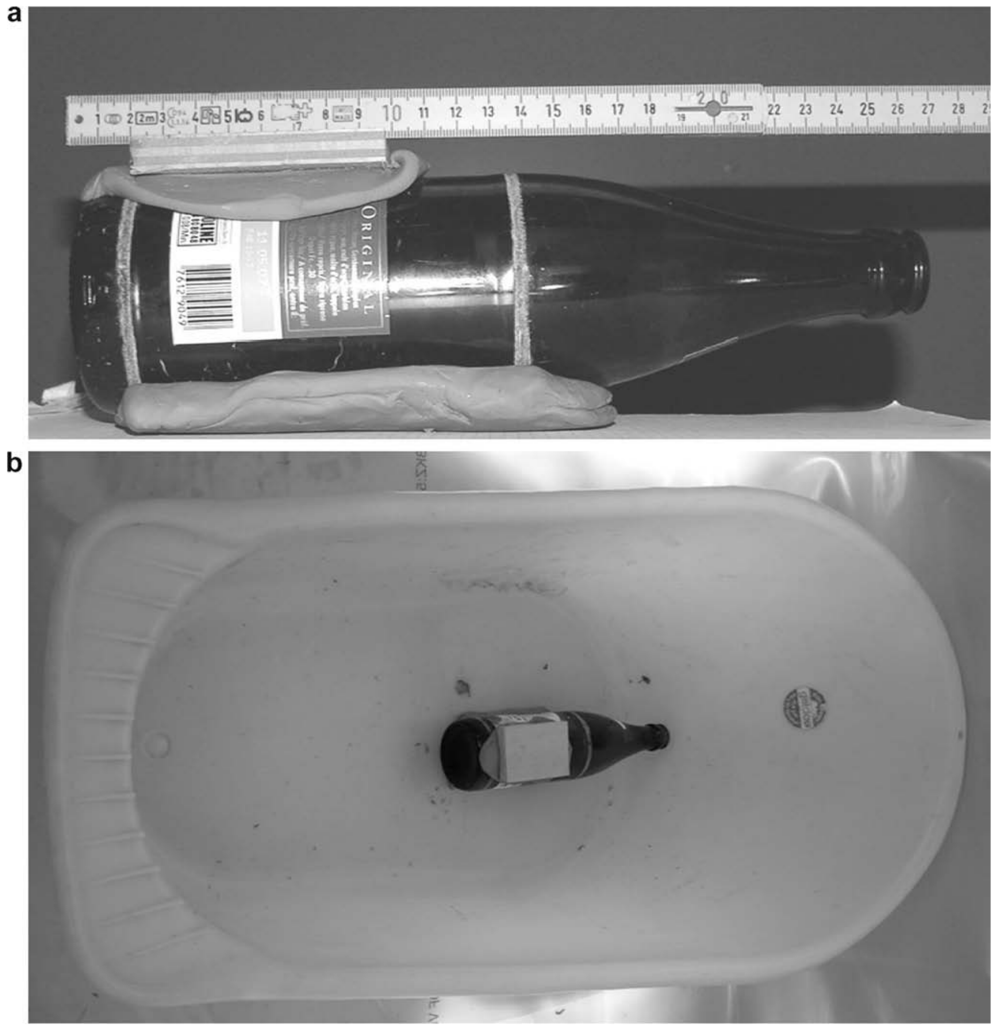

Fig. 3. A 7.5 × 5 cm wide and 7.5 × 1.2 cm thick pinewood board was fixed to the bottle using modelling clay (a) to distribute the impact of the steel ball over an area which roughly corresponds to a real-life impact area and then bedded in a baby-bath tub, again using modelling clay (b).

sumed to weigh 2.5–4 kg) and W is the work performed by the muscles. If one considers the masses of the bottles, namely full bottles weighing 898 g and empty ones 391 g, a full bottle will strike a target with almost 70% more energy than an empty bottle. In other words, it takes less muscle work to achieve a greater striking energy when fighting with a full bottle, even though lifting the bottle requires slightly more energy.

Fig. 4. The drop-tower seen from below. The system consists essentially of a vertical shaft in which a steel ball can be moved to a certain height and then dropped onto the test-object.

In electrohydraulic experiments using human cadaver heads, neurocranial fractures arose – depending on the skull region – between 14.1 and 68.5 J.[3] As the full and empty standard half-litre beer bottles break between 30 and 40 J, respectively, they are easily capable of fracturing the weaker parts of the human skull. Therefore, although beer glasses are not capable of breaking the human calvaria, beer bottles certainly are.

An aspect not dealt with in this article is the prevalence of brain damage due to blows with the beer bottles, as fractures do not necessarily coincide with these potentially life-threatening or even lethal cerebral injuries.

5. Conclusions

Empty beer bottles are sturdier than full ones. However, both full and empty bottles are theoretically capable of fracturing the human neurocranium. We therefore conclude that half-litre beer bottles may indeed present formidable weapons in a physical dispute. Prohibition of these bottles is therefore justified in situations which involve risk of human conflicts.

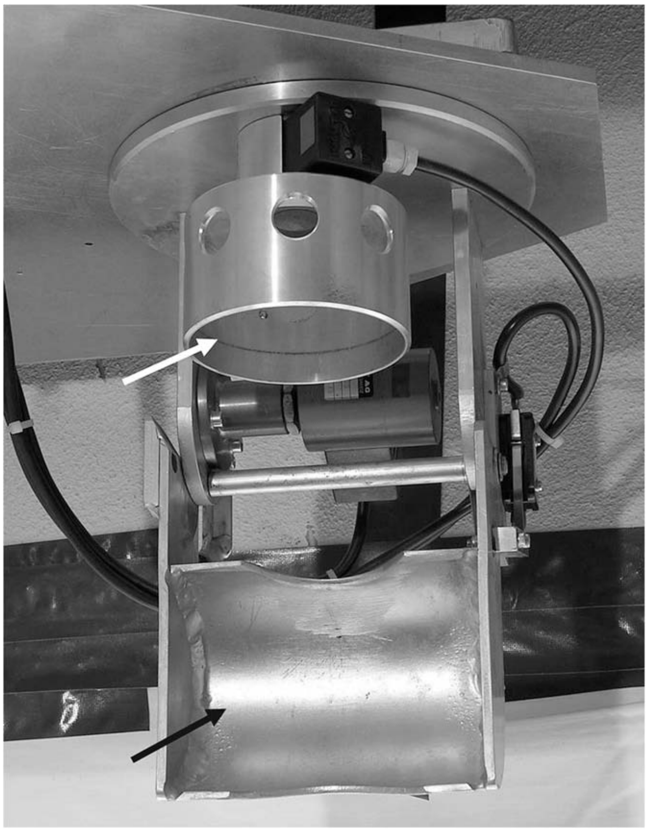

Fig. 5. The releasing mechanism of the drop-tower. A steel trap (black arrow) secures the ball until the ball is to be dropped. After releasing this safety-trap, the ball is still fixed onto a magnetic ring (white arrow). The magnetic field can then be interrupted, causing the ball to fall.

However, further studies involving different bottle types and an examination regarding the extent of brain damage is needed to assess the overall danger originating from bottle-related head trauma.

Conflict of interest statement

There are no conflicts of interest.

Acknowledgements

The authors wish to thank the Science and Technology Division, Armasuisse, Ministry of Defence, Switzerland, for assistance in conducting the experiments and to Renate and Werner Bolliger, PhD, for help in language editing and manuscript preparation.

References

1. Shepherd JP, Huggett RH, Kidner G. Impact resistance of bar glasses. *J Trauma* 1993;**35**:936–8.
2. Warburton AL, Shepherd JP. Effectiveness of toughened glassware in terms of reducing injury in bars: a randomised controlled trial. *Injury Prevent* 2000;**6**:36–40.
3. Yoganandan N, Pintar FA, Sances A, Walsh PR, Ewing CL, Thomas DJ, Snyder RG. Biomechanics of skull fracture. *J Neurotrauma* 1995;**12**:659–68.