The damaging punch

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Abstract

The mechanical properties of a boxing punch have been determined using several techniques. The results are consistent with the medical consequences of boxing discussed in the report of the Board of Science and Education Working Party on boxing. Data were gathered from a world ranked British professional heavyweight, Frank Bruno, as he punched an instrumented, padded target mass suspended as a ballistic pendulum. Within 0·1 s of the start the punch had travelled 0·49 m and attained a velocity on impact of 8·9 m/s. The peak force on impact of 4096N (0·4 ton), attained within 14 ms of contact, represents a blow to the human head of up to 6320N (0·63 ton). The transmitted impulse generated an acceleration of 520 m/s^2 (53 g) in the target head. For comparison an equivalent blow would be delivered by a padded wooden mallet with a mass of 6 kg (13 lbs) if swung at 20 mph.

Introduction

The BMA report on boxing identified two main causes of structural damage to the brain attributable to boxing[1]: one, the cumulated effects of sustained exposure to the sport, the other, the acute and direct result of a severe blow. In the report emphasis was placed on the importance of gathering "comprehensive, relevant medical data about all boxers and ex-boxers." This paper seeks to contribute to this database not on the medical issues as such but on the characteristics of the damaging blow that gives rise to the medical issues.

Attempts to measure the physical properties of a boxer's punch have been reported. Baagreev and Trahimovitch used a three component accelerometer in the centre of a boxing bag and a Kistler force plate fastened to the wall.[2] Joch, Fritsche, and Krause used an elastic walled, water filled punch bag with a built in pressure gauge.[3] Unterharnscheidt attached accelerometers to the heads of two inexperienced students and monitored them as they fought.[4]

The above methods, although informative, are not without their drawbacks. Thus, for instance, an elastic walled bag does not provide a realistic time history of forces of impact on the head; a wall mounted force plate is a daunting target to punch even if gloves are worn; head mounted accelerometers trail leads, which inhibit movement, and it is unethical to hold these targets still to standardise measurement conditions; and untrained amateurs are unlikely to generate information that is relevant for the trained professional.

This study, which seeks to determine the properties of the punch of a heavyweight professional boxer, overcomes many of the above disadvantages by combining several techniques of measurement. The scope of the work is limited to one subject, the highest rated heavyweight boxer in Britain, so, although generalisations cannot be applied to the boxing population, the results are of value and will reflect the upper limits of forces to be expected from the boxing punch.

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Subject and methods

The subject, a world ranked British professional heavyweight boxer, Frank Bruno, punched with maximum force an instrumented target suspended as a ballistic pendulum. After preliminary work seven punches were recorded over the course of one morning.

The target was a cylindrical metal mass of 7 kg (16 lb) (fig 1)—that is, roughly equivalent to the head and associated neck segments of a heavyweight opponent. At its front end was attached a target plate (0·8 kg) mounted on a shaft that moved freely on lubricated bearings. The face of the plate was initially padded with felt and leather to a thickness and yield approximating that of the human face. After preliminary trials, however, extra padding was added to make it acceptable to the boxer. An allowance was made for this additional padding from paired records of equivalent submaximal punches made with and without its protection.

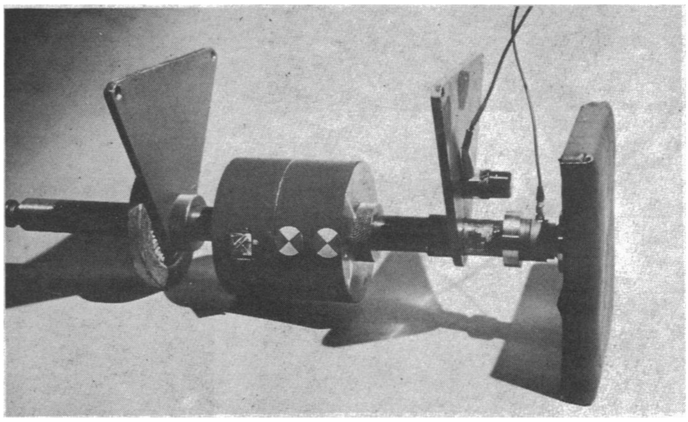

FIG 1—Instrumented target mass. Accelerometer on hanging plate, force transducer behind target plate, retroreflective prism of 3D Coda scanner, and digitising markers used in film analysis.

The punches were filmed in colour with a high quality video news film or in black and white, with a 16 mm, variable shutter Bolex camera at a nominal 64 Hz and also with a Hycam rotating prism camera operating at either 400 or 1500 Hz. A millisecond timer and a fiducial system were included in the field of view to permit the timing and scaling of events. Reference points were marked on the mass and on the boxer's glove for use in digitising the filmed records. The films were analysed with a Vanguard analyser linked to a Minc minicomputer. The punch was measured from the moment the blow was committed—that is, from the moment the elbow first began to extend—until the completion of the follow through (fig 2). The coordinates of each point were digitised eight times and quintic splines fitted to produce the displacement, velocity, and acceleration time histories of fist and mass.

Additional measurements were also taken. With a 3D Coda scanner the real time cartesian coordinates of the fist and target mass were monitored throughout selected punches. A piezoresistive accelerometer was enclosed within the boxer's fist and positioned to record accelerations normal to the impact surface of his knuckles. A piezoelectric accelerometer continuously recorded the accelerations of the target. A piezoelectric force transducer, sandwiched between the target plate and the central mass, monitored the forces of contact. All leads from the fist and target transducers were carried to appropriate amplifiers and to S E Laboratories (Engineering) Ltd ultraviolet light recorder and Racal frequency modulated tape recorder.

The films and other records when developed were examined to select for analysis only punches when the delivery was in line with the longitudinal axis of the target mass, when the point of contact was central, when the mass was displaced without undue rotational energy, and for which all records were intact. These criteria were met best by the third punch, and this punch was analysed in detail.

Results

Table I shows the results of the analysis. The preliminary movements of the body involving a slight crouch, a slow advance, and initial rotation of the trunk are part of the build up to the punch, but as they can be stopped at will, used as a feint, or diverted into an evasion they are treated as separate from the punch itself. The first two entries in the table indicate the duration and velocity of these movements before the punch starts.

The next entries describe the displacements, durations, and time derivatives of movement and force development. Finally, the magnitudes and effects of force and impulse are detailed.

Some properties of a professional boxer's punch

Variable	Value
Duration of trunk advance before start	201 ms
Velocity of trunk and fist before start	1·0 m/s (2·2 mph)
Time taken from start of punch to impact	100 ms
Distance punch travels from start to impact	490 mm
Distance of follow through	110 mm
Peak acceleration of fist before contact	90 m/s^2
Velocity of fist at impact	8·9 m/s (20 mph)
Residual velocity after impact	1·8 m/s
Rise time of force to peak	14 ms
Rise time of acceleration to peak	14 ms
Peak contact force	4096N(0·4 ton)
Estimated maximum force to human head	6320N(0·63 ton)
Impulse transmitted	41N s
Acceleration induced in head mass model	520 m/s^2 (53 g)

1N=0·225 lb; 1 m/s=2·24 mph; 1 g=9·81 m/s^2.

Discussion

Attention is drawn to the shortness of the time taken to deliver the punch from first extension of the elbow to peak contact. If basic visual reaction time is taken as 140 ms the chances of an opponent dodging a blow he sees coming are clearly slim. His protection will instead depend primarily on the adoption of successful random evasion strategies or anticipation based on earlier, subtler cues than those associated with the start of punch delivery.

The peak force recorded was the equivalent of a blow to the unpadded human face ranging up to 0·63 tons. There was moreover some residual velocity remaining after impact. This peak force was in excess of that required to fracture facial bones.[5] Of course the duration of the contact was brief, but it still lasted long enough to generate an impulse capable of lifting a 100 kg opponent some 8 mm off the ground and accelerating the target head at 520 m/s^2 (53 g) well beyond safety margins quoted by Johnson, Reid, and Mamalis.[6] An equivalent blow would have been delivered by a padded wooden mallet with a mass of 6 kg (13 lbs) if swung at 20 mph.

Unterharnscheidt reported the effects of impacts on animals of a representative mass travelling at a range of different speeds and found that while blows travelling at 7 m/s produced loss of consciousness, those with a velocity of over 10·5 m/s, even when no rotational effects were induced, caused extended unconsciousness, bleeding, and tissue damage.[4] The velocity at impact of this punch is somewhat nearer to the upper than the lower of these two critical levels. Thus the safety margin that separates this sporting contact from some of its undesirable consequences is small.

The mechanical properties of the punch of the professional heavyweight boxer have been described. These appear to be of a magnitude consistent with the medical consequences of boxing discussed in the report on boxing by the Board of Science and Education Working Party.

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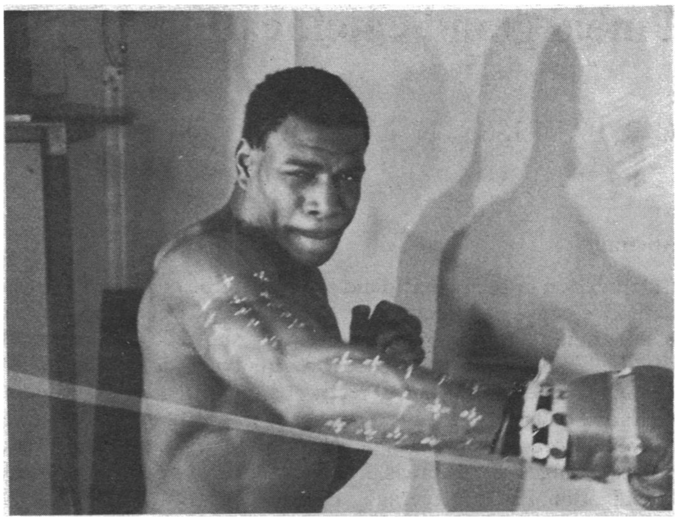

FIG 2—Frank Bruno punching padded target mass. Photograph by kind permission of *News of the World.*

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