ELASTO-PLASTIC IMPACT

Most real world collisions are neither perfectly elastic nor perfectly plastic. They are elasto-plastic impacts having a coefficient of restitution greater than zero but less then one, (i.e., $0 < e < 1$). Let us examine the effects of the coefficient of restitution and differing masses of impacting bodies on the human eye. First consider the impact of a 0.3 gm BB with the human eye. The following values are substituted in Formula 7:

$e = 0.2$ (as reported by Delori, Pomerantzeff, and Cox[3])

$M_1 = 0.3$ grams (mass of BB)

$M_2 = 7.5$ grams (mass of human eye[6])

$$\frac{T}{KE} = \left(1 - [.2]^2\right) \bullet \left(\frac{7.5}{.3 + 7.5}\right) = 0.92$$

Therefore, 92% of the impacting kinetic energy is available for tissue damage.

Now let us consider the impact of a 160 gram water balloon with an eye:

$e = 0$ (just like the impact of an egg[5])

$M_1 = 160$ grams (mass of water balloon)

$M_2 = 7.5$ grams (mass of human eye)

$$\frac{T}{KE} = \left(1 - 0^2\right) \bullet \left(\frac{7.5}{160 + 7.5}\right) = 0.04$$

Therefore, only 4% of the impacting kinetic energy of a water balloon is available for tissue damage. This general result was described in the globe deformation findings of Delori, Pomerantzeff, and Cox[3] and the ocular injury studies of Weidenthal and Schepens.[7] Thus, based upon the relative masses and the differing coefficients of restitution, a 23 fold (0.92/0.04) greater amount of energy is absorbed by the eye in the BB impact than in the water balloon impact. This absorbed energy causes ocular damage by tearing and rupture of the tissues as the impacting object hits the eye. When ocular penetration by the BB occurs, then e approaches zero (since there is no rebound) and T/KE = .96, and a 24 fold (0.96/ 0.04) greater increase of absorbed energy occurs.

Tissue damage is caused by excessive strain. Strain is linearly related to stress by Young's Modulus. Stress is defined as force per unit area. The projected cross sectional area (csa) of the impacting object applies the force. For the same magnitude of applied force, the smaller the csa the greater the stress concentration on the ocular tissues. (For instance, an icicle with a sharp point will cause much greater ocular damage than an equal amount of liquid water.) With sufficient applied force and a small csa (such as a BB), the impact stress can exceed the tissue rupture stress limit and then the impacting body can penetrate the eye. Let A_{BB} be the csa of the BB and let A_E be the csa of the human eye. In contrast, a water balloon (A_{WB}) has a much greater csa than the eye; hence, its impact can only be felt over the csa of the eye, neglecting propagation of impact energy from the bony orbital rim and orbital soft tissues to the globe. Therefore, the effective area of the water balloon, $A_{WB(eff)}$ equals the csa of the eye, A_E. The cross sectional area of a sphere of radius r is πr^2. The radius of the eye is approximately 1.18 cm and the radius of a BB is .21 cm. Thus the ratio:

$$\frac{A_{WB(eff)}}{A_{BB}} = \frac{A_E}{A_{BB}} = \frac{\pi r_E^2}{\pi r_{BB}^2} = 32$$

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Therefore, a BB will create 32 times more stress concentration on the ocular surface than a water balloon. By combining the effects of the relative masses, the coefficients of restitution and the effective cross sectional areas, a BB may be up to 768 (24x32) times more effective in causing ocular penetration than a water balloon. An additional factor which would minimize the water balloon impact relative to a BB is the Impulse-Momentum Principle,[4] wherein the time required for the water balloon to transfer its kinetic energy is much greater than for a BB. For instance, a fall onto a mattress (which has a damping effect) produces a much smaller injury than a fall onto a cement floor. This analogy qualitatively explains further why the water balloon causes less damage per unit of kinetic energy than a BB.

DISCUSSION

Eye injuries remain a significant cause of blindness and visual disability. While many such tragedies result from unexpected and accidental trauma, other eye injuries occur during preventable circumstances. In this study we report six cases of serious ocular/orbital trauma related to a "toy" which has been marketed by way of television advertisements. Injuries included orbital contusions and hematomas, facial hypesthesia, eyelid lacerations, subconjunctival hemorrhages, corneal edema and abrasion, hyphemas, traumatic iritis, iris sphincter ruptures, iris atrophy, angle recession, iridodialyses, traumatic cataract, vitreous hemorrhages, retinal hemorrhages, macular hole formation, optic atrophy, and bony orbital wall fractures.

Holds, et al.[2] have reported injuries to a 23-year-old male from the use of a giant water balloon slingshot which, reportedly, launched a water balloon a distance of 300 meters. The victim had transient loss of consciousness and ocular/orbital injuries including extensive orbital fractures with extraocular muscle entrapment, and a unilateral hyphema and vitreous hemorrhage. Three months after the injury the patient had a visual acuity of 20/300, an afferent pupillary defect, optic nerve pallor, a macular hole, and constant diplopia. Through the Consumer Product Safety Commission we have learned of ten other serious ocular/orbital injuries caused by water balloons launched using these "toys", as well as serious non-ocular injuries, including cardiac arrest (Table IV, Patient #26). Epidemiological analysis of the launched water balloon group (Table I and Graphs 1,2) revealed that children and young adults, more often males (65%), are injured by launched water balloons, most commonly (82%) in the warm weather months (May-September). In addition to eye and orbital injuries from launched water balloons, other serious complications have resulted from injuries due to the sling itself hitting the eye or orbital area, or from the use of other launched items such as potatoes and rocks (Tables II and IV). Other patients have been noted with eye injuries secondary to hand thrown water balloons[8] (Table III); and, in addition, three injuries have been reported from air filled balloons which exploded near the faces of two toddlers, producing hyphemas[9], and one adult, producing a corneal abrasion, iritis, and recurrent corneal erosion (Table V).

Based upon calculations, a projectile of mass 160 grams (manufacturer's recommendation) would require an initial velocity of 42 meters/second (95 mph) to traverse an advertised distance of 200 yards. Using that sling in field trials we determined experimentally that balloons had maximum velocities of 38-41 meters/second (85-92 mph). The maximum kinetic energies generated by the sling were 176-245 joules in our field trials, and between 141-232 joules based upon calculations and assumptions from the advertised ranges as well as from the case reported by Holds, et al.[2] In that instance for a water balloon to traverse a distance of 300 meters, a velocity of 54 meters/second (121 mph) would be necessary to hurl a 160 gram water balloon, requiring an energy of 232 joules. The field trials and calculations yield kinetic energies of extremely large magnitude, which are comparable to or greater than kinetic energies experienced with a variety of common objects well known to cause serious ocular injury, including rifle bullets (Table X). Thus, water balloon kinetic energies are more than sufficient to cause serious ocular and orbital trauma. A field demonstration documented the explosive capability of water balloons launched with these large energies.

A search of the medical literature was performed to identify studies which reported kinetic energy data required to produce various experimental ocular and orbital defects. In studies of the energies necessary to fracture the orbital floor, kinetic energies were noted to be between 1.8 and 14.7 joules.[10-13] Direct trauma to pig, monkey, or human cadaver eyes resulted in globe ruptures at energies between 1 and 5.3 joules.[11,14-16] Corneal perforations from BB gun injuries to rabbit, pig, human, and dog eyes developed at energy levels between 0.7 and 1.7 joules.[3,7,17] Although the energy delivered by the water balloon is dissipated over a much larger area than the direct forces in these studies, the extremely high kinetic energies achieved by the water balloons are clearly sufficient to cause severe injuries including permanent blindness. Our theoretical study showed that a BB may be at least 768 times more effective at perforating an eye than is a water balloon. Considering that the energy required to perforate an enucleated human eye is 1.4 joules (Table XI), the equivalent energy for a water balloon would be 1075 joules (1.4 x 768). None of our experimental studies were able to generate an energy of that magnitude, thus correlating with the fact that no perforations or globe ruptures were noted in any of the patients injured by launched water balloons reported to date.

It should be noted that orbital bone fractures have been reported from the water balloon impact. We are investigating the biomechanics of orbital injuries at this time.

CONCLUSION

This report demonstrates the serious and potentially vision and life threatening injuries inflicted by these devices. Patient #26 in Table IV suffered a cardiac arrest after being struck in the chest by a water balloon. Fortunately, this patient did not die, as did a large number of otherwise healthy patients struck in the chest during a variety of sporting activities.[18] It is not difficult to extrapolate to the even more threatening potential of this "toy" if more solid objects replace water balloons in the sling. It remains the responsibility of health care professionals to publicize such dangers, especially to parents who, presumably, have some influence over the purchase of such items. Indeed, the medical profession, legal profession, government, insurance industry, and general public should be aware of the enormous dangers proposed by the use of these elastic slingshots which are advertised, improperly, as "toys."

ACKNOWLEDGEMENTS

The authors would like to acknowledge Robert V. Hansen, Richard A. Woldin, Esquire, PhD, and Joseph F. Thomas, Jr, PhD for their assistance in the completion of this paper.

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LEGENDS

Figure 1 (a): External photograph of left eye of Patient 2, four months after water balloon injury, showing a mature traumatic cataract and inferior posterior synechiae.

Figure 1 (b): External photograph of left eye of Patient 2 two years following lensectomy and anterior vitrectomy with placement of posterior chamber intraocular lens, showing clear visual axis. Visual acuity measured 20/30.

Figure 2: External photograph of Patient 4 one day after water balloon injury showing marked ecchymosis and edema of right upper and lower eyelids.

Figure 3 (a): Coronal CT section (Patient 6) at level of mid-portion of left globe showing fracture of left orbital floor.

Figure 3 (b): Coronal CT, posterior section (Patient 6), showing fracture of left orbital floor.

Figure 4: Photograph showing custom built wooden frame with attached elastic water balloon slingshot. Second person from the left is holding the SPORTS RADAR gun to determine velocity of launched water balloons.

TABLE I
OCULAR AND ORBITAL INJURIES FROM SLINGSHOT LAUNCHED WATER BALLOONS

PATIENT NUMBER	AGE(YR)/SEX	INJURY(IES)	REPORTED BY
1	12 / M	HYPHEMA, ANGLE RECESSION	BULLOCK, ET AL
2	13 / M	BILATERAL HYPHEMA, UNILATERAL CORNEAL ABRASION, TRAUMATIC CATARACT, IRIS ATROPHY AND SPHINCTER RUPTURE	BULLOCK, ET AL
3	9 / F	VITREOUS HEMORRHAGE, EYELID LACERATION, ORBITAL FRACTURE, BILATERAL HYPHEMA	BULLOCK, ET AL
4	16 / F	ORBITAL HEMATOMA, TRAUMATIC IRITIS	BULLOCK, ET AL
5	28 / F	ORBITAL HEMATOMA, FACIAL HYPESTHESIA, RETINAL HEMORRHAGES, TRAUMATIC IRITIS	BULLOCK, ET AL
6	22 / F	EYELID LACERATION, BLOW OUT FRACTURE, SUBCONJUNCTIVAL HEMORRHAGE/HYPHEMA, IRIS SPHINCTER RUPTURE, RETINAL HEMORRHAGES	BULLOCK, ET AL
7	23 / M	HYPHEMA, VITREOUS HEMORRHAGE, ORBITAL FRACTURES, OPTIC ATROPHY, MACULAR HOLE	HOLDS, ET AL[2]
8	22 / M	"PERMANENT EYE INJURY"	NIIC-USCPSC*
9	10 / M	BLOW OUT FRACTURE, MACULAR HOLE	NIIC-USCPSC
10	14 / M	"EYE BADLY DAMAGED"	NIIC-USCPSC
11	34 / M	HYPHEMA, CORNEAL EDEMA	NIIC-USCPSC
12	23 / F	"EYE INJURY"	NIIC-USCPSC
13	14 / M	"SERIOUS EYE INJURY"	NIIC-USCPSC
14	9 / M	"SERIOUS EYE INJURY"	NIIC-USCPSC
15	22 / M	BLOW OUT FRACTURE, "LEGAL BLINDNESS"	NIIC-USCPSC
16	9 / F	BILATERAL HYPHEMAS, IRIDODIALYSES, ORBITAL FRACTURES	NIIC-USCPSC
17	14 / M	"SEVERE EYE INJURY"	NIIC-USCPSC

* NIIC-USCPSC = National Injury Information Clearinghouse - United States Consumer Product Safety Commission

TABLE II
RELATED INJURIES:

NON-WATER BALLOON OCULAR SLINGSHOT INJURIES

PATIENT NUMBER	AGE(YR)/SEX	OCULAR INJURY(IES)	EYE STRUCK BY	REPORTED BY
18	14 / M+	"LOST EYE'S FUNCTION"	ELASTIC SLING	NIIC-USCPSC*
19	19 / M	"LOST EYE"	POTATO	NIIC-USCPSC
20	14 / M+	"LOST EYE"	ELASTIC SLING	NIIC-USCPSC
21	39 / M+	"PERMANENT EYE DAMAGE"	ELASTIC SLING	NIIC-USCPSC
22	"CHILD"	"INJURED EYE"	ELASTIC SLING	NIIC-USCPSC

*NIIC-USCPSC - National Injury Information Clearinghouse - United States Consumer Product Safety Commission (Jan. 1, 1987 - June 30, 1995)
+ injured self

TABLE III
RELATED INJURIES:

NON-SLINGSHOT OCULAR WATER BALLOON INJURIES

PATIENT NUMBER	AGE(YR)/SEX	OCULAR INJURY(IES)	EYE STRUCK BY	REPORTED BY
23	11 / M	BILATERAL EYELID ECCHYMOSES AND SUB-CONJUNCTIVAL HEMORRHAGES; UNILATERAL COMMOTIO RETINAE AND MULTIPLE RETINAL TEARS	WATER BALLOON THROWN FROM MOVING AUTOMOBILE	COHN, OLSEN[5]
24	12 / M	TRAUMATIC MYDRIASIS	HAND THROWN WATER BALLOON	BULLOCK, ET AL

TABLE IV
RELATED INJURIES: NON-OCULAR SLINGSHOT INJURIES

PATIENT NUMBER	AGE(YR)/SEX	INJURY(IES)	AFFECTED BODY PART	STRUCK BY	REPORTED BY
25	35 / F	SEVERE BRUISE	THIGH	WATER BALLOON	NIIC-USCPSC*
26	9 / M	CARDIAC ARREST	CHEST	WATER BALLOON	NIIC-USCPSC
27	13 / F	"PERMANENTLY INJURED"	NS	WATER BALLOON	NIIC-USCPSC
28	13 / F	BROKEN COLLAR BONE, "NERVE DAMAGE"	NECK	WATER BALLOON	NIIC-USCPSC
29	12 / M	"INJURED"	NS	WATER BALLOON	NIIC-USCPSC
30	22 / M	"INJURED"	NS	WATER BALLOON	NIIC-USCPSC
31	NS / M	"INJURED"	FACE	WATER BALLOON	NIIC-USCPSC
32	13 / M	"INJURED"	NS	WATER BALLOON	NIIC-USCPSC
33	10 / M	BROKEN JAW, MISSING TEETH, FACIAL LACERATIONS	FACE	ROCK	NIIC-USCPSC
34	11 / M	"BADLY INJURED"	FACE	ROCK	NIIC-USCPSC
35	11 / F++	BRUISED	BACK	ROCK	NIIC-USCPSC
36	11 / F++	BRUISED	BACK	ROCK	NIIC-USCPSC

* NIIC-USCPSC - National Injury Information Clearinghouse - United States Consumer Product Safety Commission (Jan. 1, 1987 - June 30, 1995)

NS Not Stated

++ Same Incident, different patients

TABLE V
RELATED INJURIES: OCULAR INJURIES FROM AIR-FILLED BALLOONS

PATIENT NUMBER	AGE(YR)/SEX	OCULAR INJURY(IES)	EYE STRUCK BY	REPORTED BY
37	39 / F	CORNEAL ABRASION, IRITIS, RECURRENT CORNEAL EROSION	AIR-FILLED BALLOON EXPLOSION CLOSE TO EYE	BULLOCK, ET AL
38	"TODDLER" / NS+	UNILATERAL HYPHEMA	AIR-FILLED BALLOON EXPLOSION CLOSE TO EYE	MOKROHISKY, ET AL[6]
39	"TODDLER" / NS+	UNILATERAL HYPHEMA	AIR-FILLED BALLOON EXPLOSION CLOSE TO EYE	MOKROHISKY, ET AL[6]

\+ Different incidents, different patients

TABLE VI
DETERMINATION OF SLINGSHOT LAUNCHED WATER BALLOON KINETIC ENERGIES USING A RADAR DEVICE+

	M Mass		V Velocity				KE Kinetic Energy	
	(kilograms)		(m/sec)		(mph)		(joules)	
# TRIALS	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
80	.10	.50	9	41	20	92	7	176

\+ SPORTS RADAR gun, Model 3200, Sports Radar Ltd., Homosassa, FL 34448

TABLE VII
DETERMINATION OF VELOCITY AND KINETIC ENERGY OF SLINGSHOT LAUNCHED WATER BALLOONS BASED UPON THE EXPERIMENTAL MEASUREMENT OF RANGE

	a Launch Angle		M Mass		R Range				V Velocity				KE Kinetic energy	
	(degrees)		(kilograms)		(meters)		(yards)		(m/sec)		(mph)		(joules)	
# TRIALS	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
15	20	47	.10	.35	36	93	39	102	19	38	43	85	42	245

TABLE VIII
CALCULATION METHOD FOR SLINGSHOT LAUNCHED WATER BALLOON KINETIC ENERGY DETERMINATIONS

Sling Type	Advertised (Reported[2]) Range (yards)	(m)	Assumed Mass (kg)	Assumed Launch Angle (degrees)	Calculated Velocity (m/sec)	Calculated Velocity (mph)	Calculated Kinetic Energy (joules)
Hand Held[a]	30	27	.16	45	16	37	21
Wrist Supported Type 1[b]	50	46	.16	45	21	47	35
Wrist Supported Type 2[c]	75	69	.16	45	26	58	53
3 Person Type 1[d]	100	91	.16	45	30	67	71
3 Person Type 2[e]	200	183	.16	45	42	95	141
Custom-made[2]	328	300	.16	45	54	121	232

a. BALLOON BOMBER; SlingKing, Inc., 16810 Barker Springs #217, Houston, TX 77084
b. JUNIOR LAUNCHER; SlingKing, Inc., 16810 Barker Springs #217, Houston, TX 77084
c. BALLOON LAUNCHER; SlingKing, Inc., 16810 Barker Springs #217, Houston, TX 77084
d. AQUA SLING, #AS100; Riva Sport, Inc., P.O. Box 600404, San Diego, CA
e. AQUA SLING, #AS200; Riva Sport, Inc., P.O. Box 600404, San Diego, CA / BALLOON CANNON; SlingKing, Inc., 16810 Barker Springs #217, Houston, TX 77084

TABLE IX

SUMMARY OF VELOCITY AND KINETIC ENERGY DETERMINATIONS OF SLINGSHOT LAUNCHED WATER BALLOONS

METHOD NUMBER	METHOD DESCRIPTION	n	MAXIMUM VELOCITY		MAXIMUM KINETIC ENERGY
			(m/sec)	(mph)	(joules)
1	RADAR DEVICE	80	41	92	176
2	RANGE DETERMINATION	15	38	85	245
3	CALCULATION: ADVERTISED RANGE	5	42	95	141
	CALCULATION: REPORTED[2] RANGE	1	54	121	232

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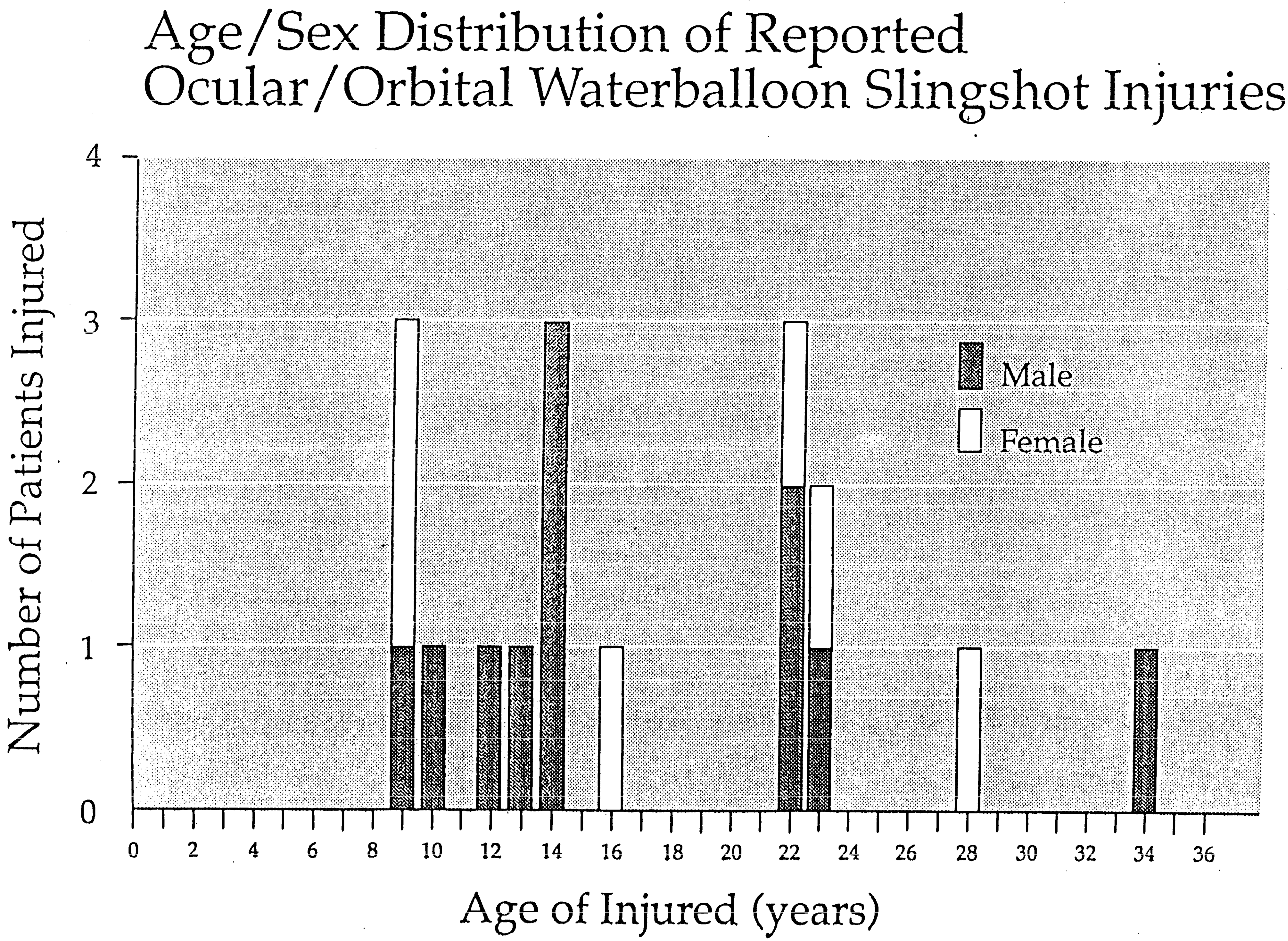
TABLE X

KINETIC ENERGIES OF COMMON OBJECTS

OBJECT	MASS (kg)	VELOCITY (m/sec)	VELOCITY (mph)	KE (joules)
AIR (PUFF TONOMETRY)	5.5×10^{-7}	9	20	2×10^{-5}
EYE DROP	6×10^{-5}	1.2	2.6	4×10^{-5}
BB	3×10^{-4}	64	144	7×10^{-1}
CHAMPAGNE CORK	9×10^{-3}	30	67	4
PAINT BALL	3×10^{-3}	70	156	7
SQUASH BALL	2.4×10^{-2}	45	100	2.4×10^{1}
RACQUETBALL	4.2×10^{-2}	45	100	4.2×10^{1}
TENNIS BALL	5.7×10^{-2}	45	100	5.7×10^{1}
BASEBALL	1.5×10^{-1}	40	90	1.2×10^{2}
GOLF BALL[a]	4.6×10^{-2}	76	170	1.3×10^{2}
22 CALIBER RIFLE BULLET[b]	3×10^{-3}	344	769	1.7×10^{2}
WATER BALLOON[c]	3.5×10^{-1}	38	85	2.5×10^{2}
416 MAGNUM RIFLE BULLET[d]	2.6×10^{-2}	730	1640	6.9×10^{3}
AUTOMOBILE[e]	1.9×10^{3}	27	60	6.8×10^{5}
SCUD MISSILE	5.5×10^{3}	1700	3800	7.9×10^{9}
JUMBO JET[f]	4×10^{5}	290	650	1.7×10^{10}

a MAXIMUM ALLOWED BY THE UNITED STATES GOLF ASSOCIATION
b @ 300 YARDS; REMINGTON R22HN1/2 (Ref. #16)
c SEE TABLES 7 AND 9
d @ MUZZLE; REMINGTON R416 R1/2 (Ref. #16)
e BMW 740iL
f BOEING 747

GRAPH 1


Age/Sex Distribution of Reported
Ocular/Orbital Waterballoon Slingshot Injuries
Number of Patients Injured
0
1
2
3
4
Male
Female
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Age of Injured (years)

233

GRAPH 2

Seasonal Distribution of Reported Ocular/Orbital Waterballoon Slingshot Injuries

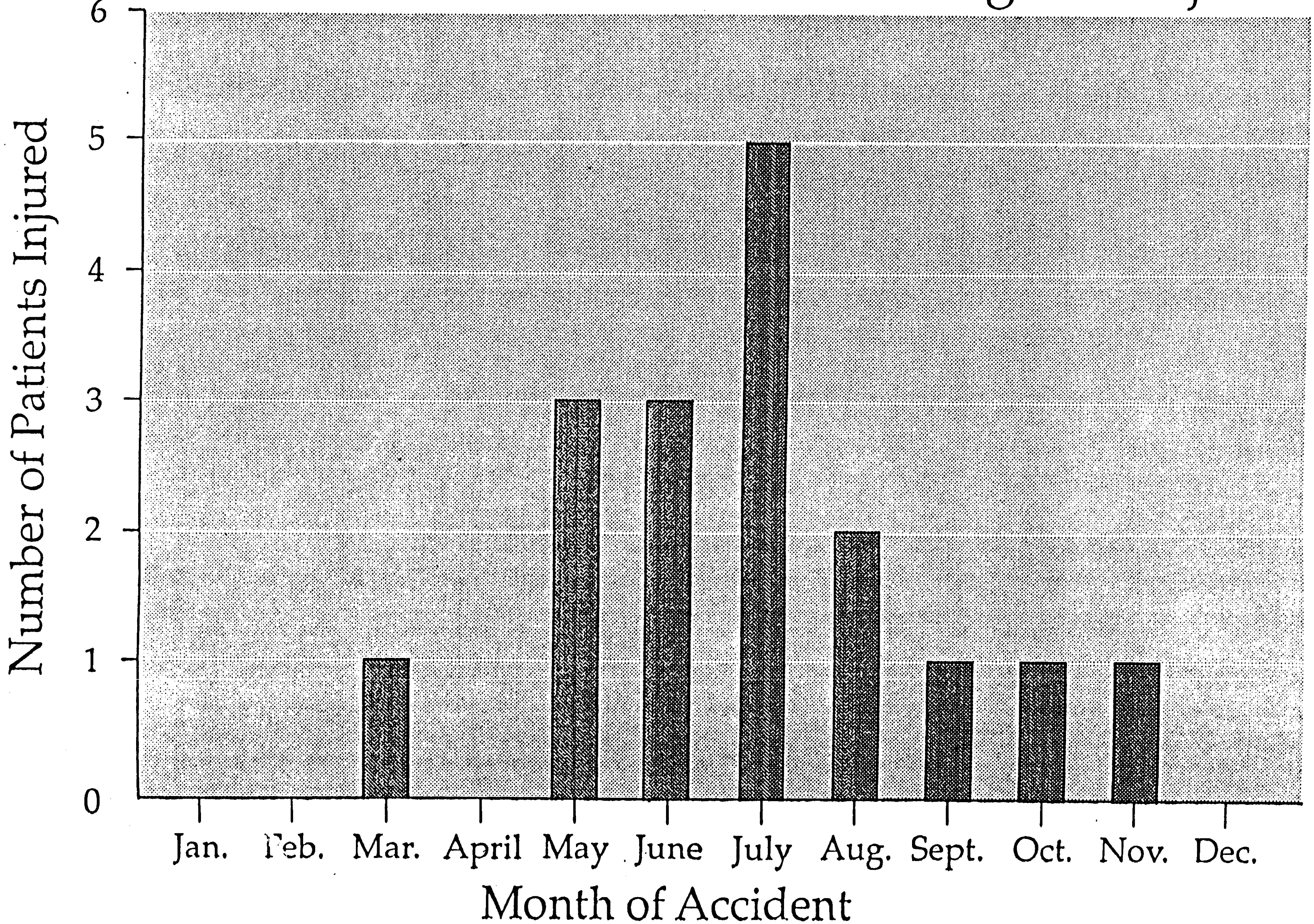


TABLE XI
KINETIC ENERGIES REQUIRED TO PRODUCE VARIOUS EXPERIMENTAL OCULAR AND ORBITAL DEFECTS

EXPERIMENTAL DEFECT	TEST OBJECT	TECHNIQUE	KINETIC ENERGY (JOULES)	AUTHOR(S)
LINEAR ORBITAL FLOOR FRACTURE	DRIED HUMAN SKULLS	DROPPED WEIGHT (.420 Kg)	1.8	FUJINO[10]
MEDIAL ORBITAL WALL/ SUPERIOR ORBITAL ROOF FRACTURES	LIVING CYNOMOLOUS MONKEY ORBITS	DROPPED WEIGHT (.303 Kg)	2.1 - 3.3	GREEN, ET AL[8]
"PUNCHED OUT" ORBITAL FLOOR FRACTURE	DRIED HUMAN SKULLS	DROPPED WEIGHT (.420 Kg)	3.2	FUJINO[10]
ORBITAL FRACTURE	3-DIMENSIONAL ORBITAL WALL MODELS	"SWING TYPE IMPACT TESTER"	4.0 - 5.0	FUJINO, SATO[12]
ORBITAL FLOOR FRACTURE	HUMAN CADAVER ORBITS	DROPPED WEIGHT (1Kg) ONTO A 4cm DIAMETER HARD WOODEN BALL PLACED ON ORBIT	14.7	BESSIERE, ET AL[13]
CORNEAL-SCLERAL RUPTURE	HUMAN CADAVER EYES	NOT STATED	1.0	KUNG, ET AL[14]
CORNEAL-SCLERAL RUPTURE	FRESH ENUCLEATED PIG EYES	"CALIBRATED DEVICE"	1.8	SAMBURSKY, ET AL[15]
SCLERAL RUPTURE	LIVING CYNOMOLOUS MONKEY EYES	DROPPED WEIGHT (.303 Kg)	2.1 - 3.0	GREEN, ET AL[8]
CORNEAL-SCLERAL RUPTURE	HUMAN EYEBANK EYES	DROPPED WEIGHT (.340 Kg)	2.2	BULLOCK, MAGNANTE (UNPUBLISHED DATA)
CORNEAL-SCLERAL RUPTURE	FRESH ENUCLEATED PIG EYES	DROPPED WEIGHT (.340 Kg)	5.3	FARRIS, ET AL[16]
CORNEAL PERFORATION	LIVING RABBIT EYES	BB FIRED BY AN AIR PISTOL/RIFLE	0.7	TILLETT, ET AL[17]
CORNEAL PERFORATION	ENUCLEATED PIG EYES	BB FIRED BY AN AIR RIFLE	0.7	DELORI, ET AL[3]
CORNEAL PERFORATION	ENUCLEATED PIG EYES	BB FIRED BY AN AIR RIFLE	0.7	WEIDENTHAL, SCHEPENS[7]
CORNEAL PERFORATION	ENUCLEATED HUMAN EYES	BB FIRED BY AN AIR PISTOL/RIFLE	1.4	TILLETT, ET AL[17]
CORNEAL PERFORATION	LIVING DOG EYES	BB FIRED BY AN AIR PISTOL/RIFLE	1.7	TILLETT, ET AL[17]