V. J. M. DiMaio,[1] M.D.; A. R. Copeland,[2] M.D.; P. E. Besant-Matthews,[3] M.D.; L. A. Fletcher;[4] and A. Jones[4]

Minimal Velocities Necessary for Perforation of Skin by Air Gun Pellets and Bullets

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ABSTRACT: A series of tests were conducted to determine the velocities necessary for lead air gun pellets (calibers .177 and .22) and caliber .38 lead bullets to perforate skin. Human lower extremities were used. Caliber .177 air gun pellets weighing 8.25 grains required a minimum velocity of 101 m/s (331 ft/s) to perforate skin. The energy per area of presentation ratio *E/a* was 1:86 m·kg/cm^2. Caliber .22 air gun pellets weighing 16.5 grains needed a minimum velocity of 75 m/s (245 ft/s). The *E/a* was 1:3 m·kg/cm^2. A round nose, caliber .38 lead bullet weighing 113 grains perforated skin at 58 m/s (191 ft/s). The *E/a* was 1.95 m·kg/cm^2. These studies appear to indicate that lightweight projectiles need greater velocity to perforate skin than do larger caliber, heavier bullets.

KEYWORDS: criminalistics, ballistics, air guns

Knowledge of the minimum velocity needed by a bullet or missile to perforate skin may be of great importance to a forensic pathologist or a firearms examiner involved in a case of assault or attempted homicide with an air gun. Proof that an individual air weapon is capable of inflicting severe or lethal wounds is necessary for successful prosecution of such a case. This wounding potential depends on the ability of a missile fired from such a gun to perforate skin and thus reach a vital organ. Knowledge of the minimal velocity needed to perforate skin is also important in determining the maximum distance at which a bullet fired from a firearm is capable of penetrating the body.

A recent review of the literature [*1*] on perforation of skin by bullets and missiles concluded that, for a missile to perforate skin and enter underlying subcutaneous tissue and muscle, a minimum velocity on the order of 70 m/s (230 ft/s) is necessary with an energy per area of presentation ratio *E/a* of approximately 2.1 m·kg/cm^2 ($E/a = wv/2gr$, where w = weight of missile, v = velocity, g = gravity, and r = radius). That review pointed out, however, that there were a number of deficiencies in the published studies. In view of this, the authors conducted a series of experiments to try to gain additional knowledge on the subject.

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[1]Chief medical examiner, Bexar County, San Antonio, TX.
[2]Pathologist, Oklahoma City, OK.
[3]Medical examiner, Dallas County, Dallas, TX.
[4]Firearms examiners, Dallas, TX.

Method

The test material consisted of legs removed at surgery, as well as two legs removed from a body donated to Southwestern Medical School for dissection and research. In most instances the surgical specimens were obtained immediately after surgery without any intervening refrigeration. The anatomical specimens were from the body of a young victim of a motor vehicle accident. They were refrigerated for a few days prior to experimentation. Identical ballistic tests on both nonrefrigerated and refrigerated specimens revealed no differences in the resistance of skin to penetration by missiles. Therefore, it appears that refrigeration, at least for a short time, does not significantly change any ballistic characteristics of skin.

The extremities were suspended immediately adjacent to a pair of chronograph screens so that the impact velocity of the missiles on the skin could be determined for each shot.

The weapons used for the test were a caliber .177 air rifle; a .22 pump air pistol and a .38 Smith and Wesson 51-mm (2-in.) barrel revolver. The 0.177 pellets were of wasp-waist Diablo style, weighed an average of 8.25 grains, and had an average diameter of 4.369 mm (0.172 in.) at the tip. The 0.22 pellets were of the Diablo style and weighed an average of 16.5 grains with an average diameter of 5.461 mm (0.215 in.). Cartridges for the caliber 0.38 revolver were hand-loaded with 113-grain round-nose bullets having a diameter of 9.119 mm (0.359 in.). Different powder loads were used to vary velocity. The impact velocity of air gun pellets on the skin was varied by altering the number of pumps per shot as well as the distance between target and weapon.

Results

Table 1 gives the results of our tests with the caliber .177 air rifle. At a velocity of 88 m/s (290 ft/s) a pellet embedded itself in (penetrated) the skin. Complete passage through the skin (perforation) with lodgement in the underlying soft tissue occurred initially at 101 m/s (331 ft/s). At velocities of 111 m/s (365 ft/s) and higher, perforation always occurred. The E/a at 101 m/s is 1.85 $m \cdot kg/cm^2$.

Table 2 gives the results of the tests with the .22 air gun. A pellet embedded itself in the skin at 68 m/s (223 ft/s). Perforation occurred initially at 75 m/s (245 ft/s) and was consistent at 87 m/s (285 ft/s) and higher. The E/a at 75 m/s is 1.30 $m \cdot kg/cm^2$.

Table 3 lists our results with the caliber .38 bullet. Penetration of the skin occurred at 51 m/s (166 ft/s), with perforation beginning at 58 m/s (191 ft/s). The E/a at 58 m/s is 1.94 $m \cdot kg/cm^2$.

Discussion

In the past 80 years, four major studies have been published concerning experimental attempts to determine the velocity necessary for penetration of skin by bullets and missiles [*2-5*]. Only two of these papers merit attention in our opinion. The first and perhaps the best article was by Journée in 1907 [*2*]. He noted that missiles with a velocity of 80 to 200 m/s (262 to 656 ft/s), which rebounded from the skin of horses, penetrated up to 20 cm (7.9 in.) of muscle after the skin had been removed. Using human cadavers, Journée found that an 11.25-mm (0.443-in.) diameter lead ball weighing 8.5 g, striking skin at a velocity of 60 m/s (197 ft/s), produced only superficial skin damage, rebounding without penetration. At a velocity of 70 m/s (230 ft/s), the ball perforated skin, penetrating into underlying muscle for several centimetres. The E/a for this last shot was 2.14 $m \cdot kg/cm^2$.

The second article was by Mattoo et al [*3*]. Even though almost 70 years separate this article and that of Journée, the results were almost identical. Mattoo et al used a missile 8.5 mm in diameter (almost exactly three fourths the diameter of that used by Journée) and weighing 4.5 g (just over half the weight). Abrasions of the skin occurred at 62 m/s (202 ft/s). Perfora-

TABLE 1—*Results with the .177 air rifle.*[a]

Impact Velocity, ft/s[b]	Penetrated Skin	Perforated Skin	Depth of Perforation in Muscle, mm
241	−	...	...
260	−	...	...
273	−	...	...
273	−	...	...
278	−	...	...
280	−	...	...
285	−	...	...
290	+[c]	−	...
292	+[c]	−	...
297	−	...	...
311	−	...	...
315	+[c]	−	...
317	−	...	...
317	−	...	...
317	−	...	...
321	−	...	...
328	−	...	...
331	+	+	17
331	+[c]	−	...
333	+	+	13
336	−	...	...
338	−	...	...
351	+	+	17
352	−	...	...
358	−	...	...
365	+	+	4
368	+	+	28
370	+	+	15
380	+	+	15
381	+	+	10
402	+	+	not recorded
406	+	+	20
407[d]	+	+	*15*

[a]+ = yes, − = no, and ... = determination cannot be made.
[b]1 ft/s = 0.305 m/s.
[c]Base projected from skin.
[d]Thirteen other velocities were recorded (409, 416, 418, 419, 424, 431, 432, 438, 450, 482, 483, 488, and 500 ft/s). The pellets perforated the skin at all of these velocities.

tion of skin with penetration into underlying muscle to a depth of 2.9 cm (1.14 in.) occurred at a velocity of 71 m/s (234 ft/s) with the E/a for this latter missile being 2.06 m·kg/cm^2.

Both Journée and Mattoo et al in their studies fail to determine if a marked difference in mass affects the velocity necessary for perforation of skin. Both of their studies involved relatively large caliber (11.25 and 8.5 mm), heavy (8.5 and 4.5 g) lead balls. Most forensic science cases in which determination of perforation velocity is important involve small caliber (0.177 and 0.22), lightweight pellets. Our study used such missiles as well as a heavy, bullet-shaped projectile of relatively standard size (9.119 mm [0.359 in.]). Our data seem to indicate that mass does have an effect on the velocity necessary to perforate skin. This conclusion is shown by comparing the data from the 0.177 pellets and the 0.38 bullets. Perforation with the 0.177 pellet initially occurred at 101 m/s (331 ft/s), while that of the 0.38 bullet occurred at 58 m/s (191 ft/s). The 0.22 pellet fell in between at 75 m/s (245 ft/s). Of note is the fact that the lead caliber 0.38 bullet closely approaches in caliber (9 mm) and mass the mis-

TABLE 2—*Results with the .22 air gun.*[a]

Impact Velocity, ft/s[b]	Penetrated Skin	Perforated Skin
205	−	...
212	−	...
223	+	−
233	−	...
235	−	...
237	−	...
244	−	...
245	+	+
245	−	...
246	−	...
247	−	...
257	−	...
258	+[c]	−
258	+	+
259	−	...
260	−	...
262	+	−
263	−	...
264	+	+
265	−	...
267	+	−
267	+	+
268	−	...
272	−	...
274	−	...
283	−	...
285	+	+
292	+	+
295	+	+
298	+	+
306	+	+
307	+	+
312	+	+
316	+	+

[a]+ = yes, − = no, and ... = determination cannot be made.
[b]1 ft/s = 0.305 m/s.
[c]Base flush with skin.

siles used by Journée and Mattoo et al. With the .38 Special revolver, the velocity necessary for the bullet to perforate 58 m/s (191 ft/s), was very close to that of Journée, 70 m/s (230 ft/s) and Mattoo et al, 71 m/s (234 ft/s).

Thus, on the basis of our experiments we conclude that lightweight missiles, such as 0.177 pellets, require a velocity of at least 101 m/s (331 ft/s) to perforate skin. In contrast, if the missile is heavy, more like that of a regular caliber 0.38 bullet, a minimum velocity of 58 m/s (191 ft/s) is necessary. This last observation is of importance in that if a standard pistol bullet missed or perforated its target it would be dangerous as long as it had a velocity of 58 m/s (191 ft/s) or more.

Comparison of the *E/a* values in our three tests to results of Journée and Mattoo et al showed findings approximately equal for the 0.177 pellets and 0.38 bullet. The 0.22 pellet, however, had a lower *E/a*.

TABLE 3—*Results with caliber .38 round-nose bullet.*[a]

Impact Velocity, ft/s[b]	Penetrated Skin	Perforated Skin	Depth of Perforation in Muscle, mm
145	−	...	...
159	−	...	...
160	−	...	...
166	−	...	...
166	+[c]	−	...
169	−	...	...
173	−	...	...
177	−	...	...
191	+	+	40
238	+	+	25
238	+	+	60
314	+	+	50
322	+	+	45
332	+	+	70[d]

[a]+ = yes, − = no, and ... = determination cannot be made.
[b]1 ft/s = 0.305 m/s.
[c]Base flush with skin.
[d]Exited.

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Address requests for reprints or additional information to
V. J. M. DiMaio, M.D.
Chief Medical Examiner
Bexar County
600 N. Leona St.
San Antonio, TX 78207