AD 633630

USAARU REPORT NO. 66-7

EXPECTED INJURY RATES FOR EXPERIMENTAL AIRBORNE OPERATIONS

By

R. A. Avner, 1st Lt., MSC

JUNE 1966

U. S. ARMY AEROMEDICAL RESEARCH UNIT
Fort Rucker, Alabama

U. S. Army Medical Research and Development Command

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ABSTRACT

Probability of injury for Army paratroopers under conditions of full combat load and unprepared drop zone was estimated to be .006 (standard error = .002, N = 5,253). Tables were computed to allow tests of departure from this rate under experimental conditions involving up to 50 jumpers.

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EXPECTED INJURY RATES FOR EXPERIMENTAL AIRBORNE OPERATIONS

INTRODUCTION AND PURPOSE

Superior equipment and training have led to an extremely low injury rate for U. S. Army parachutists. Under general unit training conditions about 1.7 injuries would be expected for every 1,000 jumps (P=.0017, standard error = .0002, N = 137,966). Under conditions of full combat load and unprepared drop zone this rate increases to about 6 injuries per 1,000 jumps (P = .006, standard error = .002, N = 5,253)*. The latter rate is probably typical of what can be expected under these more severe conditions. Both British Army parachutists (Whittingham) and U. S. Forest Service "smokejumpers" (King) are also reported to have an injury rate of about .005 under similar severe conditions.

Base injury experience has several uses in development of new airborne equipment or techniques. In the case of innovations intended to increase safety, it serves as a basis for measurement of improvement. In the case of innovations intended to meet situations which are more hazardous than usual, it can serve as a basis for measure of the "loss" or "payment" exacted (i.e., increased injury rate) for the "gain" attained (the ability to meet the new situation).

In either case, it is usually not economically feasible to evaluate new developments by use of samples of the size upon which the base rate has been determined. Use of smaller samples (e.g., 50 or fewer jumps) leads however to a less precise estimate of the injury rate. With small samples the injury or non-injury of a single man can make relatively enormous changes in the observed injury rate. If one out of a group of ten men is injured the observed injury rate for this group is 10% (or 100 per 1,000). Yet, if this is the only injury in ten groups of ten men each the observed rate is only 1% for this larger group of 100 men. Thus, there is a possibility that even for low general injury rates some small samples will occasionally show much higher observed rates. It is the purpose of this report to show with exactly what probability relatively large observed rates of injuries might occur in small samples from a population in which the true injury rate is relatively small. The major use of such information is in evaluation of ongoing programs. It is undesirable to terminate an experiment because of an "excessive" injury rate when in fact the

* Almost exactly half of these injuries were severe enough to require evacuation to permanent medical facilities and subsequent hospitalization. There were no fatalities.

injury rate is not significantly different from that expected by chance variation in the base rate. It is even more undesirable not to terminate an experiment simply because the actual number of injuries is small when this number indicates an injury rate significantly in excess of the acceptable rate.

TESTING DEPARTURES FROM STANDARD INJURY RATES

If production of injuries is assumed to occur at random with a fixed probability in a given sample group, the number of injured in this sample group will follow the binomial distribution. Normal approximations to the binomial unfortunately have relatively large errors when P approaches zero or unity even for reasonably "large" samples of N = 100. It is therefore necessary to perform any tests by use of the appropriate exact binomial distribution.

The most efficient manner in which such tests could be run is probably some form of sequential analysis (Wald) in which small samples are observed in sequence until the hypothesis of "no departure from standard rates" is either accepted or rejected. Unfortunately one of the conditions of military parachuting is usually that jumping is performed in moderately sized groups (20 to 50 men). Jumps made by smaller groups could probably not be used for a valid estimate of the results of jumps made under more typical conditions. Thus decisions must usually be based on one or two independent jumps by groups totalling less than fifty men.

The inclosed binomial table gives the expected probability of varying numbers of injuries for groups of up to 50 jumpers when the true injury rate is 6 per 1,000.

USE OF TABLE

The major use of the table is in determining if an observed injury rate is significantly higher than the expected combat-load injury rate. If it has been decided that the presence of a significantly higher rate is unacceptable, such a finding would support the termination of the test.

The procedure to be used consists of two steps. First a probability value is chosen which corresponds to how frequently the experimenter is willing to mistakenly halt the experiment when the injury rate is actually no more than normal. This is called the "alpha level" in statistical terminology. An alpha level of .01 would indicate that the experimenter is willing to have this error happen once in every 100 tests, a level of .001 indicates once in every 1000 tests, and so forth. Second, following a jump, the number of injuries is counted and the tabled probability for this many or more injuries in a group of the size used is determined. If this probability is less than the alpha level the experiment is halted, if it is more, there is no significant difference (at the level tabled) between the observed and "standard" injury rate.

If more than one group jumps (up to 50 total) the total injuries and size of the groups may be combined for a more reliable test. This combination is valid only if each of the men jump only once (the same man must not be a member of more than one of the groups).

Choice of alpha level will depend on the objective of the tests. If safety is of first importance the alpha level will be high (e.g., .15 or even .20). If safety is of importance secondary to another objective, the alpha level will be low (e.g., .01, .001, or even .0001).

Examples: 1. (a) alpha level chosen to be .01

(b) Observation: 26 men jump, 2 are injured (probability of 2 or more injuries when the true injury rate is .006 is .010633, as given by the table).

(c) Conclusion: do not halt experiment - .010633 is greater than .01

2. (a) alpha level chosen to be .001

(b) Observation: 12 men jump, 3 are injured (this many or more injuries would occur only 46 times in a million when the true injury rate is .006).

(c) Conclusion: halt experiment - .000046 is less than .001.

PRODUCTION OF TABLE

Individual binomial probabilities for P = .006; r = 0,1,7; n = 1,1,50 were computed on a Monroe Epic 2000 electronic calculator. An iterative procedure was used which, coupled with a biased roundoff in this machine, produced a maximum error of about $.5 \times 10^{-12}$ for r = 0. The error for all other values of r was less than this amount. Individual probabilities to 8 significant digits were then summed for each n to verify that this summation was equal to unity. The printed terms of the summation were then used to produce the inclosed 6 place table of cumulated binomial probabilities for p = .006; r = 0,1,6; n = 1,1,50. The table was subsequently proofread twice (independently) against the original printouts of the summations.

				n (number injured)				
N	Zero	1 or more	2 or more	3 or more	4 or more	5 or more	6 or more	N
1	.994000	.006000	-	-	-	-	-	1
2	.988036	.011964	.000036	-	-	-	-	2
3	.982108	.017892	.000108	.000000	-	-	-	3
4	.976215	.023785	.000214	.000001-	.000000	-	-	4
5	.970358	.029642	.000356	.000002	"	.000000	-	5
6	.964536	.035464	.000531	.000004	"	"	.000000	6
7	.958748	.041252	.000741	.000007	"	"	"	7
8	.952996	.047004	.000984	.000012	"	"	"	8
9	.947278	.052722	.001260	.000018	"	"	"	9
10	.941594	.058406	.001569	.000025	"	"	"	10
11	.935945	.064055	.001910	.000034	"	"	"	11
12	.930329	.069671	.002283	.000046	.000001-	"	"	12
13	.924747	.075253	.002687	.000059	.000001-	"	"	13
14	.919199	.080801	.003123	.000075	.000001	"	"	14
15	.913683	.086317	.003589	.000093	.000002	"	"	15
16	.908201	.091799	.004085	.000114	.000002	"	"	16
17	.902752	.097248	.004611	.000138	.000003	"	"	17
18	.897336	.102664	.005167	.000165	.000004	"	"	18
19	.891952	.108048	.005752	.000195	.000005	"	"	19
20	.886600	.113400	.006366	.000228	.000006	"	"	20
21	.881280	.118720	.007008	.000265	.000007	"	"	21
22	.875993	.124007	.007678	.000305	.000009	"	"	22
23	.870737	.129263	.008376	.000350	.000010	"	"	23
24	.865512	.134488	.009102	.000398	.000013	"	"	24
25	.860319	.139681	.009854	.000450	.000015	"	"	25

26	.855157	.144843	.010633	.000506	.000017	"	"	26
27	.850026	.149974	.011438	.000567	.000020	.000001-	"	27
28	.844926	.155074	.012269	.000632	.000024	.000001-	"	28
29	.839856	.160143	.013126	.000702	.000027	.000001-	"	29
30	.834817	.165183	.014008	.000777	.000031	.000001-	"	30
31	.829809	.170191	.014915	.000856	.000036	.000001	"	31
32	.824830	.175170	.015847	.000941	.000041	.000001	"	32
33	.819881	.180119	.016803	.001030	.000046	.000002	"	33
34	.814961	.185039	.017783	.001125	.000052	.000002	"	34
35	.810072	.189928	.018786	.001225	.000058	.000002	"	35
36	.805211	.194789	.019813	.001330	.000065	.000003	"	36
37	.800380	.199620	.020863	.001441	.000073	.000003	"	37
38	.795578	.204422	.021936	.001557	.000081	.000003	"	38
39	.790804	.209196	.023031	.001680	.000090	.000004	"	39
40	.786059	.213941	.024148	.001808	.000100	.000004	"	40
41	.781343	.218657	.025286	.001942	.000110	.000005	"	41
42	.776655	.223345	.026447	.002082	.000121	.000005	"	42
43	.771995	.228005	.027628	.002228	.000133	.000006	"	43
44	.767363	.232637	.028830	.002380	.000145	.000007	"	44
45	.762759	.237241	.030053	.002539	.000159	.000008	"	45
46	.758182	.241818	.031296	.002704	.000173	.000009	"	46
47	.753633	.246367	.032559	.002876	.000188	.000010	"	47
48	.749111	.250888	.033842	.003054	.000204	.000011	"	48
49	.744617	.255383	.035144	.003239	.000221	.000012	.000001-	49
50	.740149	.259851	.036466	.003430	.000239	.000013	.000001-	50

Probability of n Injuries Among N Jumpers (P = .006)

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Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author)
US Army Aeromedical Research Unit
Fort Rucker, Alabama

2a REPORT SECURITY CLASSIFICATION
Unclassified

2b GROUP

3 REPORT TITLE
EXPECTED INJURY RATES FOR EXPERIMENTAL AIRBORNE OPERATIONS

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

5 AUTHOR(S) (Last name, first name, initial)
Avner, R. A., 1st Lt., MSC

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
June 1966	6	4

8a CONTRACT OR GRANT NO

b PROJECT NO 3AO 2560 1A 819

c Task No. 036 (FY 66)

d

9a ORIGINATOR'S REPORT NUMBER(S)
USAARU Report No. 66-7

9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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12 SPONSORING MILITARY ACTIVITY
US Army Medical Research and Development Command, Washington, D. C. 20315

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DD FORM 1 JAN 64 1473

Unclassified
Security Classification

FT RUCKER 066007

Unclassified
Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Aviation Medicine						
Parachuting						
Casualty Rate						
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