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COMPRESSION FRACTURES OF THORACIC VERTEBRAE APPARENTLY RESULTING FROM EXPERIMENTAL IMPACT, A CASE REPORT

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FOREWORD

The testing which forms the basis for this report was conducted under Project 7231, "Biomechanics of Aerospace Operations," Task 723106, "Effects of Vibration and Impact." The tests were conducted in the period January through April 1964. The final physical examination which revealed the injury was in January 1965.

This technical report has been reviewed and is approved.

J. W. HEIM, PhD
Technical Director
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Laboratories

ABSTRACT

The occurrence of compression deformities of the fourth and fifth thoracic vertebrae in a human test subject (DCL) exposed in laboratory experiments to an impact acceleration profile similar to that produced by ejection seat rockets is reported. This injury was presumed to be the result of an impact profile having a peak acceleration of 18.8 G, a rate of onset of 420 G per second and a baseline duration of approximately 100 milliseconds. The subject's long axis was inclined backward 34° from the vertical force vector. The diagnosis was established upon the subject's termination of hazardous duty and separation from the service, approximately one year after the presumptive date of injury. This documented injury represents a demonstrable endpoint in impact tolerance of a subject exposed to an acceleration environment which can be specifically described.

INTRODUCTION

Vertebral fracture is a common injury produced by the force of ejection from high performance aircraft. Although it has been the best documented and most consistent survivable ejection injury, the precise definition of the acceleration environment producing the vertebral damage is usually not available. In conducting an examination of a subject (DCL) upon termination of hazardous duty on the Vibration and Impact Panel, compression deformities of the fourth and fifth thoracic vertebrae were revealed. This injury is presumed to be the result of an impact experiment (conducted for another purpose) in which the acceleration input to the subject can be precisely quantitated. The purpose of this report is to describe the injury and the conditions under which it occurred.

EQUIPMENT

For these studies a seat constructed of welded aluminum plate was suspended from the cantilevered structure of the vertical deceleration tower by a system of suspension rods and force cells. The seat was designed to provide a maximum degree of structural rigidity within the restrictions imposed by the need to maintain a low seat-to-man weight ratio for test purposes. The seat-back to seat-pan angle and the seat-pan to leg-rest angle were both 82°. The seat was suspended from the vertical deceleration tower cantilever so that the seat back was 34° aft of the vertical. The subject therefore received a combination of $+G_x$ and $+G_z$ impact force. This position simulates the orientation of the escape system rocket thrust vector in the operational situation. No seat cushion was used in these exposures. The restraint system consisted of a simulated parachute and restraint harness of the type employed with a full pressure suit. This system is shown in figure 1. A strap over the subject's thighs was used to restrain his legs. This harness was used because of the operational interest in that particular configuration. The subject grasped a nylon strap handle located between the legs in such a fashion that the arms were nearly fully extended. This simulated the body position when ejection is initiated by actuating a D-ring located between the legs.

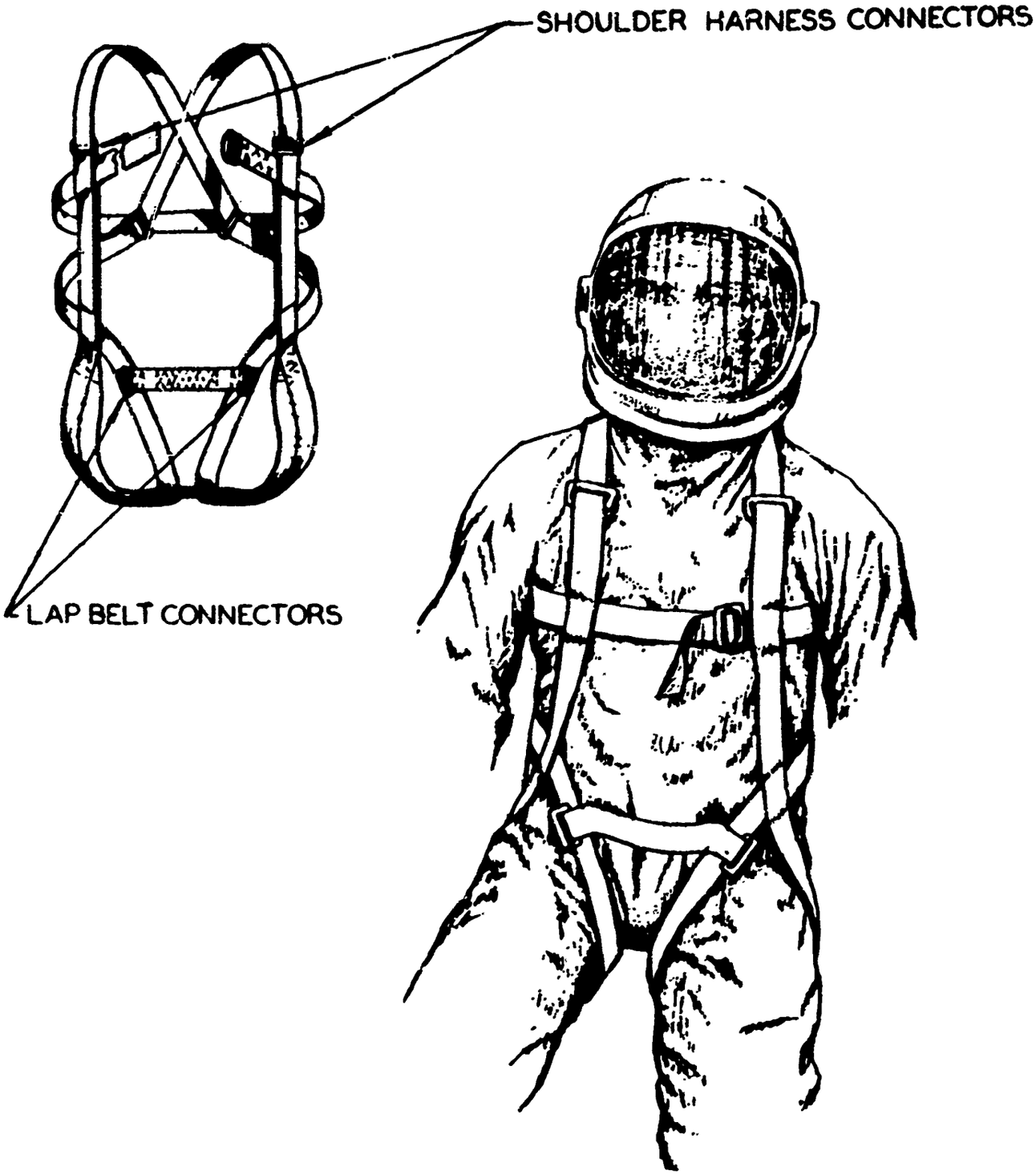

Figure 1. B-5 Restraint Harness

PROCEDURE

For medical safety, the magnitude of the peak G and velocity change were gradually increased to the level required for this operational simulation. This was done by utilizing one of a set of standardized vertical deceleration tower plungers and gradually increasing the drop height in separate experiments with one exposure per subject. The drop height was increased in the following steps: 1.9 meters, 2.5 meters, 3.1 meters, 3.8 meters, 4.4 meters, 5.0 meters, 5.7 meters, 6.3 meters, 7.6 meters. Prior to the tests from the maximum drop height indicated above, no significant adverse subjective responses were elicited in the test subjects.

The impact profile presumed to be associated with the injury is shown in figure 2. The peak acceleration was 18.8 G. The drop height, as shown above, was 7.6 meters, producing a velocity change of 12.2 meters per second. The baseline duration of this profile was 100 milliseconds. The onset rate was approximately 420 G per second.

Four exposures to this profile were made using three subjects. The description of the response of one of the subjects and the subsequent diagnosis of vertebral deformation in this individual form the basis of this report. Neither of the other two individuals, (one a medical officer who received a single exposure and another, who received two exposures separated by a three-month time interval) had significant subjective response to the exposure. Another subject was exposed to the same profile with the orientation almost a pure $+G_z$ vector without adverse response.

SUBJECT BACKGROUND

Prior to acceptance for voluntary hazard duty, the subject's anthropometric examination assured that the vibration and impact restraint systems as designed would provide good body protection during exposure to the experimental environment.

The findings of military physical examinations performed on three previous occasions (including two AF Class III examinations) were essentially normal. The official interpretation of pretest skull, chest and complete spine films was "anomalous osseous swelling on the superior, antero-lateral aspect of the right fourth rib but otherwise normal."

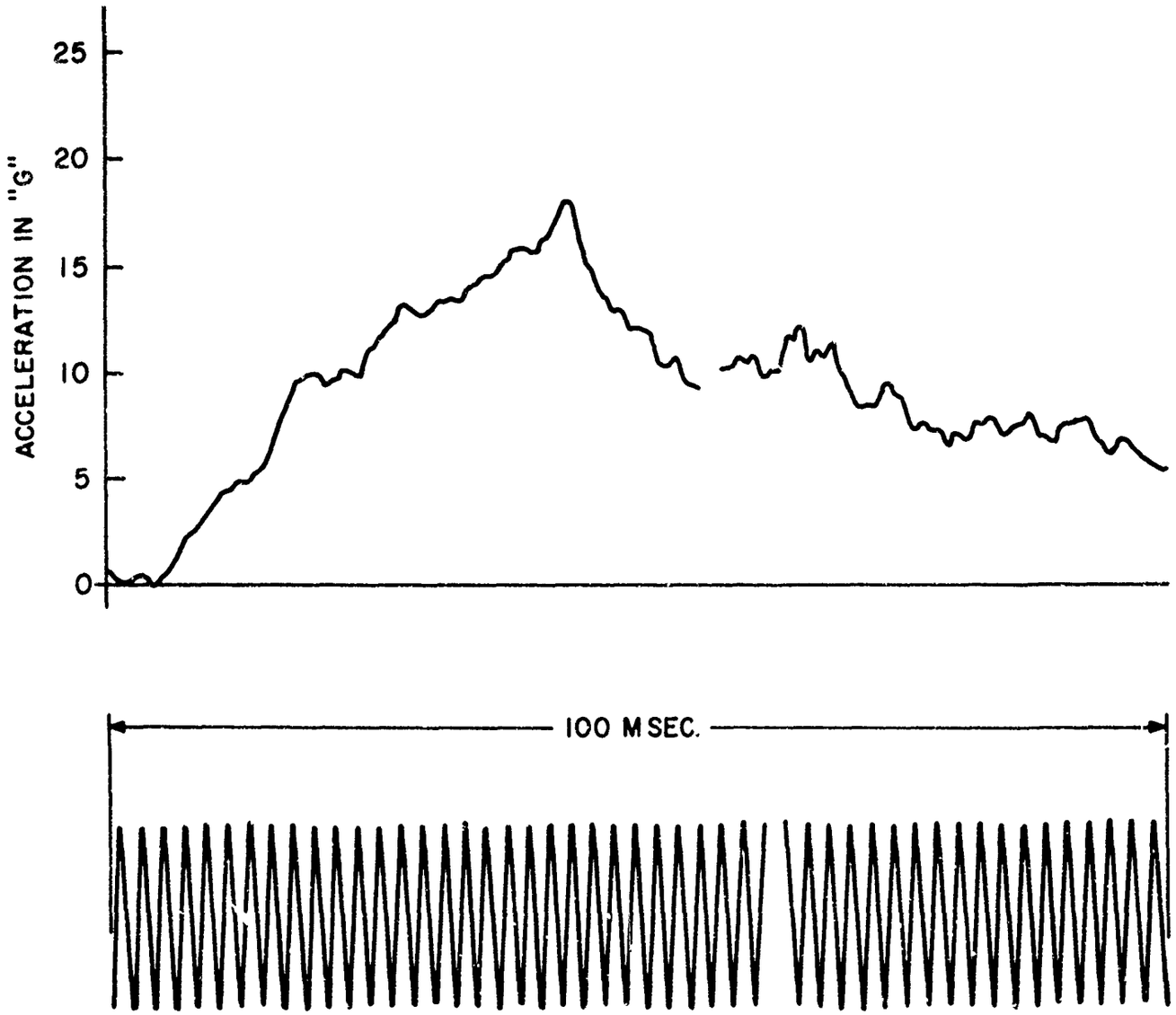

Figure 2. Impact Profile Presumed to be Associated with the Injury

During the year prior to the impact exposure described above, the subject had experienced a number of low level (1.2 G) total body vibration exposures as well as two head vibration exposures. All of these were without complaint or untoward incident. In addition, he had served as a subject in three drop tower experiments all of which were also completed without complaint.

Prior to this presently discussed impact exposure the subject's status and physical findings were completely normal. The physical examination which was conducted immediately after impact was unremarkable. Although the subject was able to egress from his difficult position in the seat with only the usual slight assistance, he did complain of a dull, high, mid-back pain and was rotating his shoulders in an obvious attempt to work out the discomfort. Further examination of this midthoracic area revealed full range of motion, absence of any palpable tenderness and indeed the only remarkable aspect was the symptomatic complaint of the subject. The discomfort rapidly receded and, insofar as similar complaints without sequela were not unusual, the decision was made to follow the subject until the symptom increased or failed to subside. During the ensuing 2 weeks; physician-subject contact was maintained and at the end of this time the subject reported that he felt no residual discomfort.

An analysis of the high-speed motion pictures taken during the drop revealed that prior to impact the restraint harness was secure and body-head position was proper. Upon impact the subject's shoulder, arms and thoracic displacement were actually less than that which occurred in other subjects who received the same profile without incident. The forces exerted by the subject on the seat (measured by force cells) were without overshoot and were comparable in shape to the force time histories of other similar tests.

The subject volunteered for nine low level (1.2 G and below) whole body vibration exposures beginning 50 days after this exposure and recalls no unusual discomfort associated with any of these. Throughout the remainder of 1964 he volunteered for multiple and varied vibration exposures including a single $+G_z$ test. Although most of these were at levels of 1.2 G and below, there were four exposures at levels from 1.8 to 3.9 G. Neither the subject's recollection nor the medical records of the individual exposures document any further back discomfort. Similarly, the subject was unable to recall any falls, back sprains, or other trauma during this period.

When the subject completed hazard duty, the termination films were compared with the initial spine x-rays, and minimal but definite compression deformities of T4 and T5 were observed. Though he was essentially asymptomatic, in view of these findings an orthopedic evaluation was obtained. The orthopedic consultant was of the opinion that the deformity was minimal and should be without sequela.

DISCUSSION

Both the previous test history and operational experience have demonstrated that the profile associated with this injury falls within generally accepted limits of human tolerance. It would, however, be regarded by most experts in the field as the probable upper limit for safe exposure since there is a probability distribution for this type of injury as has been shown by previous analyses (refs 4,5). The restraint and prepositioning under operational circumstances is, of course, not usually as good or as well controlled as it was in this test.

Ejection seats which produce a large velocity change (15-20 meters per second) and a high peak $+G_z$ (17-22 G) have produced a fairly significant incidence of compression fractures of the lower thoracic and upper two lumbar vertebrae. As a general rule pilots sustaining such injuries are able to return to flying status within 6 months after the injury. Hirsch and Nachemson (ref 1) reported on 55 pilots who had had complete spinal x-rays subsequent to catapult ejection. Evaluation of the roentgenograms revealed unsuspected vertebral fractures in 13 of the pilots. All of these pilots returned to flying status after an average convalesence of 2 months.

The site of injury in this subject, T4 and T5, is somewhat higher than is commonly seen in ejection seat injuries where the orientation of the catapult thrust vector (approximately 15 G) produces a more pure $+G_z$ load. Holcomb (ref 2) has encountered a vertebral fracture of T3 associated with an impact vector comprised of $+G_z$ and $+G_x$ components. He postulated an anterior flexion of the thoracic spine resulting from the $+G_x$ force. With the simultaneous $+G_z$ loading, he presumed the preferential high pressure on the anterior lip of the vertebra was sufficient to cause yielding. Although this finding documents another injury of the same general nature caused by the same direction of impact force, it does not provide further support to the theorized mechanics of injury.

Stapp (ref 3) reported a soft tissue injury in the area of T6, T7, and T8 resulting from a combination of $+G_z$ and $-G_x$ load.

Subjects have previously been exposed in this Laboratory to impacts with peaks of 26 G and velocity changes of 8 m/sec in the "forward, up 45°" orientation which is similar to the one used in this study. These subjects occasionally mentioned a mild transient pain over the area of the second through fifth thoracic vertebrae.

The harness used in the thoracic injury reported herein was not optimal but was better than operational harnesses in current use. The total restraint system, as shown by analysis of the high-speed motion pictures, functioned well. The Air Force has adopted arm rests with the ejection hand grips located on these arm rests to provide, among other things, a means of unloading the vertebral column by allowing the arms and pectoral girdle to support a portion of the upper body load during firing of the catapult thereby reducing the pressure on the vertebral bodies. Holding a face curtain during ejection provides similar support. The use of the D-ring, however, permits preimpact loading of the vertebral column by the subject's muscular effort and does not provide unloading of the upper vertebral column during impact. Therefore, this configuration could have contributed to the injury by causing a greater dynamic loading of the upper vertebral column.

REFERENCES

1. Hirsch, C. and A. Nachemson, "Clinical Observations on the Spine in Ejected Pilots," Aerospace Med., 34:629, 1963.

2. Holcomb, G. A. and M. J. Huheey, A Minimal Compression Fracture of T-3 as a Result of Impact, Impact Acceleration Stress, (National Academy of Sciences-National Research Council Publication 977), p 191-194, 1962.

3. Stapp, J. P. and E. R. Taylor, "Space Cabin Landing Impact Vector Effects on Human Physiology," Aerospace Med., 35:1117-1133, December, 1964.

4. Stech, E. L., The Variability of Human Response to Acceleration in the Spinal Direction, Frost Engineering Development Corporation, Report No. 122-109.

5. Stech, E. L. and P. R. Payne, The Effect of Age on Vertebral Breaking Strength, Spinal Frequency and Tolerance to Acceleration in Human Beings, Frost Engineering Development Corporation, Report No. 122-101, January, 1963.

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