AMRL-TR-64-144

A RESTRAINT SYSTEM FOR APPLICATION IN R_Z AND $-G_X$ ACCELERATION ENVIRONMENTS WITH EMPHASIS UPON KNEE AND LOWER LEG RESTRAINTS

ROBERT E. VAN PATTEN

15 P

DECEMBER 1964

BIOPHYSICS LABORATORY
AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

A RESTRAINT SYSTEM FOR APPLICATION IN R_Z AND $-G_X$ ACCELERATION ENVIRONMENTS WITH EMPHASIS UPON KNEE AND LOWER LEG RESTRAINTS

ROBERT E. VAN PATTEN

FOREWORD

This report was prepared by the Multienvironment Division of the Biophysics Laboratory of the Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. Mr. Robert E. Van Patten, Environmental Stress Branch, was the principal investigator. The work was performed in support of Project 7222, "Biophysics of Flight." The restraint system described in this report was developed over the period from December 1963 to February 1964.

Acknowledgement is given to: Captain Charles W. Urschel, USAF, MC, principal investigator in the studies being conducted on the cardiovascular effects of R_z acceleration; Technical Sergeant Clarence F. Wiggins, for his assistance in fabrication; and Mr. John M. Horrocks of the Model and Plastics Section, Aeronautical Systems Division, for his assistance in providing molds and casts of the subjects upon whom the restraints were modeled.

This technical report has been reviewed and is approved.

J. W. HEIM, PhD
Technical Director
Biophysics Laboratory

ABSTRACT

This report describes the development of a lower leg restraint system design suitable for use in yaw (R_z) and transverse P-A G ($-G_x$) acceleration environments. The design is based upon the principle of avoiding restraining force concentrations along the anterior crest of the tibia and has been worn with comfort for periods of up tc three minutes with the legs in a 9.8 G field.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION I

INTRODUCTION

The restraint system covered herein was developed for use during R_z spin studies conducted by the Aerospace Medical Research Laboratories. The studies were made to determine the cardiovascular effects of spin as well as to investigate vestibular thresholds and effects. At the outset it was obvious that a rather specialized restraint system would be required to restrain the head to avoid Coriolis artifacts on the vestibular system which would result from forward and rotary motions about the spin axis. Further, the torso and hips would require restraint, though with the subject's trunk aligned co-linerarly with the spin axis the restraining forces were expected to be slight. The thighs and lower legs, however, presented a different problem.

As distance from the axis of spin increases, so does the centripetal acceleration and thus the thighs and lower legs were, in effect, in a G gradient, the tips of the toes being in the highest intensity field (see figure 1).

Also, owing to the natural pivot points of the hip joints, the knees could be expected to align themselves along radial lines, resulting in forces which would tend to spread the subject's legs apart.

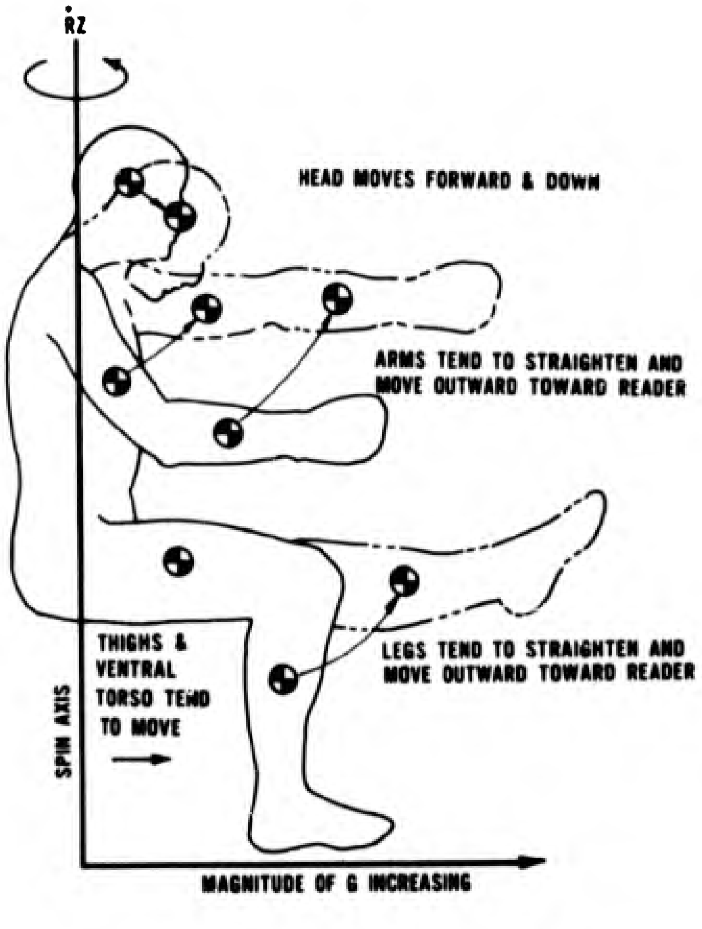

Figure 1. The R_z Acceleration Environment and its Inertial Effects.

The final restraint-system design satisfactorily overcame the problems involved in restraint design for the R_z acceleration environment and is applicable to the $-G_x$ environment as well.

SECTION II

DETAILS OF THE R_z RESTRAINT SYSTEM

The restraint system includes: (1) the head restraint, (2) the torso restraint, (3) the hip restraint, (4) the knee restraint, (5) lower leg restraint, and (6) the foot restraint.

The major details of the head restraint consists of flat reinforcement plates fastened to a conventional crash helmet with swivel fasteners combined with straps and tie plates (see figure 2). The main features of the torso restraint consists of two 3-inch-wide nylon straps crossed at 90 degrees and sewn to a flat nylon chest pad. The torso restraint assembly is tailored to distribute restraint loads almost exclusively over the hard area of the rib cage and, to a very small degree, the clavicles. The restraint straps are secured at the rear of the chair to appropriate aluminum tie points.

The hip restraint is completely conventional; it consists of a standard USAF seat belt installed to bear upon the iliac crests (see figure 2).

The foot and ankle restraint consists simply of 3-inch-wide nylon straps passing across the ankle joint and making approximately a 45-degree angle with the horizontal. The end of the ankle strap is first passed through a center restraint bracket which serves to provide more "wrap" for the restraint and

Figure 2. Head, Torso, and Hip Restraints

thus decrease the opportunity for lateral movement of the feet. The ankle straps are passed through tiedown brackets outboard of the feet and made secure (see figure 3).

The portions of the restraint are straightforward, uncomplicated, and follow conventional practice. The knees and lower leg restraints, however, warrant further discussion in following sections.

Figure 3. Knee, Lower Leg, and Foot Restraints

SECTION III

THE KNEE RESTRAINTS

Owing to the inertial forces developed in R_z and acting upon the legs, it was assumed, at the outset, that there would be a general tendency of the hips to slide outward with a motion aligned along a radial line. The hip restraint could be expected to handle this load; however, to obviate any tendency of the subject to "submarine" under the lap belt, knee restraints were used to oppose the inertial load of the thighs.

These restraints consist of nylon mesh cups tailored to fit the knees (see figure 3). The straps fitted to either side of the individual cups are, in turn, secured to tiedown plates located between the legs of the subject and affixed to the structure of the chair by stranded cables with suitable aircraft-quality and fittings.

During R_z or $-G_x$, the outward radial displacement of the pelvis and thighs is reacted against by both the lap belt and the knee cups, and the loads at the knee cups are transferred back to the hips through the rigid linkage of the femur.

SECTION IV

THE LOWER LEG RESTRAINT

The lower leg restraint used in the early phases of the R_z study consisted simply of 3-inch-wide nylon straps arranged transverse to the long axis of the legs and located 3 to 4 inches distal to the knee joint.

As the rotational speeds used in the tests increased to 90 rpm and above, it was apparent that a change was necessary in the design of the lower leg restraint. The subjects indicated discomfort from the pressure concentration applied by the straps to the anterior crests of the tibiae, and marked impressions of the strap weave were noted in the flesh of the subjects. The situation was further aggravated by the lengthy static-holding times required for checkout and countdown (with the subject restrained) prior to commencement of rotation.

At the cross section of interest in the lower leg, the tibiae lay close to the surface with very little intervening tissue available for the distribution of any loads applied along the anterior crest (see figure 4). It was therefore decided to construct a greave or shinguard-like reinforced fiberglas shell to the contour of the lower leg and to pad this shell with Ensolite (a high hysteresis, dense foam material) having thicknesses in approximately inverse proportion to the thickness of tissue between bone and flesh.

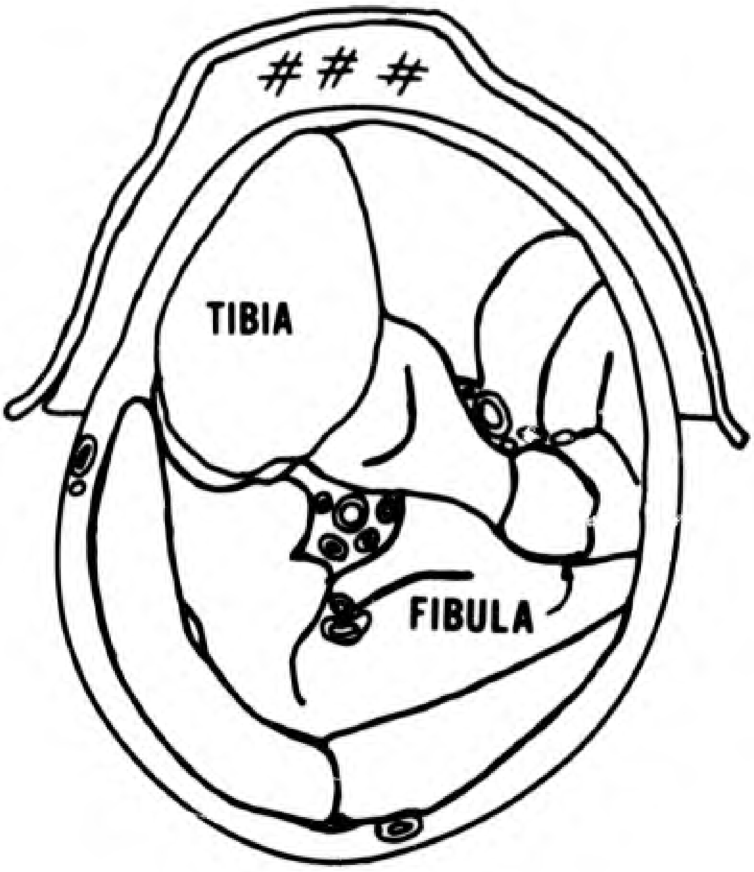

Figure 4. Cross Section of Leg 9 cm Distal to the Knee Joint with Restraint Element in Place

SECTION V

FABRICATION PROCEDURES

Two subjects were chosen to serve as models for the construction of the shells. To make the basic contour molds, each subject was seated (on an elevated platform) in a chair with his legs placed in simple wooden molds. The molds had been bandsawed to the approximate transverse contour of the subject's legs, the anterior halves of his legs thus were enclosed in the mold. The approximate contouring was done after the modelmaker had traced the outline of the inside and outside of the legs on wood.

The molds were then filled with a mixture of clean common core sand and Steinex® binder. After the mixture was tamped to a consistent density, gaseous CO_2 was bled through the mixture, resulting in a chemical reaction with the Steinex® which transformed the mixture into a rigid mass forming a highly detailed molding of the contours.

The resulting molds were then coated with a polyester resin to provide a smooth glassy surface from which a male plaster of Paris cast could be pulled. After the plaster cast was made, it was coated with slab-like layers of modeling clay representing the various thicknesses of Ensolite which were required for distribution of the acceleration loads. The final greave-like fiberglas shell was laid up upon the resulting composite surface.

The finished shells were then equipped with layers of Ensolite varying in thickness from 1/2 inch to 1 inch (see figure 5). To allow subjects to ambulate with the shells in place, tailored, adjustable, nylon-mesh, zippered closures were attached which wrap around the leg and zip up to the posterior of the calf.

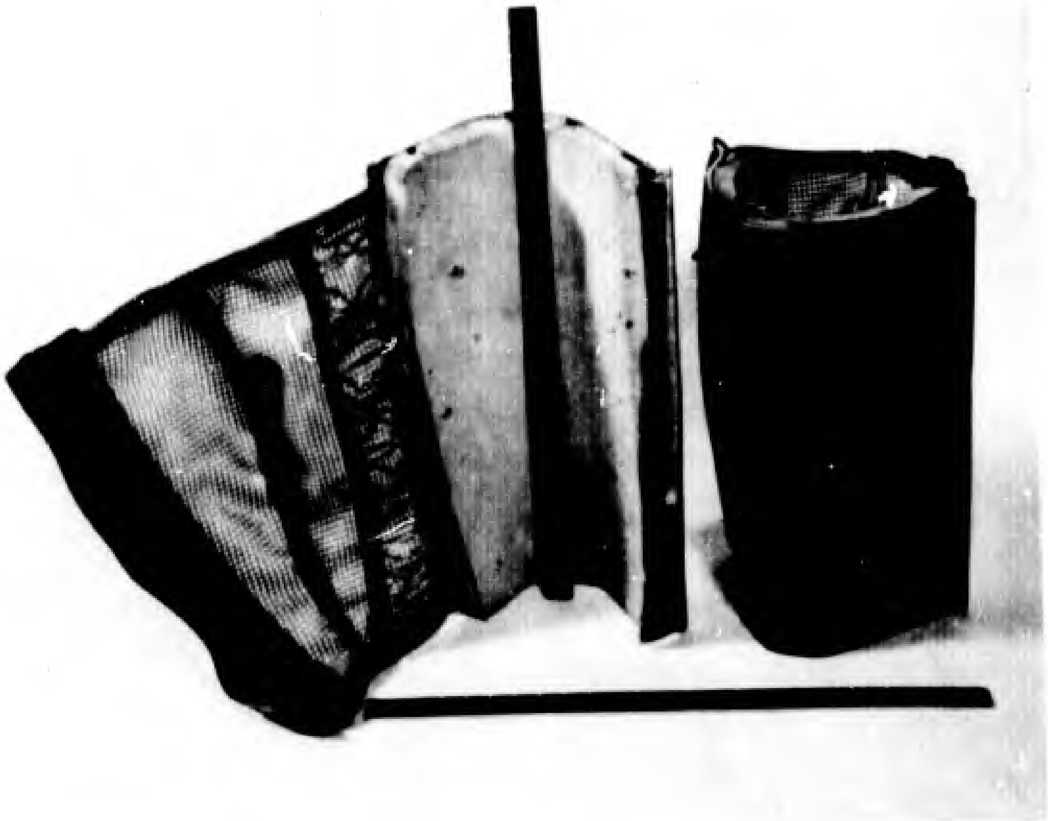

Figure 5. Overall View of Small and Medium Lower Leg Restraints

SECTION VI

RESULTS OF TEST

During subsequent tests, the shells were used exclusively with very good results. The subjects were spun at speeds up to 120 rpm (for periods of from 0 to 3 minutes) which resulted in accelerations of 9 to 10 G being imposed upon the lower legs. During post-run interviews, the subjects unanimously reported complete relief from the hitherto painful restraint-force concentration.

SECTION VII

CONCLUSIONS

The success of the restraint element design warrants the further application of the pressure contour proportioning principle.

Since the design principle is practical for use in the R_z acceleration environment, it could function equally well in the $-G_x$ acceleration environment, as the legs were essentially in a field of $-G_x$ acceleration.

Because it is necessary to develop a six-degree-of-freedom restraint system for use in the Dynamic Escape Simulator under construction at the Aerospace Medical Research Laboratories, further research and development is being undertaken (in-house) to develop the pressure contour proportioning principle in applications to all acceleration axes.

BLANK PAGE

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)*
Aerospace Medical Research Laboratories,
Aerospace Medical Division, Air Force Systems
Command, Wright-Patterson Air Force Base, Ohio

2a REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

2b GROUP
N/A

3 REPORT TITLE
A RESTRAINT SYSTEM FOR APPLICATION IN R_z AND $-G_x$ ACCELERATION ENVIRONMENTS WITH EMPHASIS UPON KNEE AND LOWER LEG RESTRAINTS

4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Final report, December 1963 - February 1964

5 AUTHOR(S) *(Last name, first name, initial)*
Van Patten, Robert E.

6 REPORT DATE December 1964	7a TOTAL NO OF PAGES 7	7b NO OF REFS 0

8a CONTRACT OR GRANT NO.
b PROJECT NO 7222
c
d

9a ORIGINATOR'S REPORT NUMBER(S)
AMRL-TR-64-144

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

10 AVAILABILITY/LIMITATION NOTICES
Qualified requesters may obtain copies of this report from DDC.
Available, for sale to the public, from the Clearinghouse for Federal Scientific and Technical Information, CFSTI (formerly OTS), Sills Bldg, Springfield, Virginia 22151.

11 SUPPLEMENTARY NOTES

12 SPONSORING MILITARY ACTIVITY
Aerospace Medical Research Laboratories,
Aerospace Medical Division, Air Force
Systems Command, Wright-Patterson AFB, Ohio

13 ABSTRACT

This report describes the development of a lower leg restraint system design suitable for use in yaw (R_z) and transverse P-A G ($-G_x$) acceleration environments. The design is based upon the principle of avoiding restraining force concentrations along the anterior crest of the tibia and has been worn with comfort for periods of up to three minutes with the legs in a 9.8 G field.

DD FORM 1 JAN 64 1473
AF-WP-B-AUG 64 400

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Safety devices						
Life support						
Acceleration tolerances						
Safety harness						
Astronauts						
Gravity (artifical)						
Acceleration						
Aviation safety						
Human engineering						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2*a*. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2*b*. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7*a*. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7*b*. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8*a*. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8*b*, 8*c*, & 8*d*. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9*a*. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9*b*. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
____ ."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
____ ."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
____ ."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, *or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.