5-1971

# Effect of body tilt on the constancy of the stereo vertical

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### Abstract
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### Degree Type
Thesis

### Degree Name
Master of Science in Vision Science

### Committee Chair
Colin Pitbaldo

### Subject Categories
Optometry

# EFFECT OF BODY TILT ON THE CONSTANCY OF THE STEREO VERTICAL

A Sixth Year Thesis Presented
to the Faculty of the College
of Optometry Pacific University

by
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In partial fulfillment of the
requirements for the degree
Doctor of Optometry
May 1971

Faculty Advisor
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Approved: 4/8/71 Colin Pitblado

TABLE OF CONTENTS

# I. INTRODUCTION

Many studies have been made on the human observer's ability to perceive the upright under various conditions. The majority of these studies have involved the discrimination of verticality in the observer's parallel frontal plane. Less emphasis has been put on judging the vertical in the subject's median plane. This stereoscopic discrimination of a vertical line and the effect of body tilt upon it is the topic of this paper.

Examining the effect of body tilt in the frontal parallel plane researchers have found that slight amounts of body tilt without a visual frame of reference increases the error in the subjective discrimination of vertical.[1,2,3] These effects in the frontal parallel plane are well documented and known as the "A" and "E" effect. They were discovered by Aubert, 1861, and further studied by Müller, 1916; Passey and Ray, 1950; and Bauermeister, 1964.

Similarily the effect of body tilt in the median plane on judgement of the stereoscopic vertical has been studied. Schubert and Brecher[4] found an apparent displacement of the vertical in the direction of body tilt. Ebenholtz[5] found significant variation in judgements of the vertical involving body tilt in the median plane analogous to the "A" and "E" effect in the fronto-parallel plane. He proposed that the constant error was related to the angle of body tilt, the degree of stereopsis, the length of the rod, the pupillary distance, and the observational distance. The equation presented implies that the subject is able to compensate for the loss of visual information with other sensory modes but systematic variations from the objective vertical are due to the disparity configuration determined by the parameters of the target display.

In contrast, Clausen and Bravo,[6] in a study of the effect of head tilt, found that the perceived stereoscopic vertical is not altered by a change in head tilt. Varying the angle of the head 45° backwards and 45° forwards from a vertical position, with the subject in a sitting position, they found no significant difference between the subjective and objective vertical. The fact that these subjects also worked under reduced cue conditions implies that they were able to use other sensory modes to compensate for the loss of visual information.

Some studies have been made relating the effect of other sensory modalities on the judgement of the upright.[7,8,9] These modalities are vestibular, tactual, and kinesthetic.

Information from at least one of these modes is necessary to resolve the ambiguity of a binocularily disparite target and make a correct vertical judgement.[10]

Other studies have found that the stereoscopic judgements are not determined by one specific display of binocular disparity but on a wide range of displays.[11,12] A subject's ability to adapt to optical distortions and still make correct stereo-localizations tells us that the binocular disparity used is not fixed.

In this study we have deprived the subject of a visual frame of reference and of visual information of his body posture.

By maintaining neck and trunk position constant over all body tilts we eliminated the kinesthetic input to the system. The motor outflow was similarily kept at a minimum as the body rotation was passive - done by the experimenter.

We then tested the subject's ability to judge the verticality of a luminous line under various angles of body tilt in the median plane. We were thus trying to determine whether the subjects could compensate for body tilt using only binocular disparity and postural information from the vestibular and tactile sensory modalities.

## Apparatus

A tilt-table (78" X 30") was constructed, permitting the subjects to be tilted backwards in the median plane (see Fig. 1a). It was covered with a 3" thick slab of polyfoam and was fitted with a footrest and adjustable headrest. The headrest was constructed such that it restrained the subject's head in a straight ahead position. The headrest was adjustable in the mid-frontal (coronal) plane to maintain the head in its normal position relative to the neck and trunk. It was also adjustable vertically to accommodate various subjects over a height range from 4 ft. 8 in. to 6 ft. 4 in.

The table could be swung through an arc of $100^{\circ}$ and could be locked in seven positions, varying in $15^{\circ}$ increments from $0^{\circ}$ (standing perpendicular to the floor) to $90^{\circ}$ (lying parallel to the floor). (See Fig. 1b.) The positioning was such that the exact angle of tilt could be reproduced from subject to subject. In the $0^{\circ}$ position the subject stood on the footrest which was 12" wide and parallel to the floor. A safety strap was installed on the table for the subject's security and to minimize body movement during the testing sequence.

The test target was a bright luminous line 25" long and 0.03" wide. This was achieved by two 12 volt, 1.5 amp bulbs contained in a "black box" which had an opaque glass cover. The test line was formed by scribing the glass cover to make it translucent. The light emitted from the target was insufficient to make any of the apparatus visible to the subject.

The target was pivoted in a supporting frame attached solidly to the table at the head end. The entire target apparatus moved with the table when the table was moved to various angles of tilt. The line could rotate through an arc of more than 180° for any position of table tilt. The target was suspended on a 3/4" wood dowel which rotated in two 1" X 5" X 24" boards attached to the framework. These boards were adjustable up and down in one inch increments through a range of 20 inches. This allowed the center of the line to be fixated with the eyes in the primary position and the head in the normal upright position regardless of the height of the subject. The center of the line was a constant 28 inches from the back of the headrest at all positions of table tilt. This placed the line approximately 20-24 inches from the subject's face depending on head size and facial structure.

A scale marked in degree increments was attached to the center of rotation of the target, and a pointer indicated in degrees the angle of the target. This scale could easily be read to an accuracy of $\pm 0.5^{o}$. The perpendicularity of the illuminated line was checked in all positions, with the subject in the apparatus, using a carpenters plumb-bob. The target was recalibrated in the $0^{o}$ tilt position before testing each subject (see Fig. 1c).

A diffuse beam of light set in a square of white cardboard 12" X 12" was used as a means of preventing the subjects from dark adapting by placing it in front of the subject's eyes except during the actual judging periods.

A pair of adjustable goggles, which restricted peripheral vision, was worn by all subjects. These goggles reduced the peripheral field to $30^{o}$ (see Fig. 1d).

All the apparatus except the white diffuse light occluder was painted with a non-glossy flat black paint. The testing room was totally dark.

Subjects

The 19 subjects, 14 males and 5 females, ranging in age from 12 to 48 years were tested. All subjects were screened for a minimum of 80% stereopsis as measured by the keystone multistereo card, PP-10 (S-2). Nine of the subjects had corrected vision, glasses or contact lenses, and the remaining ten wore no correction. Those requiring the lens corrections wore them during the test sequence.

Test Conditions

The subject was brought into the testing room and the necessary measurements required for adjustment of the apparatus were taken. One experimenter made the appropriate adjustments while the other tested the subject for stereopsis. Those subjects exhibiting less than 80% were excused from further testing and the procedure was started over for the next subject.

After passing the stereopsis test, the subject was positioned on a tilt-table by means of a restraining headrest and a waist strap. The subject was then given the following information and instructions:

"We want you to say 'Now' when the luminous line in front of you appears to be vertical; that is, perpendicular to the floor. We will start each judgement from a preset position with the top either toward you or away from you and slowly move it toward the vertical position." This procedure was then demonstrated with the room lights still on. "From time to time we are going to change the position of the table and ask you to repeat your judgements by saying, 'Now', when the line appears perpendicular to the floor. The test will be conducted in the dark but in between judgements we will hold this diffuse light occluder between you and the test target. We want you to look directly at the light while it is on. This is to keep you from dark adapting." The light occlusion technique was then demonstrated. "Please keep your head stationary in the headrest, moving only your eyes during the test sequence." Restricted viewing goggles were then adjusted to the subject with the explanation that, "these goggles are to restrict your peripheral vision and since there are no lenses in them they will not interfere with your judgements." "During the repositioning of the table we will completely occlude your vision by means of a cover for your goggles." The use of the cover was then demonstrated.

No further information or instructions were given to the subject during the testing sequence. He was not allowed any feedback as to the accuracy of his judgements. Any questions asked concerning the apparatus or test were deferred until completion of the test sequence. Three of the nineteen subjects tested showed some nervousness about their performance at which time they received additional encouragement to relax and were told they were "doing fine."

Following the pre-test instructions the room lights were turned off and the test sequence commenced. Preventing the subject from dark adapting provided further assurance that only the luminous line was visible during the time that vertical judgements were made. The method of adjustment was used with an equal number of preset positions toward and away. The line was moved toward the objective vertical at a steady velocity of approximately $2^o$ per second by the experimenter from randomized preset positions from $5^o$ to $20^o$. The subject was "light-occluded" after each judgement and the line was rotated to a new preset position. This procedure was continued until the subject had made six judgements of verticality at each of seven different positions of body tilt. The subject was totally occluded during movement from tilt position to the next. Approximately one minute was then allowed to "light adapt" and to reduce any motion after-effects.

The seven positions of body tilt used were $0^o$ (perpendicular to the floor - or vertical position), $15^o$, $30^o$, $45^o$, $60^o$, and $75^o$ of backwards tilt and $90^o$ or horizontal (parallel to the floor). The sequence of test positions was $0^o$, $45^o$, $15^o$, $75^o$, $30^o$, $60^o$, and $90^o$ for all subjects. The first position also served as a practice trial to ensure that the subject understood the instructions. The entire test sequence averaged approximately thirty-five minutes per subject.

## II. RESULTS

The subjective vertical measurements were recorded in degrees from an expanded scale accurate to within $\pm 0.5^{o}$. The calibrated objective vertical for the seven positions of body tilt were $90^{o}$, $103^{o}$, $118^{o}$, $134^{o}$, $150^{o}$, $168^{o}$, and $180^{o}$. These calibrations were constant for the target-tilt table assembly and did not vary between subjects.

In order to facilitate data interpretation the target scale was set up such that subjective vertical measurements greater than the calibrated (objective) vertical measurements indicated that the top of the target was tilted away from the subject. Six judgements of vertical were recorded for each position of body tilt. These data were averaged and recorded in Table I for each subject for each position of body tilt with the exception of the horizontal position (i.e., $90^{o}$ of body tilt). The data from this position were eliminated from further analysis because the subject would theoretically have seen the target line as a point when it was in the vertical position. The physical limitations of the target prohibited this observation, thus the error introduced was considered an artifact of the apparatus design and not indicative of subjective error in judgement.

The group performance is summarized in Table III, where it can be seen that the standard deviation, for body tilts of less than $30^{\circ}$, is less than $\pm 2^{\circ}$. For body tilts of $30^{\circ}$ and greater it ranges between $\pm 3.45^{\circ}$ and $\pm 4.75^{\circ}$. The standard deviation increases slightly up to approximately $30^{\circ}$ and then remains essentially constant thereafter. The group mean deviations from the subjective vertical in the upright ($0^{\circ}$ tilt) position are also summarized in Table III. The differences here were less than the group mean deviations from the objective vertical, with the exception of the $60^{\circ}$ body position, thus indicating that if the reference baseline is the perceived vertical in the $0^{\circ}$ body position the subjective and objective verticals are practically the same for body tilts in the median plane ranging from $0^{\circ}$ to $60^{\circ}$.

The group mean deviations of subjective vertical from objective vertical as a function of the degree of body tilt are plotted in Figure 2. In each position of body tilt the group's mean deviation is less than one (1) standard deviation for that position. Figure 2 also contains the lines representing the theoretical conditions in which the judgements of verticality are independent of visual disparity (i.e., a horizontal line at the $0^{\circ}$ deviation from vertical where the subjective vertical equals the objective vertical), and where the judgements are entirely dependent on visual disparity (i.e., a linear function with a slope of one (1) crossing the independent disparity line at the $0^o$ body position). The mean data for the group shows a perfect constancy function.

Data for each of the individual subjects are plotted in Figures 3 through 21, where variations are evident when compared to the group's performance in Figure 2. However, all data indicates that the subjective vertical is close to the objective vertical up to $75^o$ of body tilt.

Neither the individual or the group data were indicative of any constant error in vertical judgements as a function of body tilt in the median plane. The small variations in the group data were within normal variation for psychophysical measurements on human subjects.

## III. DISCUSSION

The results of this study show that the judgement of a gravitationally vertical test line is not significantly affected by body tilt. The angular difference between the subjective vertical and objective vertical is minimal. There is no constant error as the angle of body tilt is increased.

It is clear that body tilt backwards from $0^o$ to $60^o$ does not affect the constancy of the stereoscopic vertical. It is proposed that the variation at $75^o$ and beyond is an artifact of the apparatus and technique.

As a different oculocentric disparity is necessary at each position of body tilt to judge the vertical, our data suggests, similar to Bravo and Clausen 1970, that a constant binocular disparity is not a factor.

In this study as many extraneous clues as possible were eliminated. In the dark, non-adapted state, the subject did not have a visual frame of reference to assist him. He did not have visual information of his angle of body tilt and was unable to observe his own body parts. The visual sensory information was restricted to the binocular disparity of the luminous line.

The kinesthetic information from the neck and trunk was constant over all positions of body tilt as the subject was strapped to a rigid table with the head restrained. Motor outflow information from active participation was also minimal as the rotation was passive - i.e., done by the experimenter. The motor outflow from ocular scanning movements must be inherently ambiguous since they can be programmed relative only to eye-in-head posture and not to gravity.

The possible coding variables in this instance are reduced to the otolith function of the vestibular sense, the tactile sense of weight distribution, and the golgi tendon receptors. Separating these would necessitate running the experiment under null-gravity conditions.

The subject has in his normal interaction with the environment learned to judge the upright in various reclining positions. Eliminating much of the visual information has little effect on this judgement. The binocular disparity he observes is conceivably necessary under these reduced conditions, but not sufficient to make an accurate judgement. The different binocular disparities encountered must be encoded with information from other modalities to make the correct judgement. The binocular disparity alone is ambiguous, but combined with postural information regarding the direction and orientation of the body the ambiguity is resolved and an accurate discrimination made possible.

It is evident that the subjects were able to interpret their angle of body tilt, and choose the proper binocular disparity. This was presumably done by integrating the information received from the visual binocular disparity, and some combination of the otoliths, the tactile sense, and the golgi receptors; then correlating it with previously obtained encoded disparity information.

We probably must assume that normal interaction with the environment provides the subject with a store of encoded postural-disparity information to which he can refer.

Contrary to the results of a similar study by Ebenholtz our data does not support the view that effects analogous to the "A" and "E" effect occur with backward body tilt in the median plane. The fact exists that the equation for angle of tilt of the line from true upright as derived by Ebenholtz is invalid. The subject is able to compensate under reduced cue conditions, and correlate his body tilt with the correct disparity configuration of a vertical line. Any variation of the subject's response from the objective vertical is small and probably does not represent any constant error that can be calculated using the parameters of the target display.

The results of this study indicate that further experiments are needed to tease out the various aspects of visual postural relationships. This kind of research is basic for a better understanding of optometric visual therapy.

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## BIBLIOGRAPHY


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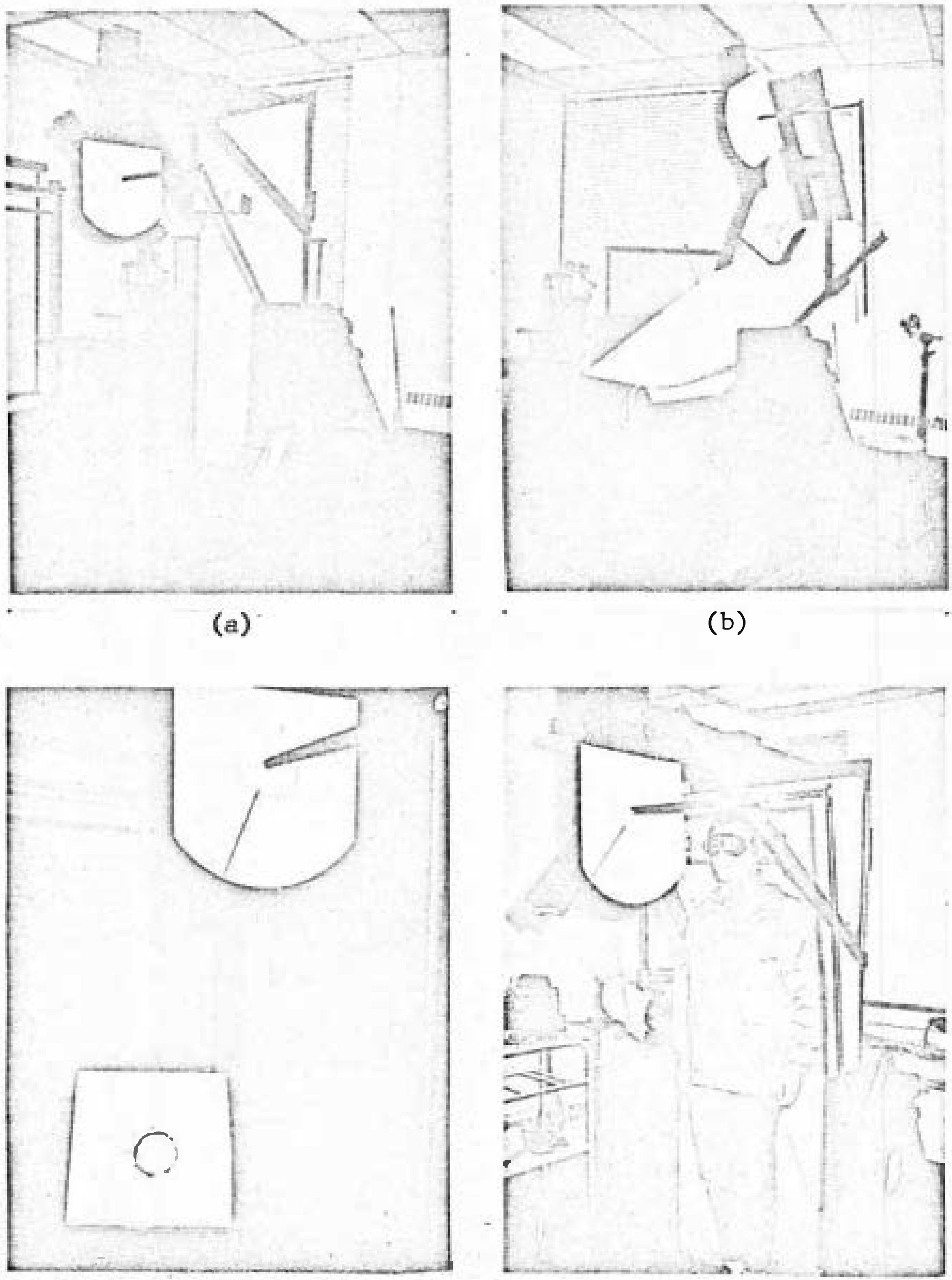
# APPENDIX

FIGURES

Figure 1: Test Apparatus



(a)

(b)

(c)

(d)

Figure 2: Group Mean Deviations of Subjective Vertical from Objective Vertical as a function of the degree of body tilt

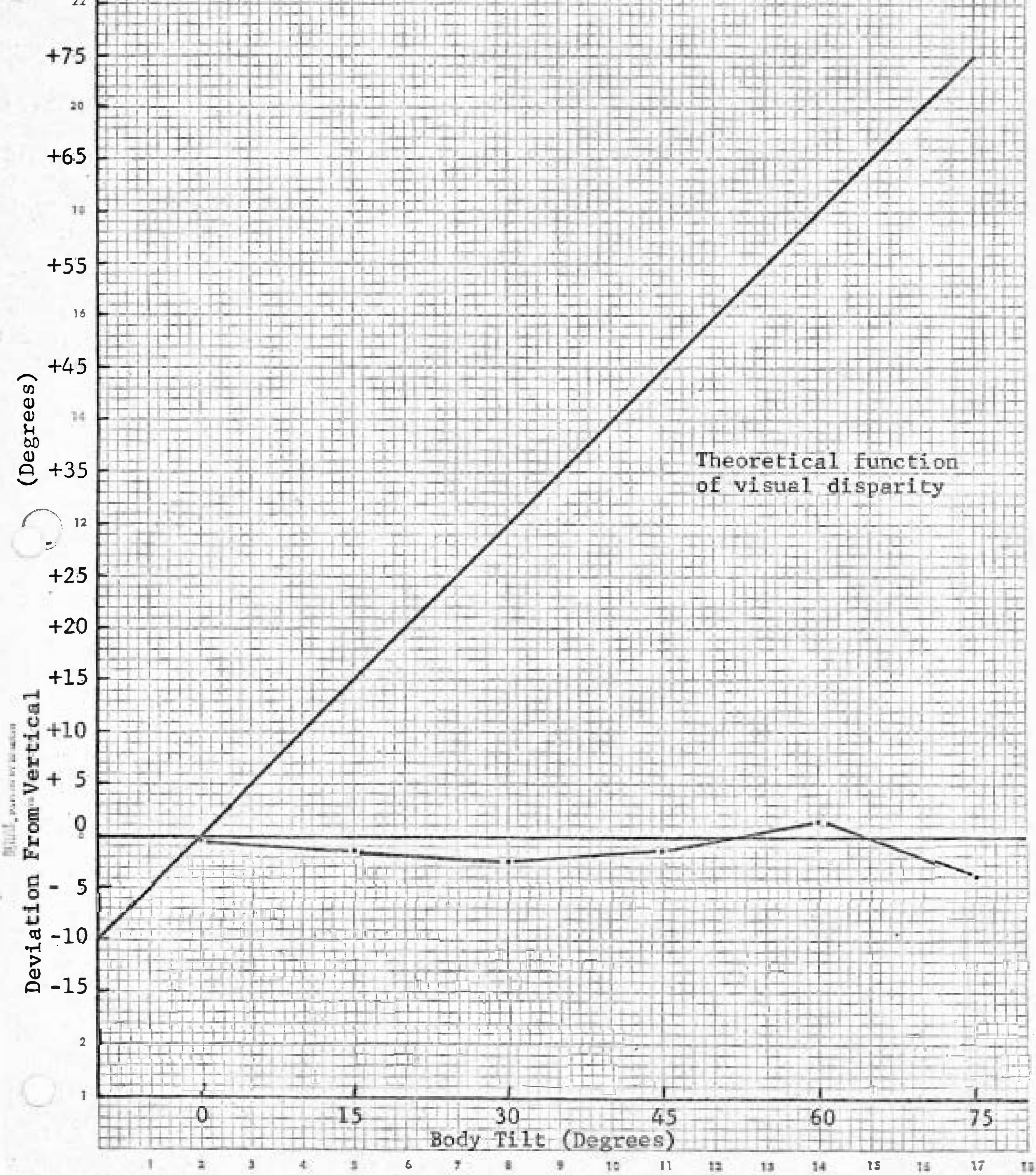


Figure 3: Subject D.H.

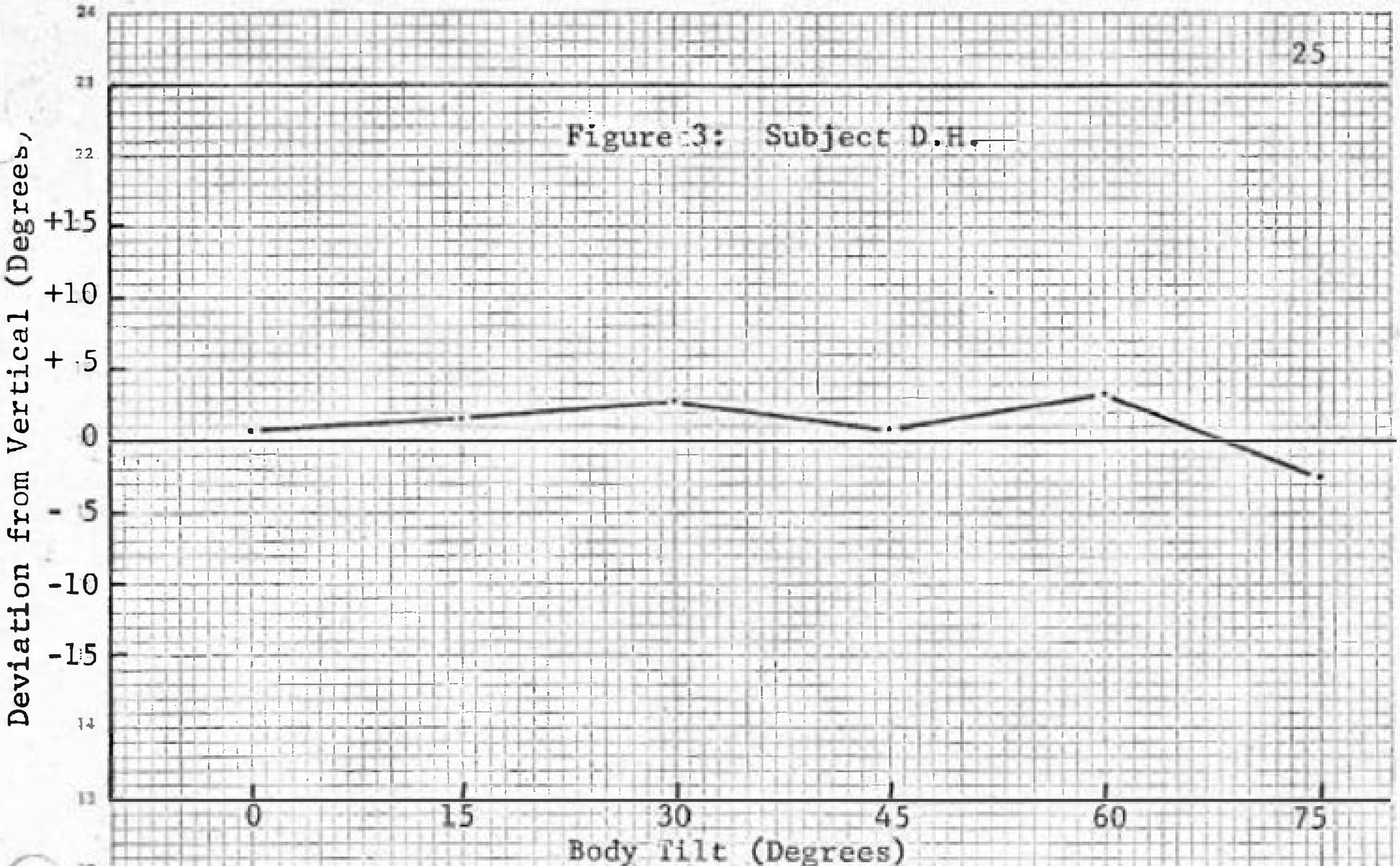
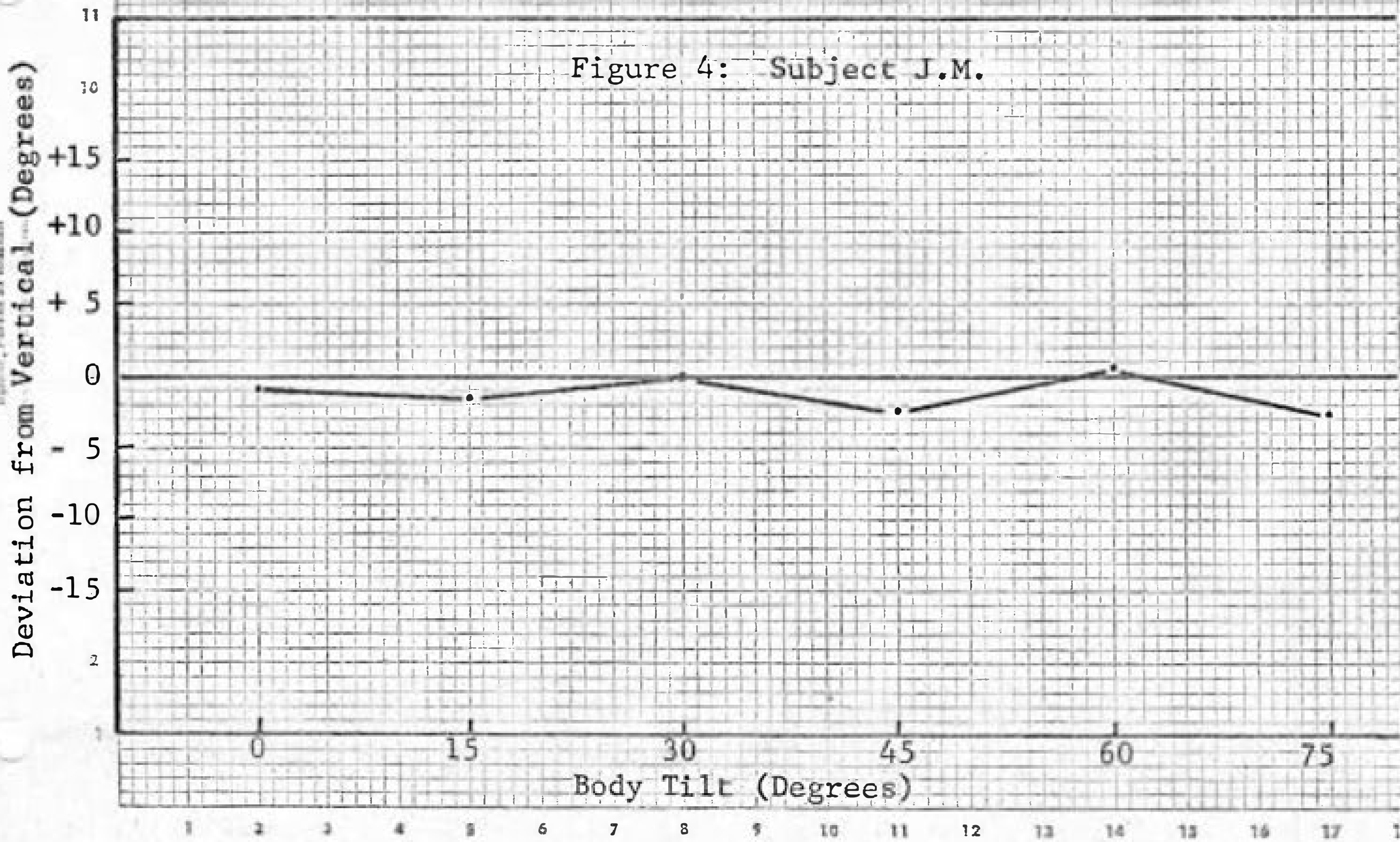



Figure 4: Subject J.M.



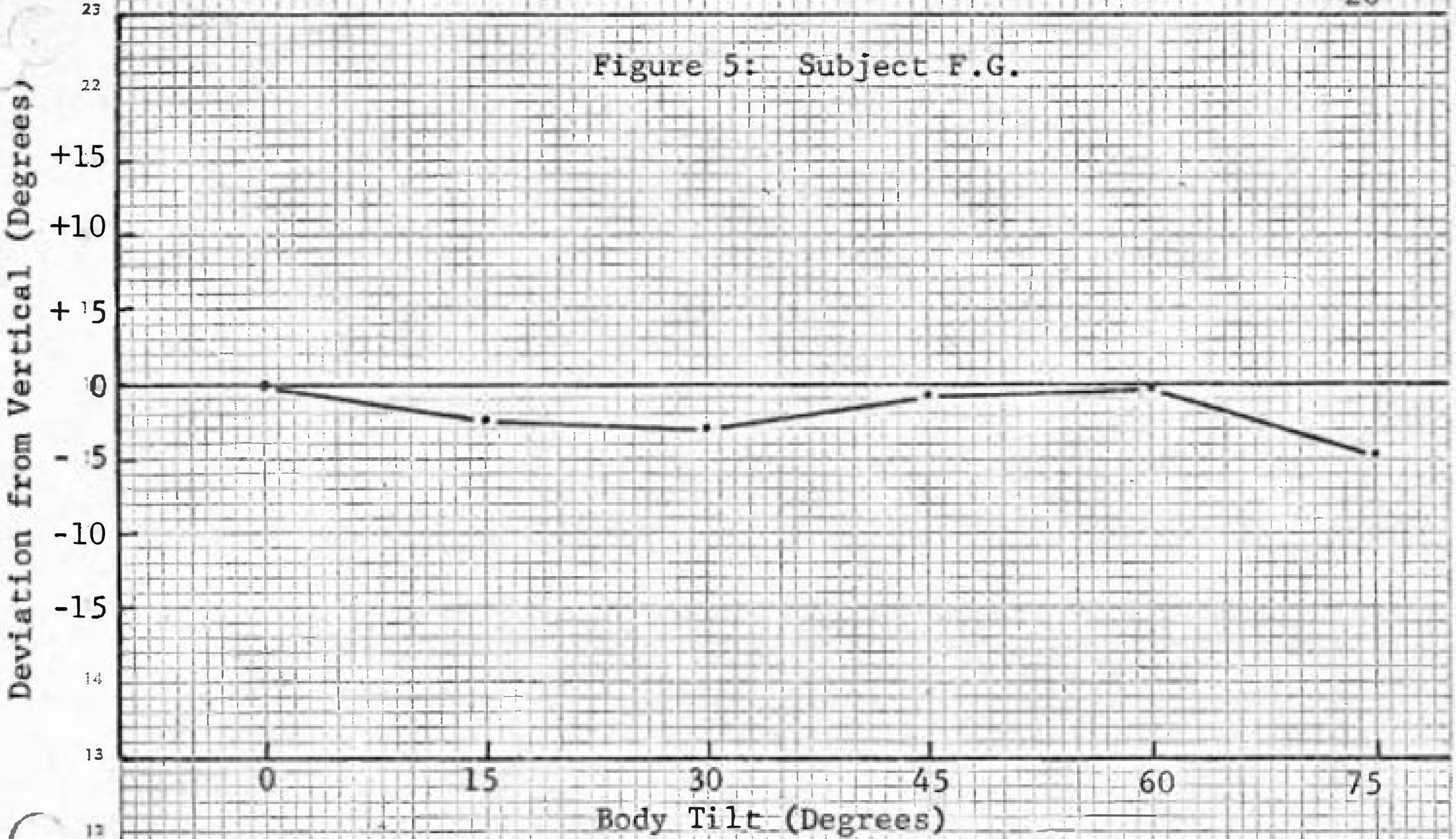



Figure 5: Subject F.G.

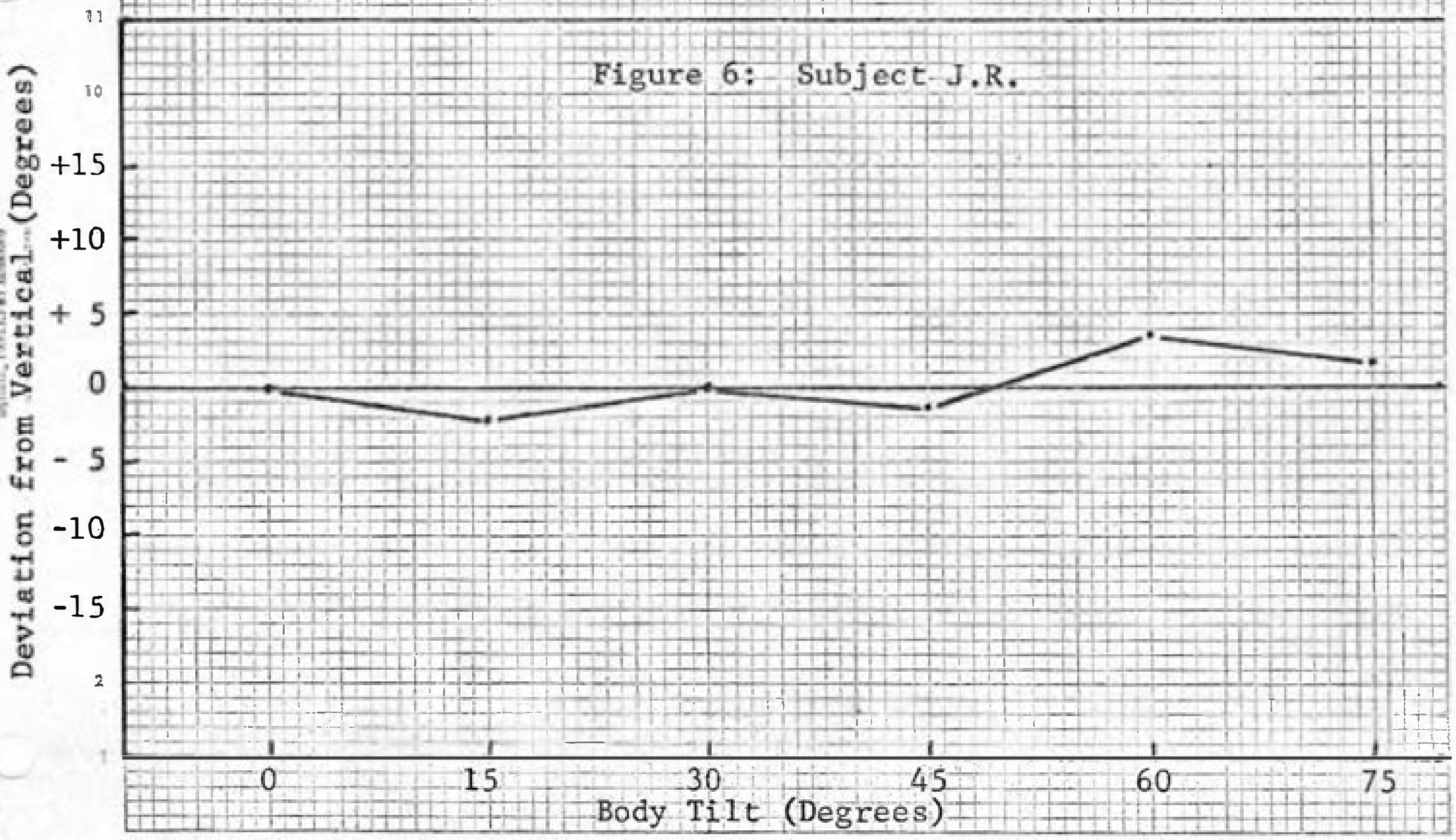



Figure 6: Subject J.R.

Figure 7: Subject W.M.

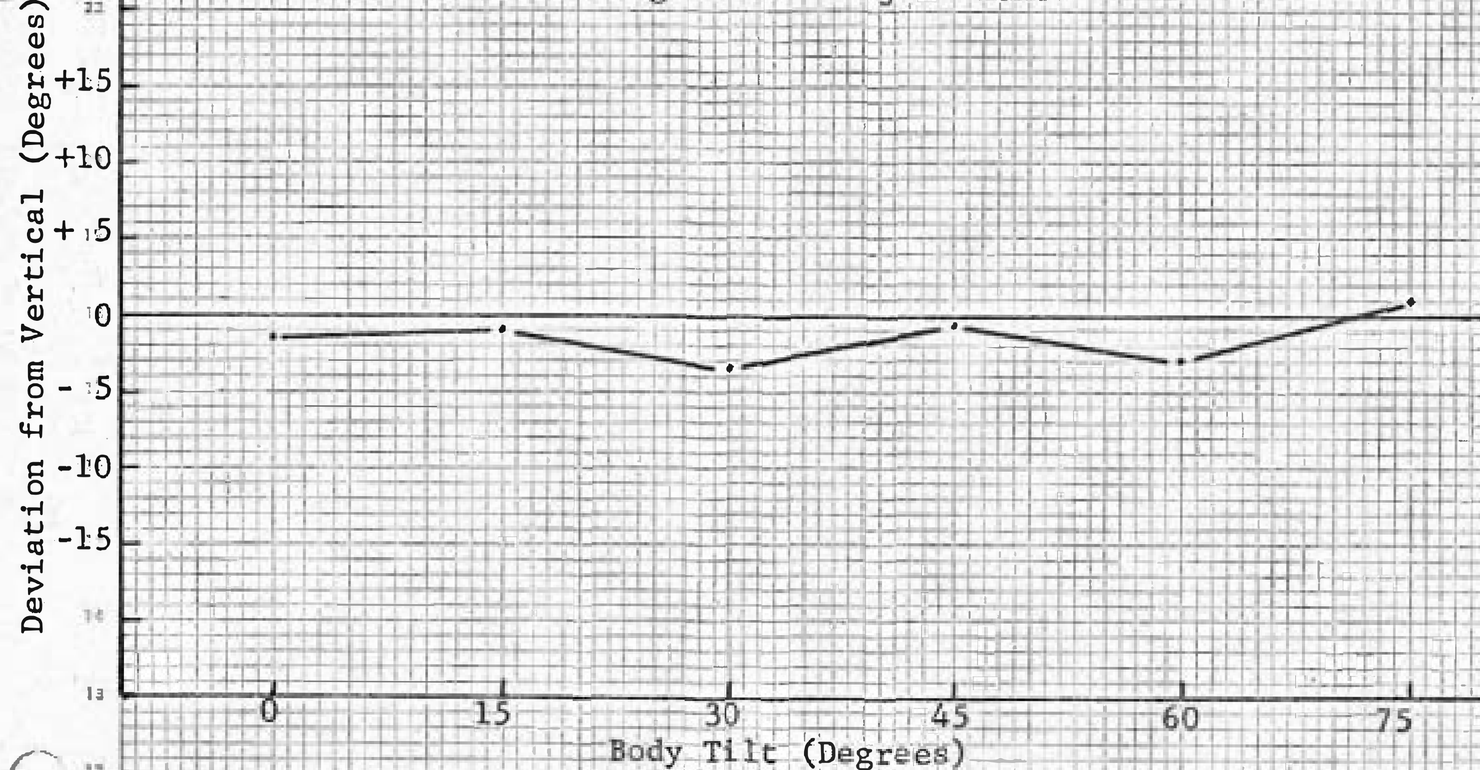



Figure 8: Subject D.W.

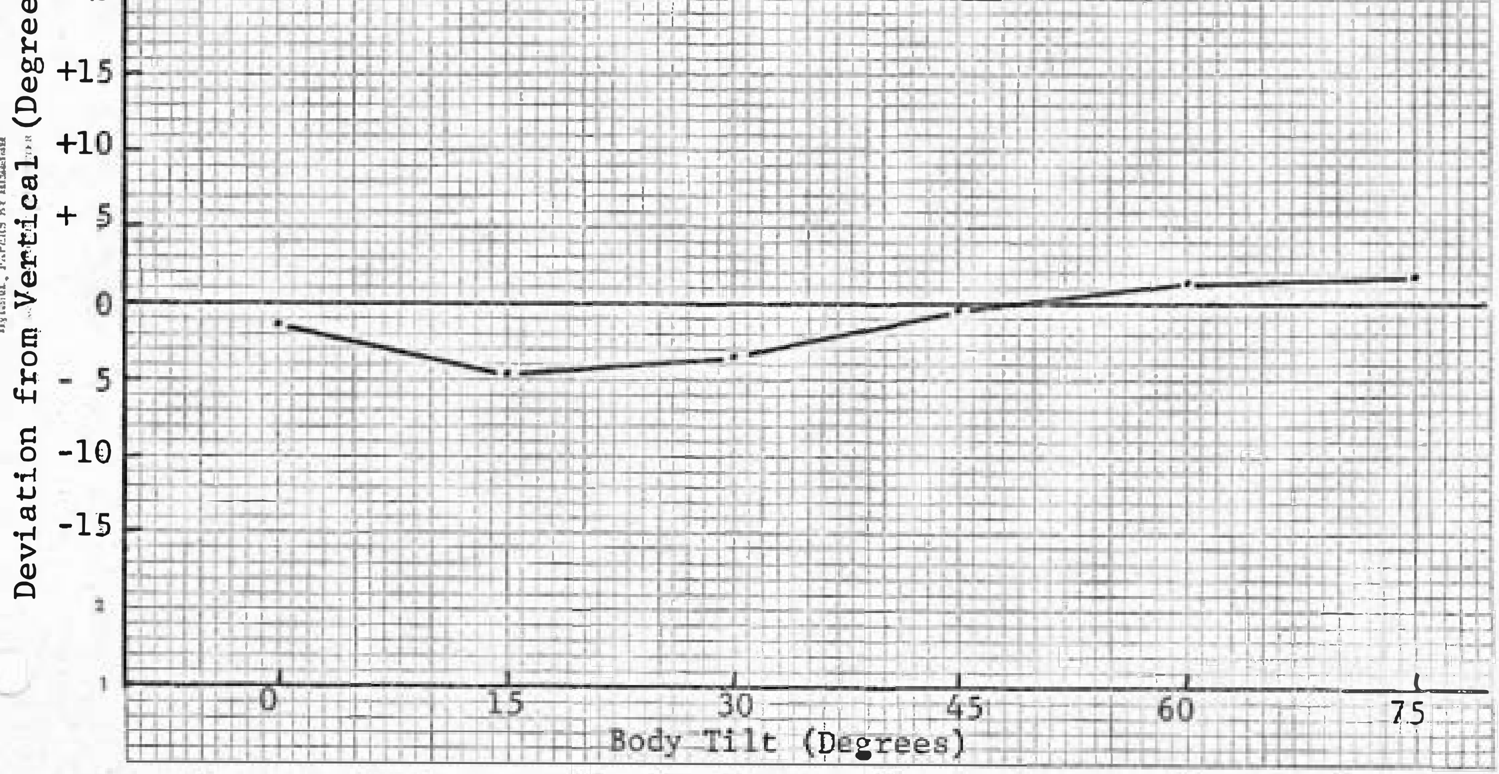


Figure 9: Subject S.H.

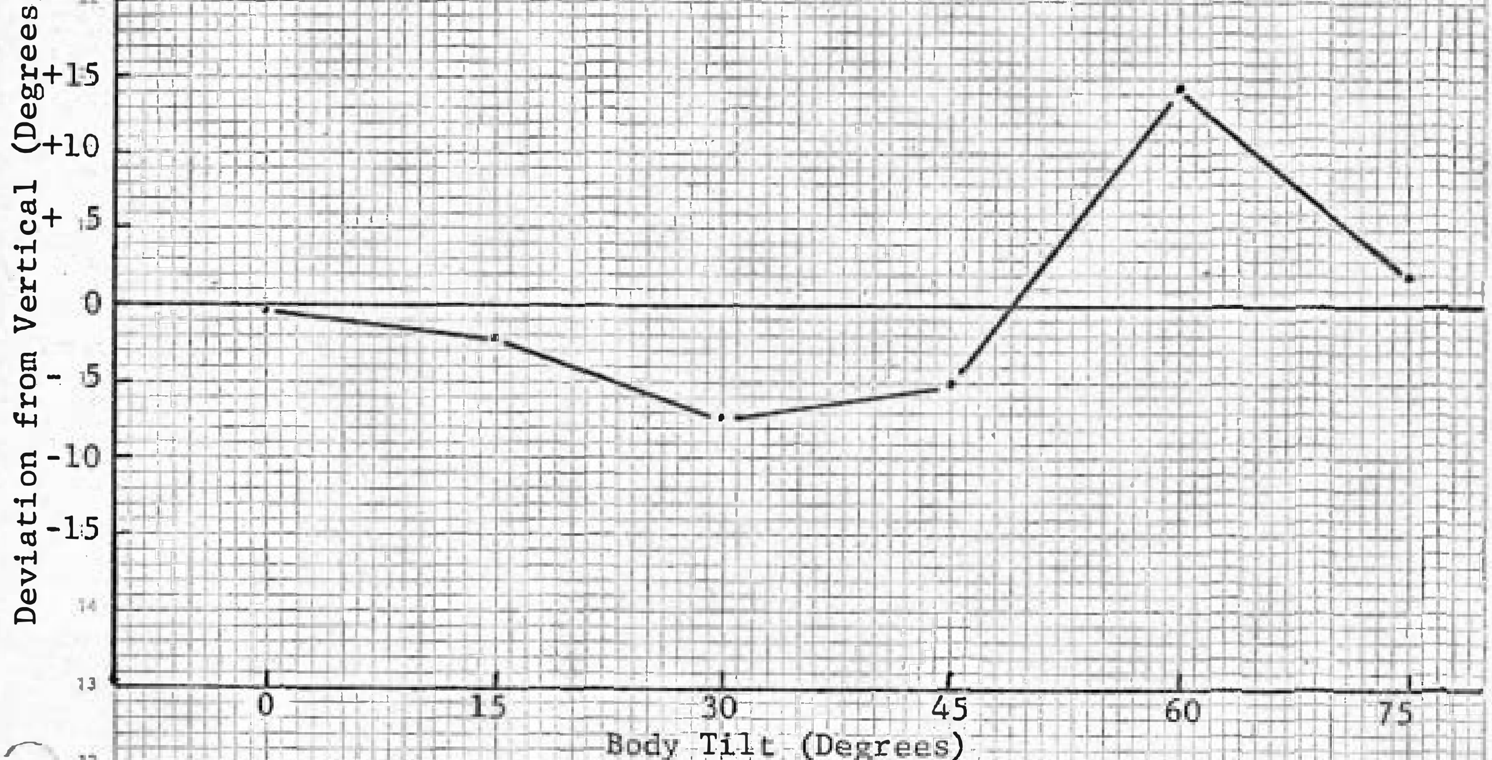



Figure 10: Subject M.G.

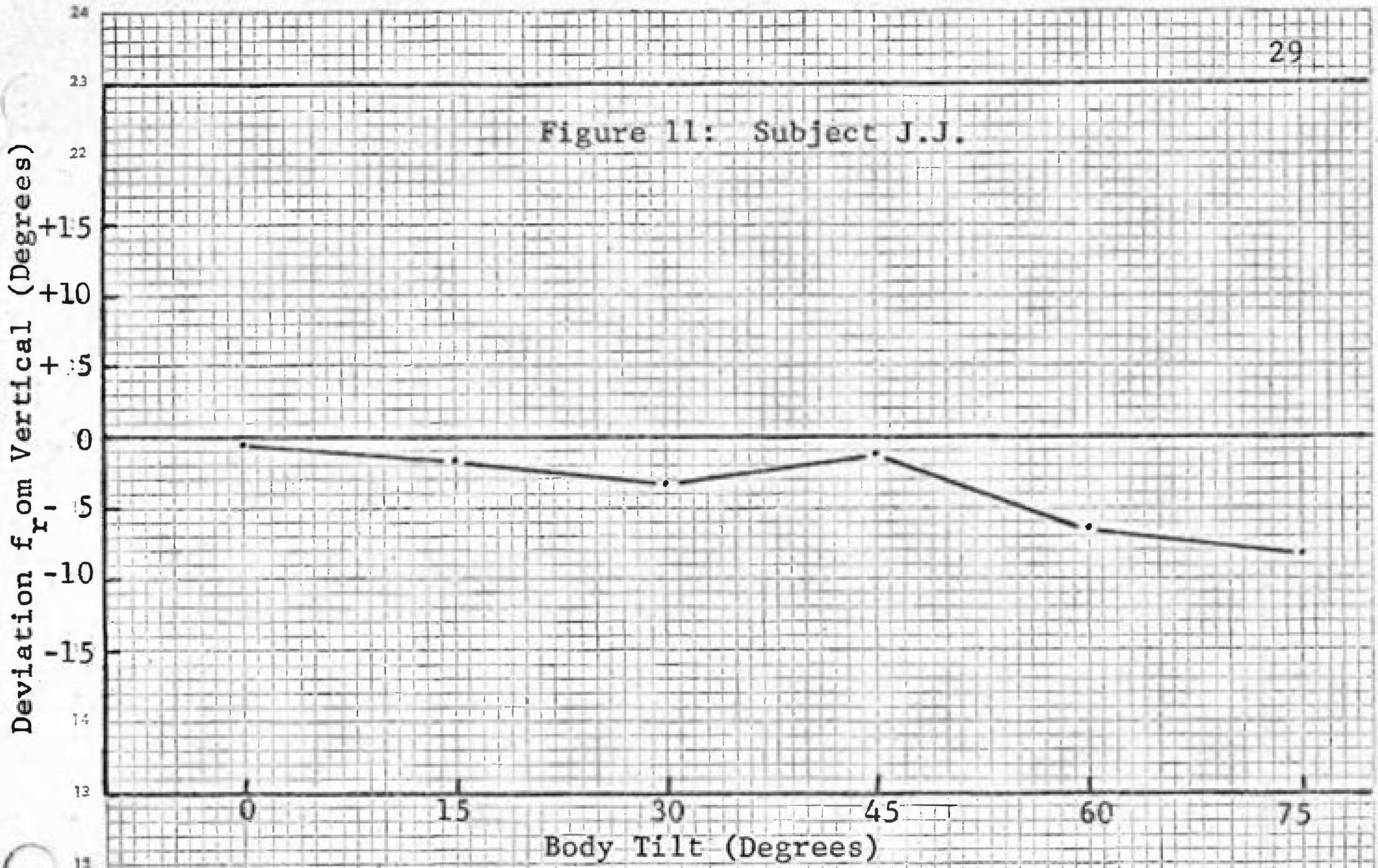


Figure 11: Subject J.J.

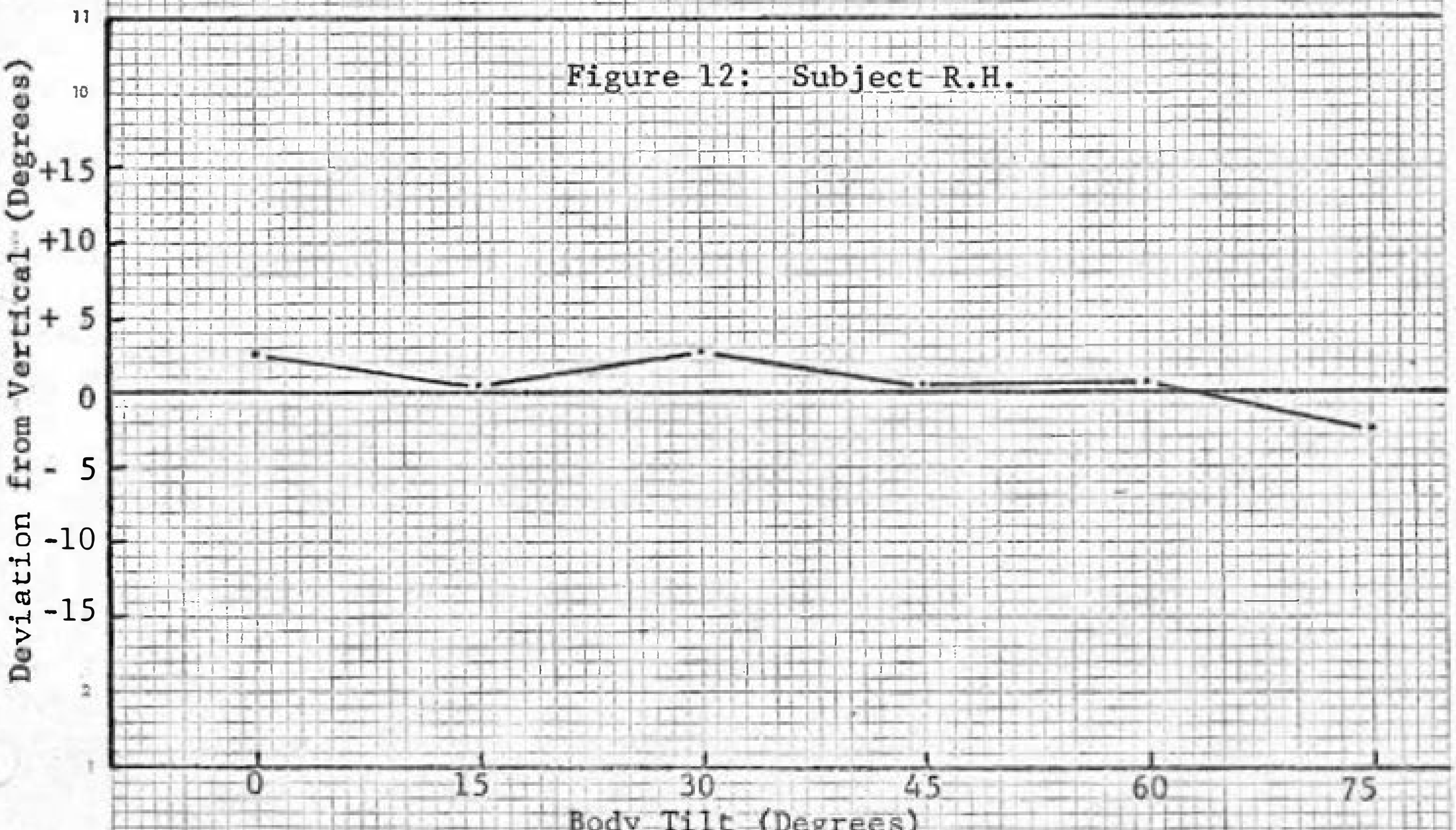


Figure 12: Subject R.H.

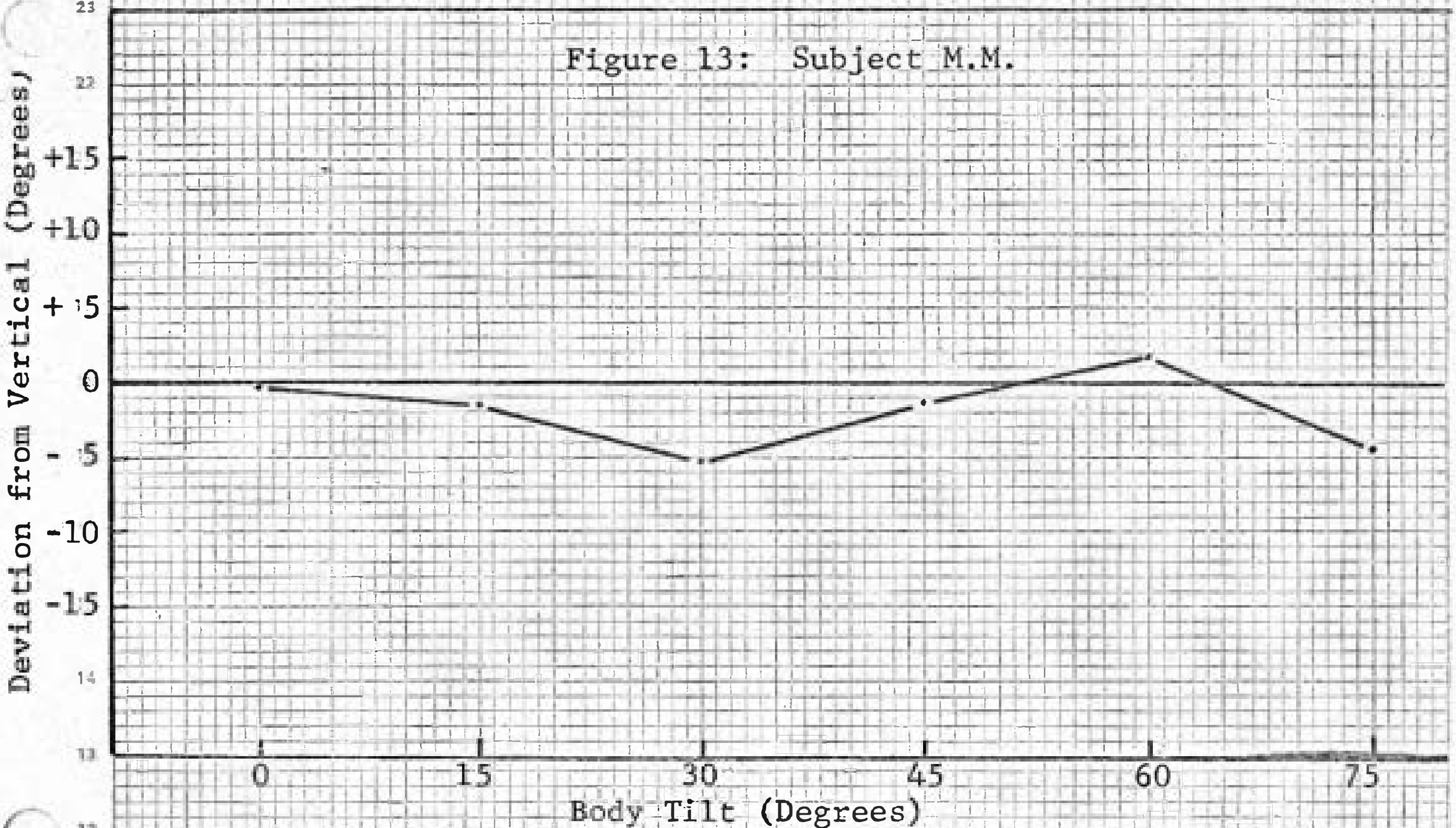


Figure 13: Subject M.M.
Deviation from Vertical (Degrees)
+15
+10
+ 5
0
- 5
-10
-15
0
15
30
45
60
75
Body Tilt (Degrees)

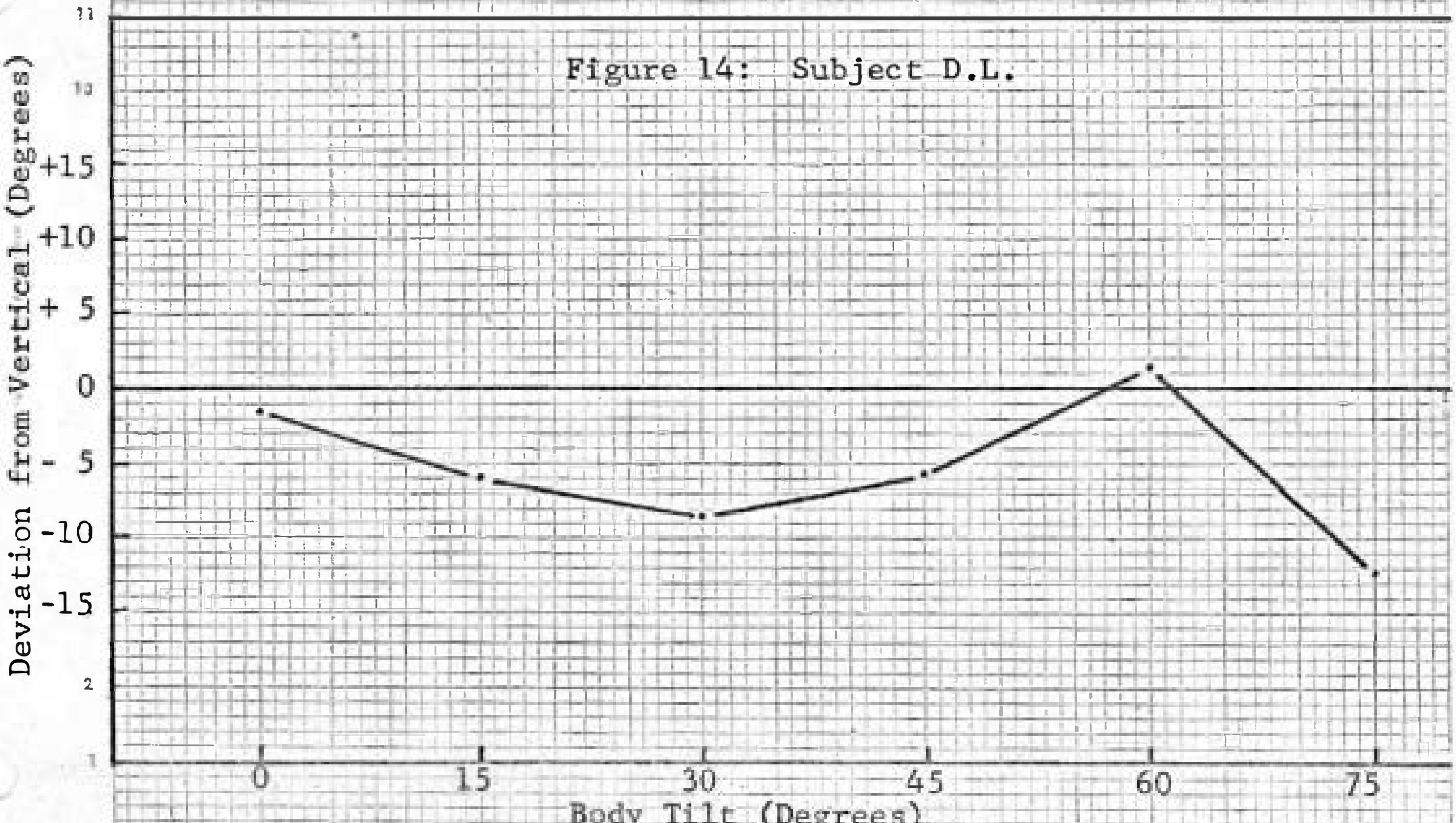


Figure 14: Subject D.L.
Deviation from Vertical (Degrees)
+15
+10
+ 5
0
- 5
-10
-15
0
15
30
45
60
75
Body Tilt (Degrees)

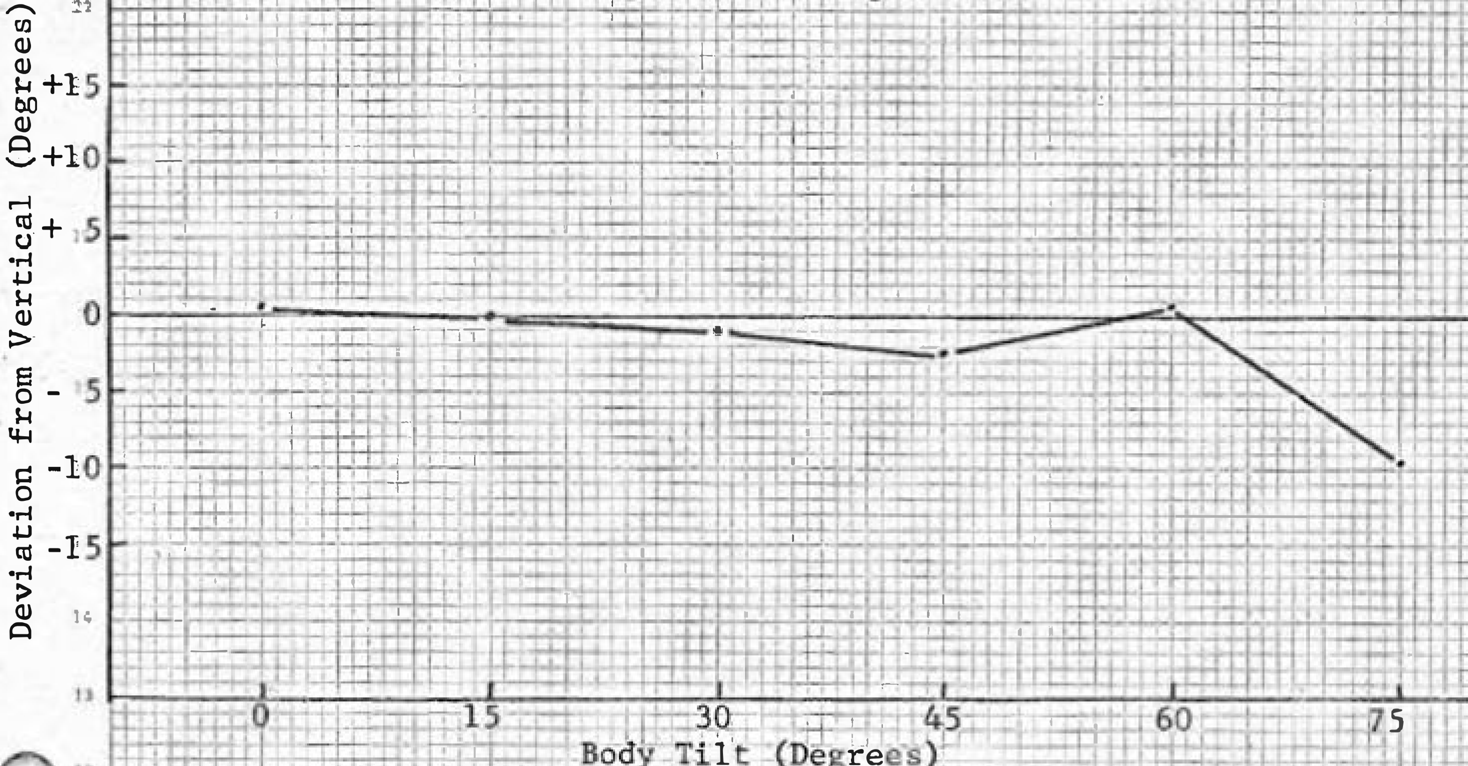



Figure 15: Subject A.J.

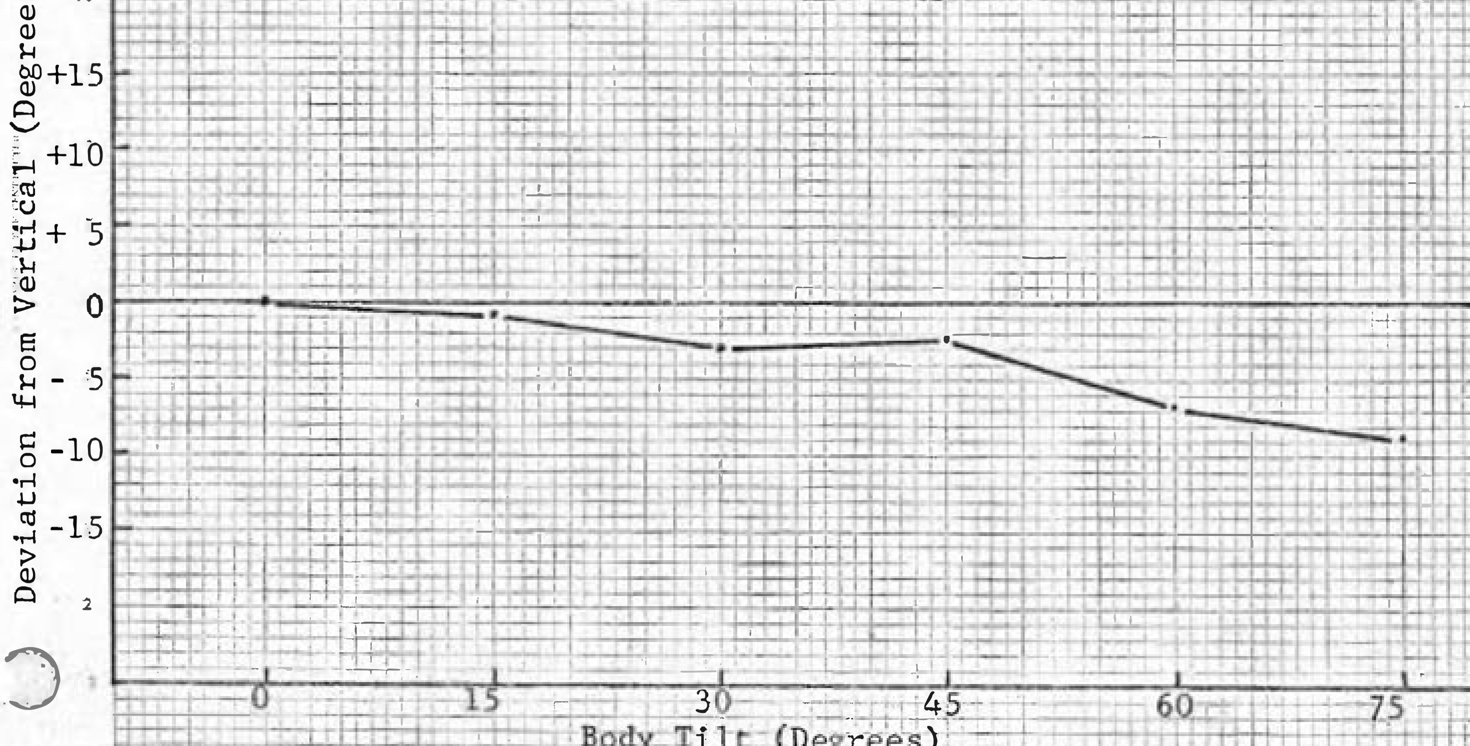



Figure 16: Subject C.S.

Figure 17: Subject B.G.

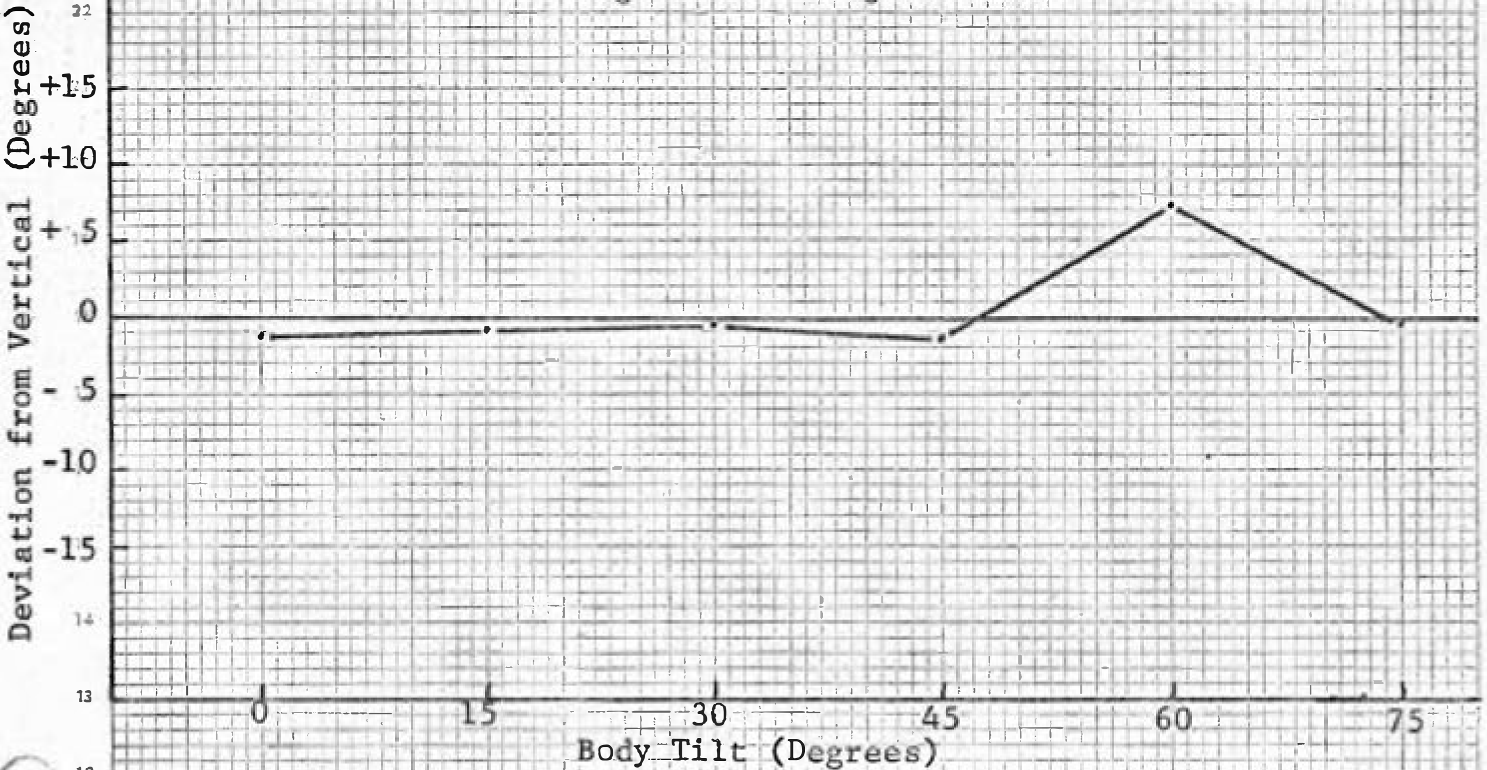
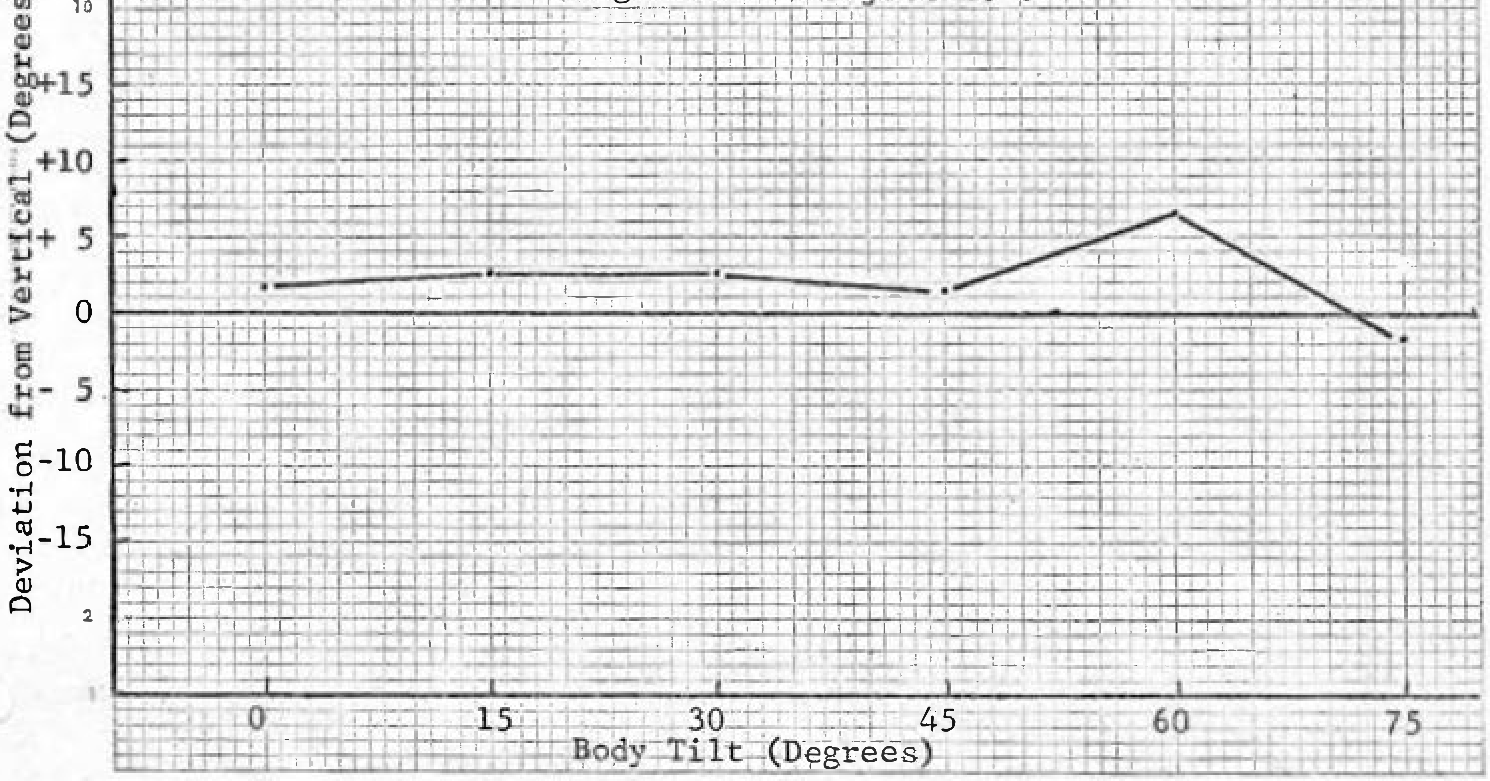



Figure 18: Subject T.M.



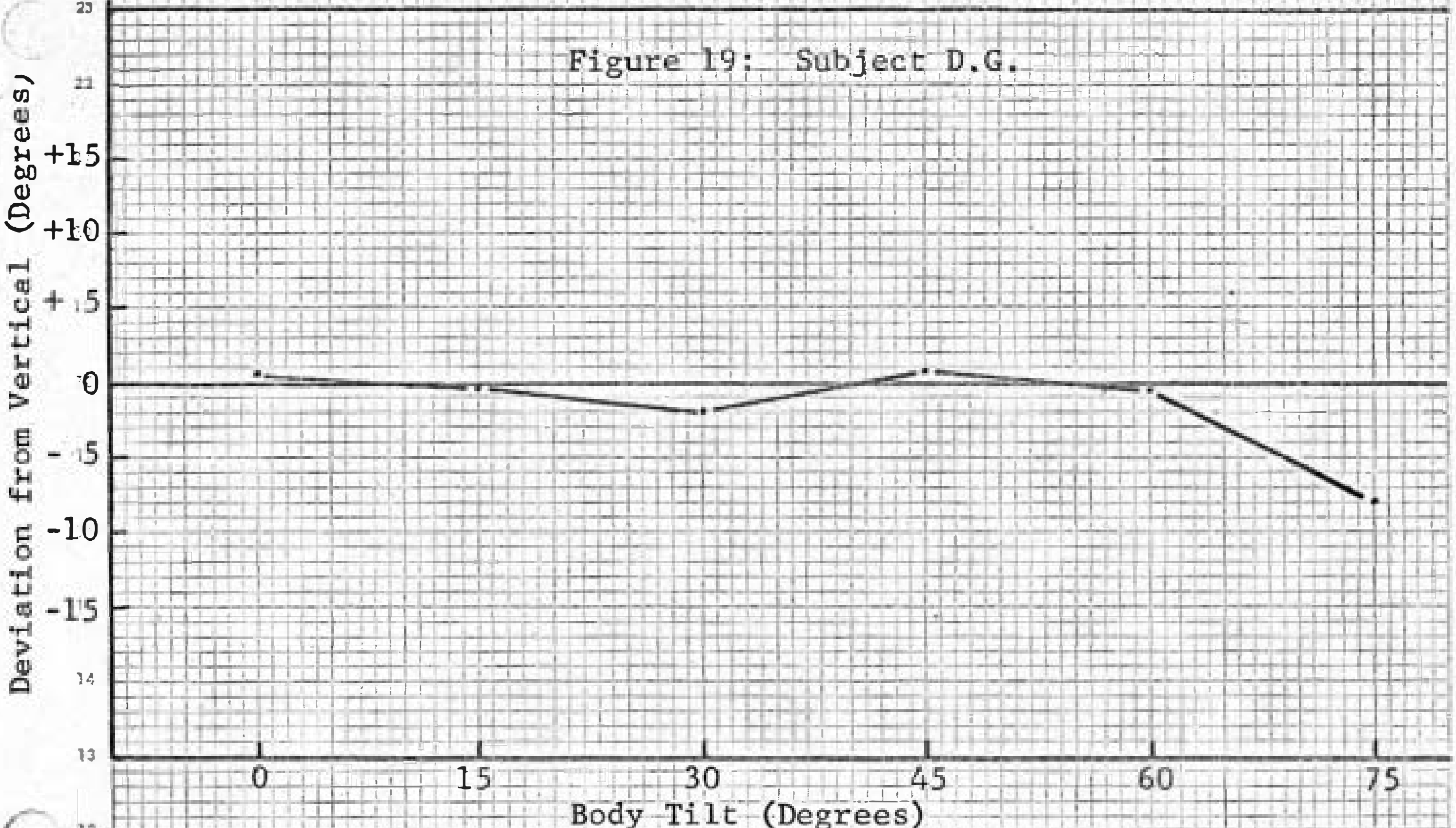


Figure 19: Subject D.G.

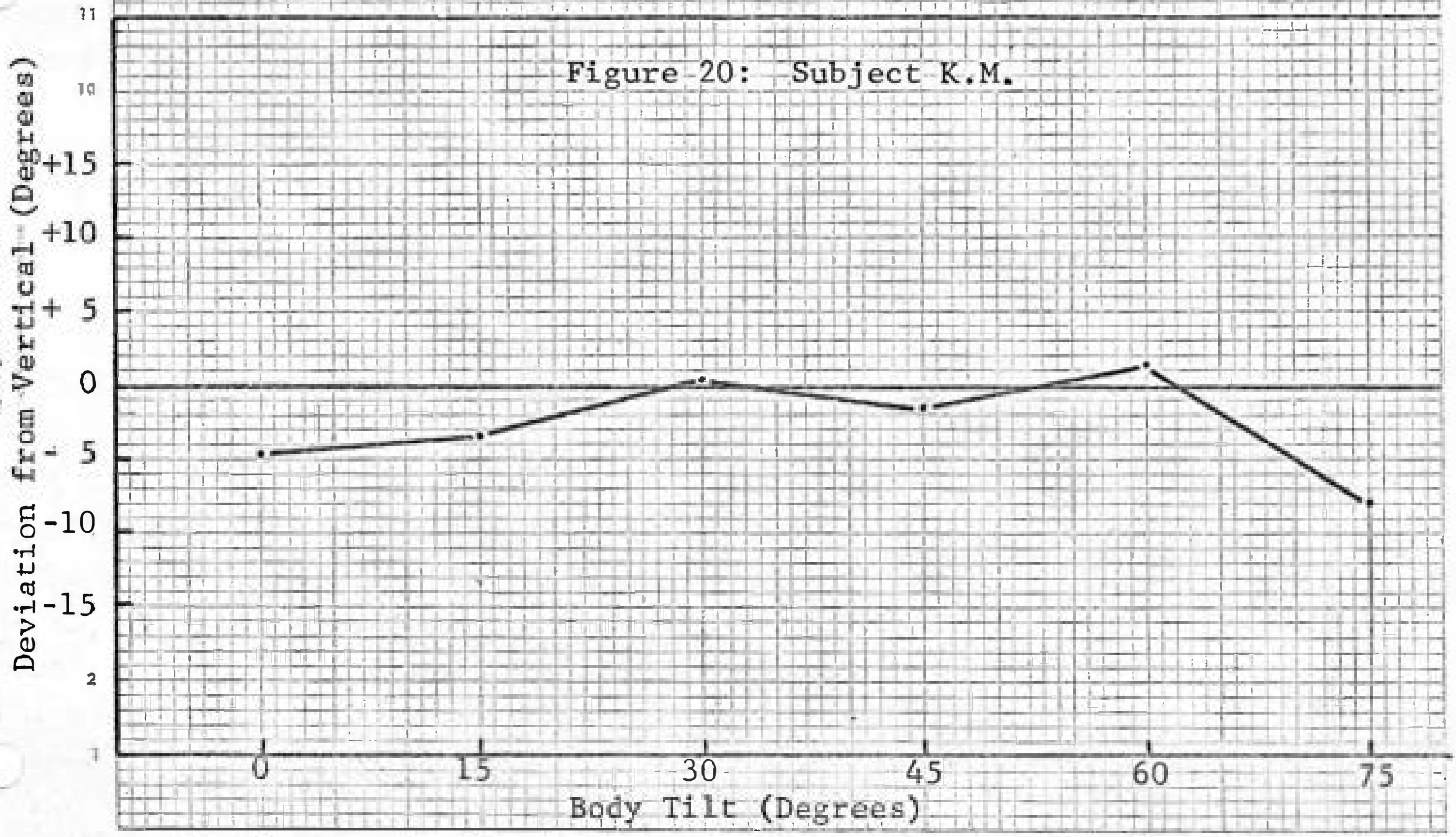
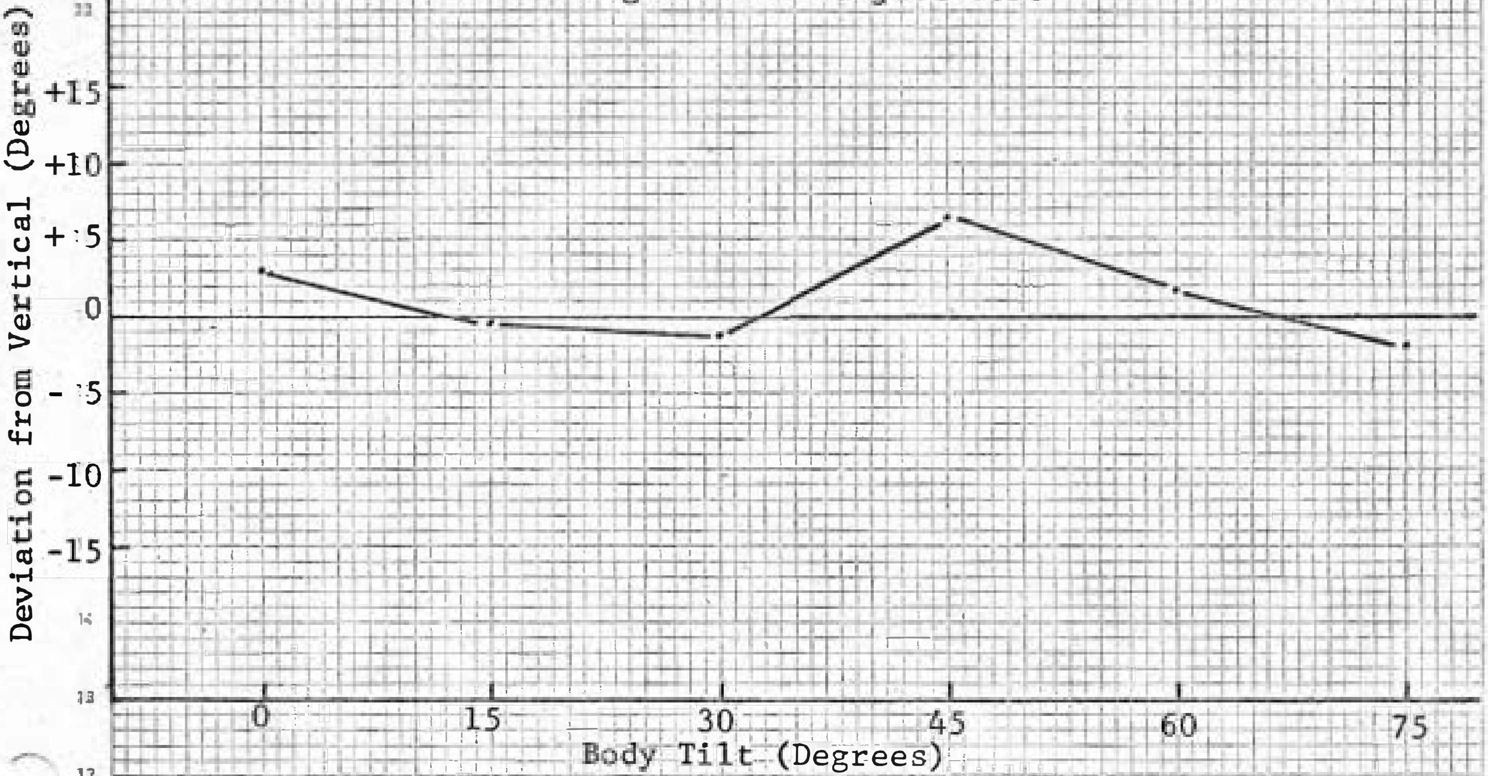


Figure 20: Subject K.M.

Figure 21: Subject C.P.



TABLES

TABLE I

INDIVIDUAL DATA

| Body Tilt | Objective Vertical | Subjective Vertical Preset Away | | | Preset Toward | | | Mean |
|---|---|---|---|---|---|---|---|---|
| Subject D.H. | | | | | | | | |
| 0 | 90 | 89 | 88 | 95 | 92 | 90 | 89 | 90.5 |
| 15 | 103 | 101 | 108 | 104 | 106 | 103 | 105 | 104.5 |
| 30 | 118 | 124 | 123 | 124 | 118 | 119 | 116 | 120.7 |
| 45 | 134 | 133 | 140 | 135 | 132 | 135 | 134 | 134.8 |
| 60 | 150 | 158 | 155 | 156 | 150 | 151 | 150 | 153.3 |
| 75 | 168 | 167 | 165 | 167 | 165 | 165 | 164 | 165.5 |
| Subject J.M. | | | | | | | | |
| 0 | 90 | 90 | 92 | 92 | 85 | 85 | 84 | 88.0 |
| 15 | 103 | 106 | 107 | 108 | 96 | 95 | 96 | 101.3 |
| 30 | 118 | 115 | 123 | 121 | 117 | 115 | 117 | 118.0 |
| 45 | 134 | 138 | 137 | 137 | 126 | 126 | 125 | 131.5 |
| 60 | 150 | 157 | 155 | 156 | 145 | 145 | 145 | 150.5 |
| 75 | 168 | 169 | 170 | 170 | 160 | 161 | 161 | 165.2 |
| Subject F.G. | | | | | | | | |
| 0 | 90 | 88 | 92 | 90 | 89 | 90 | 91 | 90.0 |
| 15 | 103 | 100 | 100 | 99 | 103 | 101 | 100 | 100.5 |
| 30 | 118 | 115 | 114 | 115 | 115 | 115 | 116 | 115.0 |
| 45 | 134 | 130 | 131 | 135 | 135 | 134 | 134 | 133.2 |
| 60 | 150 | 153 | 152 | 152 | 147 | 147 | 148 | 149.8 |
| 75 | 168 | 162 | 162 | 164 | 164 | 164 | 163 | 163.2 |
| Subject J.R. | | | | | | | | |
| 0 | 90 | 92 | 92 | 93 | 88 | 88 | 87 | 90.0 |
| 15 | 103 | 105 | 104 | 102 | 98 | 98 | 98 | 100.8 |
| 30 | 118 | 118 | 120 | 119 | 116 | 117 | 118 | 118.0 |
| 45 | 134 | 135 | 134 | 135 | 130 | 130 | 132 | 132.7 |
| 60 | 150 | 155 | 157 | 156 | 150 | 152 | 151 | 153.5 |
| 75 | 168 | 171 | 172 | 172 | 170 | 172 | 172 | 173.0 |

| Body Tilt | Objective Vertical | Subjective Vertical Preset Away | | | Subjective Vertical Preset Toward | | | Mean |
|---|---|---|---|---|---|---|---|---|
| **Subject W.M.** | | | | | | | | |
| 0 | 90 | 89 | 90 | 90 | 86 | 88 | 88 | 88.5 |
| 15 | 103 | 104 | 103 | 105 | 98 | 102 | 100 | 102.0 |
| 30 | 118 | 117 | 116 | 115 | 114 | 114 | 111 | 114.5 |
| 45 | 134 | 134 | 137 | 133 | 132 | 132 | 132 | 133.3 |
| 60 | 150 | 148 | 148 | 148 | 145 | 145 | 148 | 147.0 |
| 75 | 168 | 171 | 171 | 172 | 165 | 167 | 168 | 169.0 |
| **Subject D.W.** | | | | | | | | |
| 0 | 90 | 87 | 90 | 89 | 89 | 87 | 90 | 88.7 |
| 15 | 103 | 100 | 96 | 98 | 100 | 96 | 94 | 98.2 |
| 30 | 118 | 110 | 112 | 113 | 120 | 116 | 116 | 114.5 |
| 45 | 134 | 130 | 137 | 132 | 134 | 134 | 135 | 133.7 |
| 60 | 150 | 151 | 150 | 151 | 151 | 152 | 153 | 151.3 |
| 75 | 168 | 172 | 167 | 170 | 169 | 170 | 170 | 169.7 |
| **Subject S.H.** | | | | | | | | |
| 0 | 90 | 90 | 91 | 91 | 88 | 89 | 89 | 89.7 |
| 15 | 103 | 99 | 101 | 99 | 103 | 102 | 99 | 100.8 |
| 30 | 118 | 110 | 112 | 110 | 110 | 112 | 110 | 110.7 |
| 45 | 134 | 130 | 129 | 129 | 127 | 130 | 129 | 129.0 |
| 60 | 150 | 168 | 167 | 165 | 164 | 161 | 162 | 164.5 |
| 75 | 168 | 167 | 172 | 171 | 169 | 171 | 170 | 170.0 |
| **Subject M.G.** | | | | | | | | |
| 0 | 90 | 88 | 89 | 89 | 91 | 89 | 93 | 89.3 |
| 15 | 103 | 101 | 101 | 101 | 103 | 104 | 102 | 102.0 |
| 30 | 118 | 117 | 113 | 116 | 114 | 115 | 116 | 115.2 |
| 45 | 134 | 125 | 126 | 130 | 124 | 128 | 127 | 122.7 |
| 60 | 150 | 150 | 148 | 148 | 151 | 147 | 146 | 148.3 |
| 75 | 168 | 162 | 160 | 164 | 158 | 158 | 152 | 159.0 |

| Body Tilt | Objective Vertical | Subjective Vertical Preset Away | | | Subjective Vertical Preset Toward | | | Mean |
|---|---|---|---|---|---|---|---|---|
| **Subject J.J.** | | | | | | | | |
| 0 | 90 | 92 | 92 | 88 | 88 | 89 | 88 | 89.5 |
| 15 | 103 | 104 | 103 | 100 | 100 | 99 | 101 | 101.2 |
| 30 | 118 | 107 | 105 | 106 | 104 | 103 | 103 | 104.7 |
| 45 | 134 | 136 | 133 | 136 | 130 | 129 | 133 | 132.8 |
| 60 | 150 | 148 | 145 | 142 | 144 | 142 | 140 | 143.5 |
| 75 | 168 | 168 | 162 | 162 | 155 | 156 | 156 | 159.8 |
| 75 | 168 | 168 | 162 | 162 | 155 | 156 | 156 | 159.8 |
| **Subject R.H.** | | | | | | | | |
| 0 | 90 | 94 | 96 | 95 | 90 | 90 | 90 | 92.5 |
| 15 | 103 | 105 | 103 | 104 | 103 | 102 | 102 | 103.2 |
| 30 | 118 | 124 | 121 | 122 | 119 | 120 | 118 | 120.7 |
| 45 | 134 | 134 | 134 | 135 | 135 | 134 | 134 | 134.3 |
| 60 | 150 | 150 | 150 | 148 | 147 | 151 | 151 | 150.5 |
| 75 | 168 | 167 | 164 | 168 | 162 | 167 | 165 | 165.5 |
| **Subject M.M.** | | | | | | | | |
| 0 | 90 | 90 | 91 | 92 | 87 | 90 | 89 | 89.8 |
| 15 | 103 | 105 | 103 | 103 | 98 | 100 | 99 | 101.3 |
| 30 | 118 | 116 | 116 | 115 | 111 | 109 | 108 | 112.8 |
| 45 | 134 | 140 | 136 | 138 | 148 | 148 | 149 | 151.8 |
| 60 | 150 | 155 | 156 | 155 | 148 | 148 | 149 | 151.8 |
| 75 | 168 | 168 | 170 | 168 | 158 | 160 | 157 | 163.5 |
| **Subject D.L.** | | | | | | | | |
| 0 | 90 | 90 | 88 | 87 | 89 | 88 | 88 | 88.5 |
| 15 | 103 | 95 | 95 | 99 | 97 | 97 | 99 | 97.0 |
| 30 | 118 | 109 | 109 | 109 | 109 | 112 | 109 | 109.5 |
| 45 | 134 | 128 | 126 | 128 | 132 | 128 | 127 | 128.2 |
| 60 | 150 | 152 | 150 | 150 | 155 | 146 | 155 | 146.0 |
| 75 | 168 | 155 | 154 | 160 | 155 | 157 | 154 | 155.8 |

| Body Tilt | Objective Vertical | Subjective Vertical Preset Away | | | Preset Toward | | | Mean |
|---|---|---|---|---|---|---|---|---|
| **Subject A.J.** | | | | | | | | |
| 0 | 90 | 90 | 89 | 88 | 87 | 92 | 88 | 90.5 |
| 15 | 103 | 104 | 105 | 100 | 102 | 101 | 106 | 103.0 |
| 30 | 118 | 120 | 116 | 113 | 117 | 118 | 118 | 117.0 |
| 45 | 134 | 129 | 133 | 129 | 135 | 133 | 130 | 131.5 |
| 60 | 150 | 150 | 148 | 149 | 155 | 155 | 147 | 150.7 |
| 75 | 168 | 160 | 156 | 158 | 160 | 160 | 156 | 158.3 |
| **Subject C.S.** | | | | | | | | |
| 0 | 90 | 88 | 93 | 90 | 88 | 92 | 89 | 90.0 |
| 15 | 103 | 104 | 95 | 106 | 103 | 102 | 103 | 102.2 |
| 30 | 118 | 121 | 115 | 116 | 111 | 112 | 115 | 115.0 |
| 45 | 134 | 134 | 132 | 136 | 130 | 134 | 124 | 131.7 |
| 60 | 150 | 156 | 156 | 157 | 140 | 125 | 125 | 143.2 |
| 75 | 168 | 168 | 168 | 166 | 150 | 157 | 146 | 159.2 |
| **Subject B.G.** | | | | | | | | |
| 0 | 90 | 90 | 90 | 98 | 85 | 85 | 85 | 88.8 |
| 15 | 103 | 105 | 105 | 105 | 98 | 101 | 98 | 102.0 |
| 30 | 118 | 119 | 120 | 117 | 115 | 115 | 119 | 117.5 |
| 45 | 134 | 132 | 137 | 135 | 129 | 134 | 128 | 132.5 |
| 60 | 150 | 162 | 161 | 162 | 152 | 153 | 153 | 157.2 |
| 75 | 168 | 170 | 169 | 170 | 167 | 165 | 165 | 167.7 |
| **Subject T.M.** | | | | | | | | |
| 0 | 90 | 95 | 94 | 94 | 90 | 89 | 88 | 91.7 |
| 15 | 103 | 108 | 108 | 110 | 100 | 104 | 103 | 105.5 |
| 30 | 118 | 124 | 124 | 125 | 116 | 117 | 117 | 120.5 |
| 45 | 134 | 136 | 140 | 141 | 127 | 135 | 133 | 135.3 |
| 60 | 150 | 162 | 160 | 160 | 152 | 154 | 151 | 156.5 |
| 75 | 168 | 170 | 170 | 170 | 160 | 162 | 165 | 166.2 |

| Body Tilt | Objective Vertical | Subjective Vertical Preset Away | | | Subjective Vertical Preset Toward | | | Mean |
|---|---|---|---|---|---|---|---|---|
| **Subject D.G.** | | | | | | | | |
| 0 | 90 | 95 | 95 | 98 | 85 | 84 | 86 | 90.5 |
| 15 | 103 | 107 | 111 | 111 | 96 | 95 | 96 | 102.7 |
| 30 | 118 | 120 | 121 | 120 | 112 | 109 | 114 | 116.0 |
| 45 | 134 | 140 | 141 | 142 | 128 | 129 | 130 | 134.7 |
| 60 | 150 | 157 | 155 | 152 | 144 | 145 | 147 | 149.5 |
| 75 | 168 | 167 | 165 | 170 | 154 | 149 | 155 | 160.0 |
| **Subject K.M.** | | | | | | | | |
| 0 | 90 | 88 | 88 | 90 | 81 | 83 | 82 | 85.3 |
| 15 | 103 | 104 | 102 | 104 | 96 | 96 | 95 | 99.5 |
| 30 | 118 | 122 | 114 | 116 | 115 | 108 | 105 | 118.3 |
| 45 | 134 | 135 | 138 | 135 | 129 | 130 | 128 | 132.5 |
| 60 | 150 | 158 | 156 | 155 | 148 | 146 | 145 | 151.3 |
| 75 | 168 | 164 | 164 | 167 | 153 | 156 | 156 | 160.0 |
| **Subject C.P.** | | | | | | | | |
| 0 | 90 | 95 | 94 | 94 | 92 | 91 | 92 | 93.0 |
| 15 | 103 | 104 | 103 | 101 | 102 | 103 | 103 | 102.7 |
| 30 | 118 | 118 | 113 | 116 | 116 | 120 | 117 | 116.7 |
| 45 | 134 | 145 | 145 | 135 | 137 | 141 | 139 | 140.3 |
| 60 | 150 | 154 | 150 | 149 | 155 | 152 | 150 | 151.7 |
| 75 | 168 | 165 | 166 | 166 | 166 | 167 | 166 | 166.0 |

TABLE II

RESULTS SHOWING THE MEANS OF THE SIX TRIALS AT EACH BODY POSITION

| Body Position | 0 | 15 | 30 | 45 | 60 | 75 |
|---|---|---|---|---|---|---|
| Objective Vertical | 90 | 103 | 118 | 134 | 150 | 168 |
| D.H. | 90.5 | 104.5 | 120.7 | 134.8 | 153.3 | 165.5 |
| J.M. | 88.0 | 101.3 | 118.0 | 131.5 | 150.5 | 165.2 |
| F.G. | 90.0 | 100.5 | 115.0 | 133.2 | 149.8 | 163.2 |
| J.R. | 90.0 | 100.8 | 118.0 | 132.7 | 153.5 | 173.0 |
| W.M. | 88.5 | 102.0 | 114.5 | 133.3 | 147.0 | 169.0 |
| D.W. | 88.7 | 98.2 | 114.5 | 133.7 | 151.3 | 169.7 |
| S.H. | 89.7 | 100.8 | 110.7 | 129.0 | 164.5 | 170.0 |
| M.G. | 89.3 | 102.0 | 115.2 | 122.7 | 148.3 | 159.0 |
| J.J. | 89.5 | 101.2 | 104.7 | 132.8 | 143.5 | 159.8 |
| R.H. | 92.5 | 103.2 | 120.7 | 134.3 | 150.5 | 165.5 |
| M.M. | 89.8 | 101.3 | 112.8 | 132.7 | 151.8 | 163.5 |
| D.L. | 88.5 | 97.0 | 109.5 | 128.2 | 146.0 | 155.8 |
| A.J. | 90.5 | 103.0 | 117.0 | 131.5 | 150.7 | 158.3 |
| C.S. | 90.0 | 102.2 | 115.0 | 131.7 | 143.2 | 159.2 |
| B.G. | 88.8 | 102.0 | 117.5 | 132.5 | 157.2 | 167.7 |
| T.M. | 91.7 | 105.5 | 120.5 | 135.3 | 156.5 | 166.2 |

| Body Position | 0 | 15 | 30 | 45 | 60 | 75 |
|---|---|---|---|---|---|---|
| Objective Vertical | 90 | 103 | 118 | 134 | 150 | 168 |
| D.G. | 90.5 | 102.7 | 116.0 | 134.7 | 149.5 | 160.0 |
| K.M. | 85.3 | 99.5 | 118.3 | 132.5 | 151.3 | 160.0 |
| C.P. | 93.0 | 102.7 | 116.7 | 140.3 | 151.7 | 166.0 |

TABLE III

GROUP DATA FOR SUBJECTIVE VERTICAL AT EACH BODY POSITION

| Body Position (Degrees) | 0 | 15 | 30 | 45 | 60 | 75 |
|---|---|---|---|---|---|---|
| Objective Vertical (Degrees) | 90 | 103 | 118 | 134 | 150 | 168 |
| Group Mean for Subjective Vertical (Degrees) | 89.8 | 101.6 | 115.5 | 132.5 | 151.3 | 163.9 |
| Group Mean deviation of Subjective Vertical from Objective Vertical (Degrees) | - 0.2 | - 1.4 | - 2.5 | - 1.5 | + 1.3 | - 4.1 |
| Group Mean deviation of Subjective Vertical from Subjective Vertical perceived in $0^{o}$ body position (Degrees) | - - | - 1.2 | - 2.3 | - 1.3 | + 1.5 | - 3.9 |
| Standard Deviation (Degrees) | 1.70 | 1.98 | 4.02 | 3.45 | 4.75 | 4.43 |