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A clinical analysis of vertical fixation disparity graphs

Angela J. Morley
Pacific University

Jacqueline R. Clair
Pacific University

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Abstract

Historically, vertical fixation disparity curves have been described as straight lines. This suggests minimal prism adaptation to vertical prism stress. There have been reports in the literature, and it has been our clinical experience, that while many vertical fixation disparity curves are straight lines, many others are sigmoidal. This study evaluated the slopes of thirty vertical fixation disparity curves from non-asthenopic subjects to see if the magnitude of the change in slope is striking enough to identify the curves as something other than a straight line. The results indicate that the majority of the graphs are straight lines, as most literature suggests, with a total of twenty straight line curves and ten sigmoid shaped. However, two sigmoidal curves show a large magnitude of change across the slope suggesting vertical prism adaptation is indeed possible.

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Committee Chair

Dennis L. Smith

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A CLINICAL ANALYSIS OF VERTICAL FIXATION DISPARITY GRAPHS

BY

ANGELA J. MORLEY
JACQUELINE R. CLAIR

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Adviser:

DENNIS L. SMITH O.D., M.S.

A CLINICAL ANALYSIS OF VERTICAL FIXATION DISPARITY GRAPHS

SIGNATURES:

RESEARCHERS:

ANGELA J. MORLEY

JACQUELINE R. CLAIR

ADVISER:

DENNIS L. SMITH, O.D., M.S.

Biography Page of the Authors

Angela J. Morley

Angela attended Red Deer College for her undergraduate studies, she obtained her Bachelor of Visual Science from Pacific University in May of 1992. She will graduate from Pacific University College of Optometry in May of 1994. Upon graduation, she hopes to return to Alberta, Canada and practice in a primary care environment. Angela is a member of the American Optometric Student Association and a member of Beta Sigma Kappa Optometric Honor Fraternity.

Jacqueline R. Clair

Jacqueline attended Pacific University for her undergraduate studies in which she received her Bachelor of Visual Science in May of 1992. She will graduate from Pacific University College of Optometry in may of 1994. Future plans include returning to Colorado and practicing primary care optometry; with emphasis in contact lenses. Jacqueline is a member of the American Optometric Student Association and a member of Beta Sigma Kappa Honor Fraternity.

ABSTRACT

Historically, vertical fixation disparity curves have been described as straight lines. This suggests minimal prism adaptation to vertical prism stress. There have been reports in the literature, and it has been our clinical experience, that while many vertical fixation disparity curves are straight lines, many others are sigmoidal. This study evaluated the slopes of thirty vertical fixation disparity curves from non-asthenopic subjects to see if the magnitude of the change in slope is striking enough to identify the curves as something other than a straight line. The results indicate that the majority of the graphs are straight lines, as most literature suggests, with a total of twenty straight line curves and ten sigmoid shaped. However, two sigmoidal curves show a large magnitude of change across the slope suggesting vertical prism adaptation is indeed possible.

Acknowledgments

The authors of this thesis would like to thank Dr. Dennis L. Smith for his knowledge on this subject and patience with us while working on this study. We would also like to thank Beta Sigma Kappa for the funds to purchase the accessory prisms. Angela wishes to thank Jacqueline for understanding the disorganization and for all the laughs and fun. Jacqueline would like to thank Angela for her great sense of humor, daily pep talks, and for a great friendship that will last a lifetime.

INTRODUCTION

The image of an object viewed with both eyes is rarely fixated bifoveally, but rather on two nonfoveal points. This tolerable misalignment is referred to as fixation disparity, and the reason why the misalignment does not create a diplopic image is because these two points fall within an area on each retina called Panum's fusional area.[1] Panum's fusional area extends vertically and horizontally around each fovea. "The horizontal extent of this area is small at the center (6 to 10 minutes of arc near the fovea) and increases toward the periphery (30 to 40 minutes of arc at 12 degrees from the fovea)."[2] Once a point is outside this area, it is seen as double.

Fixation disparity curves, either horizontal (with BO or BI prism) or vertical (with BU or BD prism) can be drawn by plotting the fixation disparity as a function of the amount of induced prism stress. According to Ogle, vertical fixation disparity curves show a straight line slope unlike horizontal fixation disparity curves which have four distinctive curve types.[1] This would suggest that there was minimal or no ability for the visual system to adapt to induced vertical prism stress.

It has been suggested by some investigators that the slope of the straight line might be related to some ability to adapt to vertical stress with steep slopes indicating no adaptation and flat slopes (less than 45 degrees) indicating adaptation. Eskridge, in his investigation of vertical fixation disparity, also found that statistically (by first order correlation analysis) the curves were best depicted as straight lines.[3] The reason for the linearity in vertical fixation disparity is thought to be due to the absence of, or the extremely slow rate of vertical prism adaptation.[4]

Horizontal prism adaptation is thought to occur more quickly allowing for the different curve types.

One of the curve types showing ready adaptation to induced prism stress is a sigmoid curve, referred to as the Type 1 curve. This response type is found in approximately 60% of horizontal fixation disparity graphs.[1] Prism adaptation is shown on the Type 1 curve at the flattest portion of the sigmoid curve "with a steep rise in fixation disparity near both the BI and BO fusional limits."[1]

This adaptation, seen in the flattest portion of the Type 1 curve occurs when the visual system resets its resting level during periods of stress. According to Schor's model[5,6,7,8] when a control prism is introduced before the eyes of a binocularly fixating subject, the disparate retinal images cause an immediate stress to be placed on the fusional system. The initial reaction is an immediate fast-fusional vergence response designed to eliminate the disparate retinal images by initiating either convergence or divergence movement. This fast or "phasic" response turns on the slow-fusional vergence also known as tonic vergence. As the tonic vergence comes into action, it allows for the decay of the phasic response. The slow-fusional vergence is responsible for the gradual shift of the tonus position and reduces the effort required of the fast-fusional vergence. "Eventually the slow-fusional vergence takes over from the fast acting mechanism."[8] If the tonic response decays, retinal disparity occurs resulting in a feedback loop to the fast fusional vergence to initiate the cycle again.

In a study by Petito[4], two patient's vertical fixation disparity curves were measured and both were strikingly sigmoidal, suggesting an adaptation mechanism smaller to that found in the Type1 horizontal fixation disparity curve. Petito suggests that "the presence of a flat portion in the measurement of the vertical fixation disparity may indicate that mechanisms similar to those responsible for the shape of the horizontal curves are present and active in vertical vergence." [4] He further suggests that an essential step necessary to elicit this adaptation components to utilize small prism amounts (0.5^{Δ} increments as opposed to the standard of 1.0^{Δ}).

In the clinic, we too have noticed that vertical fixation disparity curves are as often non-linear as they are linear. We agreed with Petito[4] that smaller prism increments should be employed but felt that two subjects were insufficient for statistical validity. In our study, the vertical fixation disparity curves, created by forced vertical vergence, were evaluated in 0.50 prism diopter steps, on thirty non-asthenopic college students. The slopes were evaluated to see if the magnitude of the change in slope was "striking" enough to identify the curves as something other than a straight line.

METHODS

The subjects for this study consisted of thirty college students from Pacific University College of Optometry. The requirements for each subject were the following: near visual acuity of 20/20 or better checked under standard conditions, no ocular disease, non-presbyopic subjects between the ages of 20-35, stereo acuity of 40 arc seconds or better using the Titmus stereo circles, a lateral phoria of no more than 8^{Δ} diopters esophoric or exophoric at near measured in an AO phoropter with standard lighting requirements, and no asthenopic symptoms.

The entire study was conducted in one exam room equipped with a standard AO phoropter and controlled lighting. Each subject's vertical fixation disparity curve was measured using a Sheedy Disparometer at 40 cm. Instead of using the Risley prism incorporated in the AO phoropter, accessory cells with powers 0.5, 1, 2, and 3 prism diopters were used for better accuracy.

For the study each subject either wore their contact lenses or had their spectacle prescription placed in the phoropter. Each vertical fixation measurement was recorded when an "equal" or "in line" response was reported by the subject. These recordings included the range of all "equal" responses for each prism power. This variability or range is shown on the graphs as error bars. A vertical fixation disparity measurement was taken with each change in prism, starting with 0^{Δ}, 0.5^{Δ}BD, 0.5^{Δ}BU, continuing to alternate BU and BD in half diopter increments up to 4.0^{Δ} or until fusion was no longer possible. The prism accessory cells were placed in front of both eyes to create the desired prismatic stress and to try and ensure that one eye's image was not degraded more than its fellow.

RESULTS

Most practicing optometrists evaluate a patient's vertical fixation disparity graphs based on the visual presentation of the curve and the steepness of the slope. The graphs of this experiment were separated into two groups: those which were visually dramatic straight lines and those which resembled a sigmoid curve. The range of the slopes in this experiment are comparable to those found in previous reports by

Eskridge[3,9,10,11,12,13] and Petito[4]. The slopes, varying from patient to patient, ranged from 0.87 to 0.98 with the average being 0.96.

This data revealed ten graphs which can be best described as sigmoid curves (Figure1). This particular sigmoid curve shows a large magnitude of change across the slope as Petito reported in symptomatic patients with vertical phorias; however, our subjects had no asthenopic complaints or significant vertical phorias. The other twenty graphs can best be described as being straight lines. (Figure 2).

FIG 1

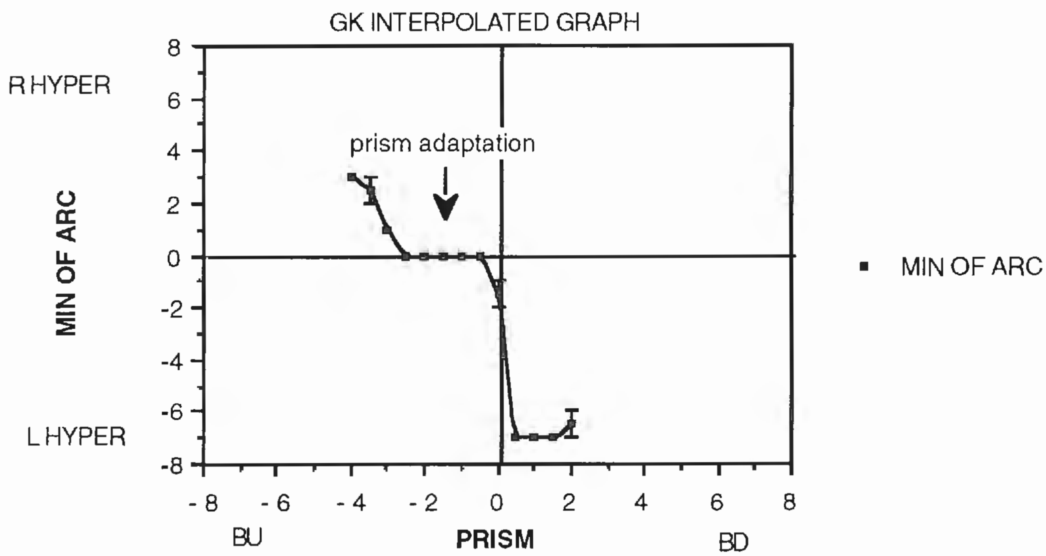
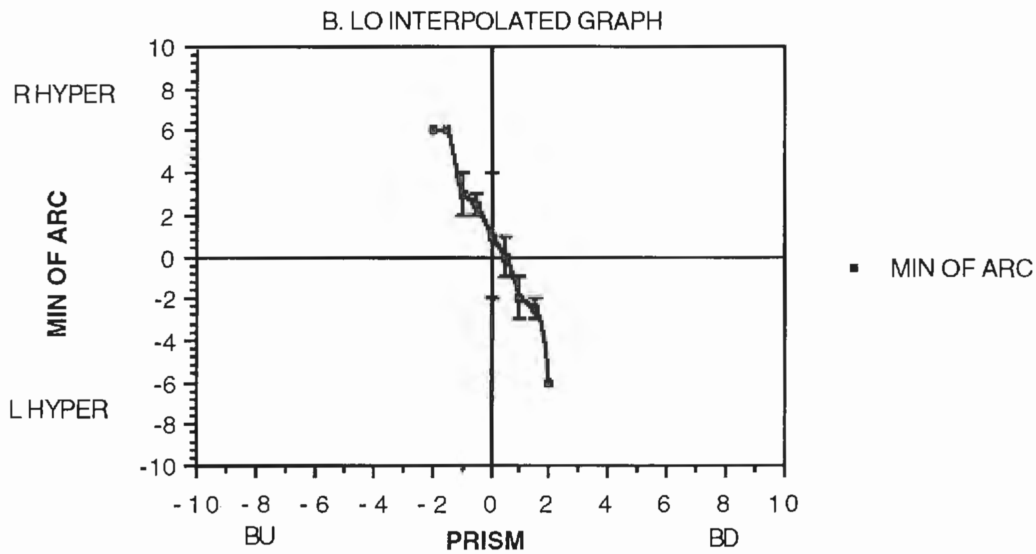


FIG 2



DISCUSSION

The results from this study indicate that the majority of the vertical fixation disparity graphs are straight lines as most literature suggests; however, a few graphs did have a sigmoidal shape indicating some form of vertical prism adaptation. As seen in Figure 1, there is a flat portion from 2.5$^{\Delta}$BU to .5$^{\Delta}$BU. This flat area shows prism adaptation as seen in horizontal curves. Using smaller increments of prism did accentuate this sigmoidal shape; therefore, as Petito suggested, smaller increments of prism could be responsible for the sigmoid shape curve.[4] This may be the reason why the vertical fixation disparity graphs are typically described as straight lines; the measurements are not always taken with small enough increments. Also, if a flat portion of the curve is seen on a vertical fixation disparity graph taken with 0.5$^{\Delta}$ increments, it may not be considered as significant as a flat portion seen in a horizontal curve. The reason for this is because larger prism increments can be used with horizontal curves, making, the flat area of adaptation more dramatic in appearance.

This experiment led to another interesting observation that changed the way we obtained our fixation disparity readings. Initially, prism was presented in one direction (e.g. BU) until a limit was reported and then in the opposite direction until a limit was reported. It was discovered that two subjects adapted in the direction of the prism which was first administered and then had greatly reduced ranges in the opposite direction (Figure 3) Upon retesting with alternating BU and BD increments both subject's curves appeared more "normal". Figure 4 represents the same individual seen in Figure 3 after retesting. For the remainder of this experiment, vertical prism was presented to the subjects in 0.5^{Δ} alternating BU and BD.

FIG 3

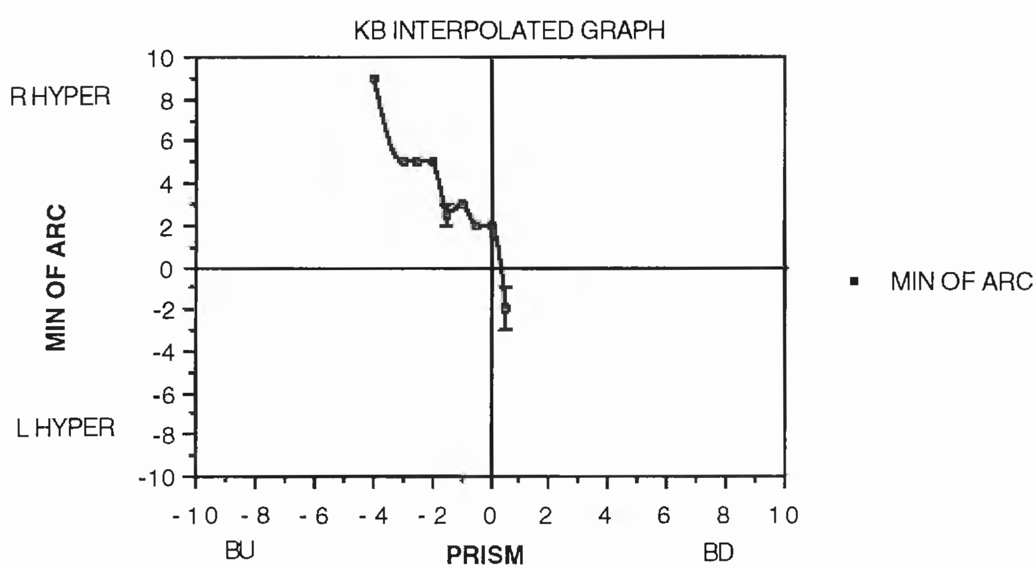
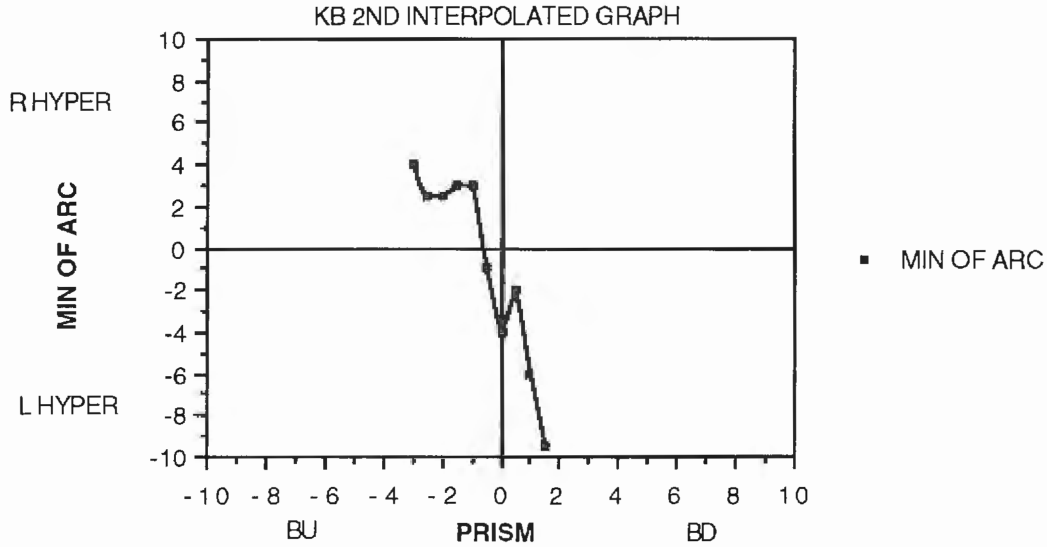


FIG 4



SUMMARY

This vertical fixation study confirmed other studies' findings regarding the shape of the curves. In this study the graphs were grouped into two categories based on visual examination; the categories being straight line curves and sigmoid shaped curves. The results confirm Eskridge's studies[3,11,12,13] that vertical fixation disparity curves are straight lines and agree with Petito[4] that some graphs do resemble the Type 1 curves found in horizontal graphs. If horizontal and vertical fixation disparity mechanisms are the same, it might be expected that different curve types exist for vertical disparity curves as well. Even though this study did show that some curves appeared to be like Type 1 curves, this study can not conclude that vertical fixation disparity mechanisms work the same as horizontal because the majority of the graphs were straight line curves.

In this experiment, as in most experiments, the prism was placed in front of the patient's eye and the vertical fixation measurement was taken immediately. Ogle and Prangen concluded that when vertical prism is presented to a patient "there is an immediate, reflex-type adaptation to the vertical prism, and that the time required for complete adaptation to occur varied from 3 minutes to 10 minutes."[10] Using this information, another study could be done involving the construction of vertical fixation disparity graphs with each prism measurement taken with prolonged time for adaptation (3-10 minutes). This longer adaptation time with each prism measurement may give the vertical slow, adaptive component more time. Thus, the vertical fixation disparity curves may resemble horizontal fixation disparity curves which would more fully demonstrate the similarities between vertical and horizontal vergence responses.

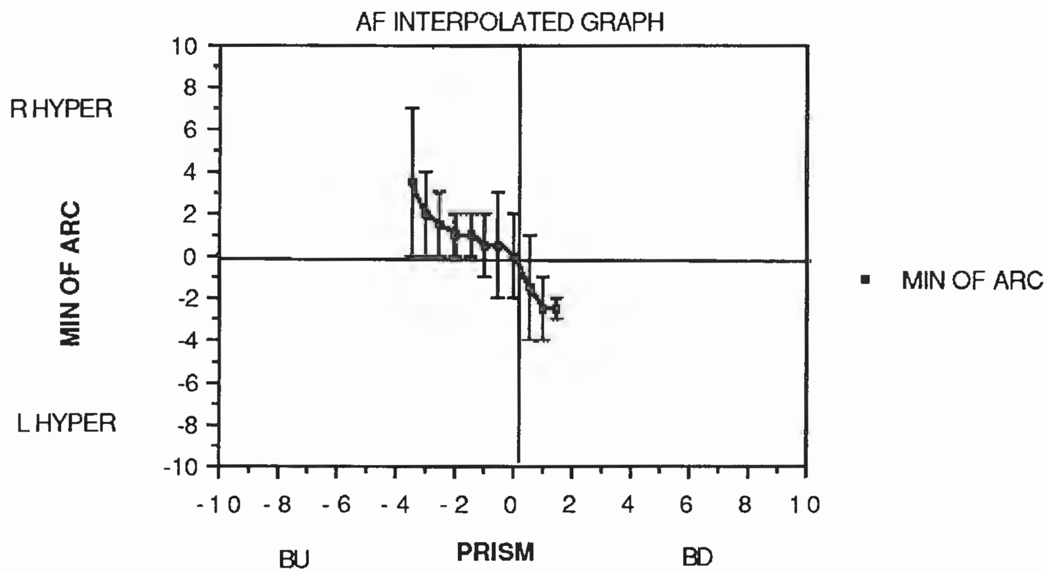
An optometrist should pay special attention to the vertical component of the visual system when the patient presents with asthenopic symptoms. Understanding how to evaluate the curves of a vertical fixation disparity graph becomes very helpful in providing an appropriate prescription for the asthenopic patient. Eskridge[10] suggests that three steps should be considered before prescribing vertical prism for a patient. First, the patient should be carefully interviewed to determine whether they are experiencing asthenopic symptoms, such as headache, eye ache, or diplopia. If the patient is indeed symptomatic, their likelihood of accepting prism correction is more favorable. Secondly, the slope of the vertical fixation disparity curve should be evaluated. Eskridge states that steep slopes (straight lines) are less likely to adapt to prism, and therefore, represent patients who are more likely to accept vertical prism correction. It should be made clear that a vertical fixation disparity graph with a steep curve should not be the only factor analyzed when determining a correction for a vertical heterophoria. Thirdly, the amount of vertical prism to be prescribed should be considered. "Several studies have shown that a vertical heterophoria has a high probability of being treated successfully if the vertical prism that reduces the vertical fixation disparity to zero is prescribed."[10] However, it is becoming more clear that measuring this fixation disparity might involve considering more complex and time-consuming procedures than initially thought. We are hopeful that our findings will prompt future research in the area of vertical fusion response and its measurement.

REFERENCES

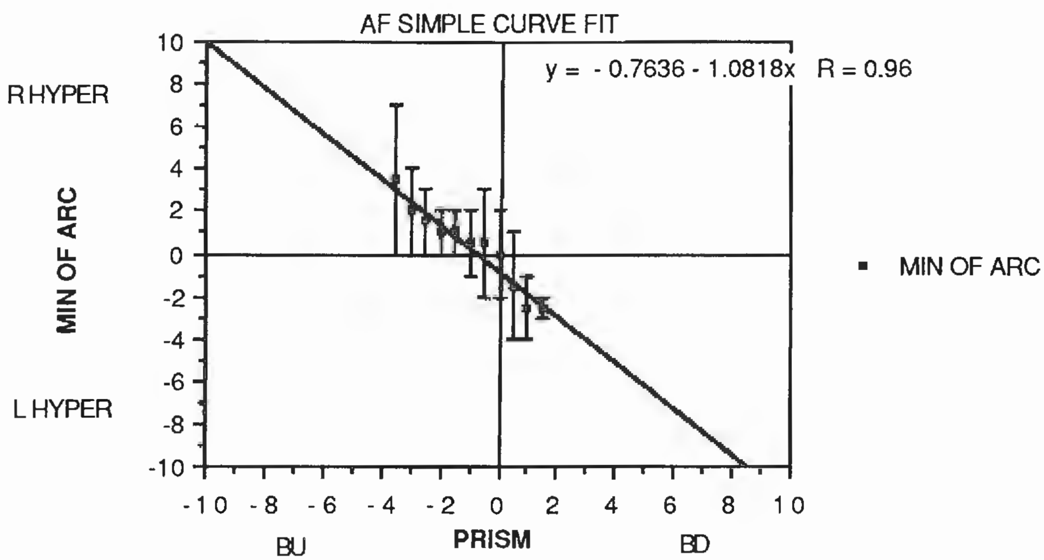
1. Goss DA. Introduction to fixation disparity. In: Ocular accommodation, convergence, and fixation disparity. Boston: Butterworth-Heinemann,1986: 127-135.
2. Walonker AF. Section 3 of the extraocular muscles. In: Moses RA, Hart WM, eds. Adler's Physiology of the Eye. St. Louis: C. V. Mosby, 1987: 169-170.
3. Rutstein RP, Eskridge JB. Clinical evaluation of vertical fixation disparity Part I. Am J Optom Physiol Opt 1983; 60:690
4. Petito TG. Nonlinear forced vertical vergence fixation disparity curves and their clinical significance. Am J Optom Physiol Opt: 1986;63(11): 908-914.
5. Schor, C. M. (1988) The influence of accommodative and vergence adaptation on binocular motor disorders. Am J. Optom. Physiol. Opt. 65, 464-475.
6. Schor, C. M. and Kotulad, J. C. (1986) Dynamic interactions between accommodation and convergence are velocity sensitive. Vision Res. 26, 927-942.
7. Schor CM. Models of mutual interactions between accommodation and convergence. Am J Optom Physiol Opt 1985; 62:369-74.
8. Smith, DL. Interpretation of Schor's model. In: Advanced case analysis and motor dysfunction lecture notes 1993.
9. Eskridge JB. Adaptation to vertical prism. Am. J Optom Physiol Opt: 1988; 65(5): 371-376.
10. Eskridge JB. Vertical muscle adaptation. In: Ocular Vertical and Cyclovertical Deviations. Vol. 4, No. 4. 1992: 622-627.
11. Eskridge JB, Rutstein RP. Clinical evaluation of vertical fixation disparity. Part II. Reliability, stability, and association with refractive status, stereo-acuity, and vertical heterophoria. Am J. Optom Physiol Opt 1985;62:579-84.
12. Rutstein RP, Eskridge JB. Clinical evaluation of vertical fixation disparity. Part III. Adaptation to vertical prism. Am J Optom Physiol Opt 1985;62:585-90.
13. Eskridge JB, Rutstein RP. Clinical evaluation of vertical fixation disparity. Part IV. Slope and adaptation to vertical prism of vertical heterophoria patients. Am J Optom Physiol Opt 1986;63:662-667.

APPENDIX

STRAIGHT LINE CURVES



AF INTERPOLATED GRAPH
R HYPER
MIN OF ARC
L HYPER
PRISM
BU
BD
MIN OF ARC



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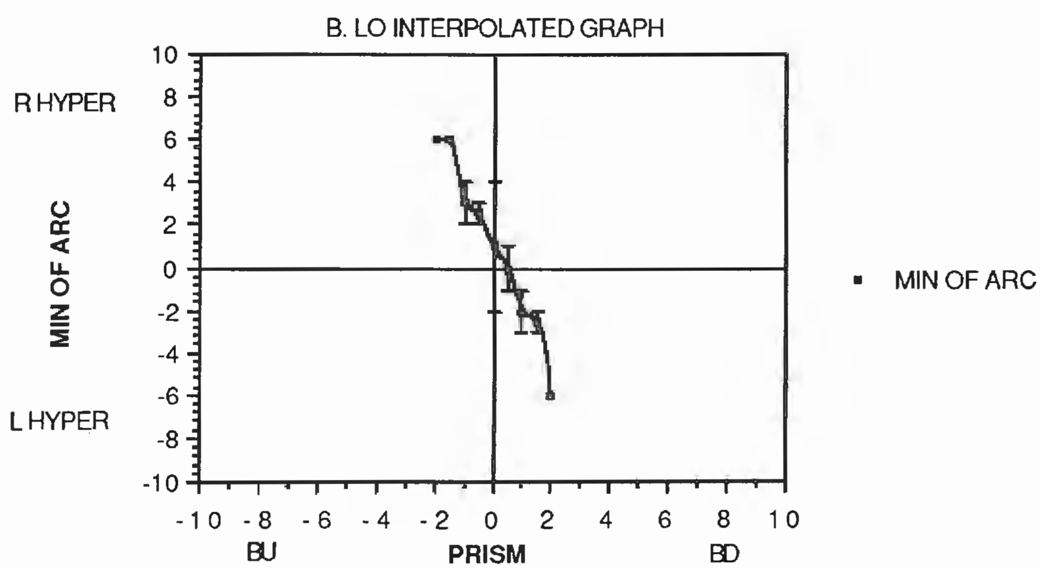
L HYPER
PRISM
BU
BD
MIN OF ARC



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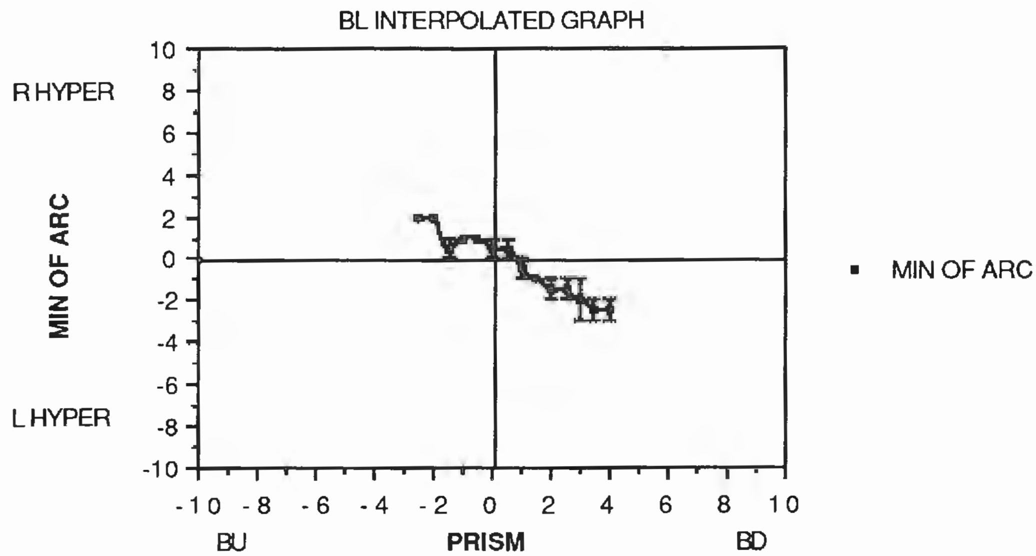
BU
BD
MIN OF ARC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L HYPER
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8
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4
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-4
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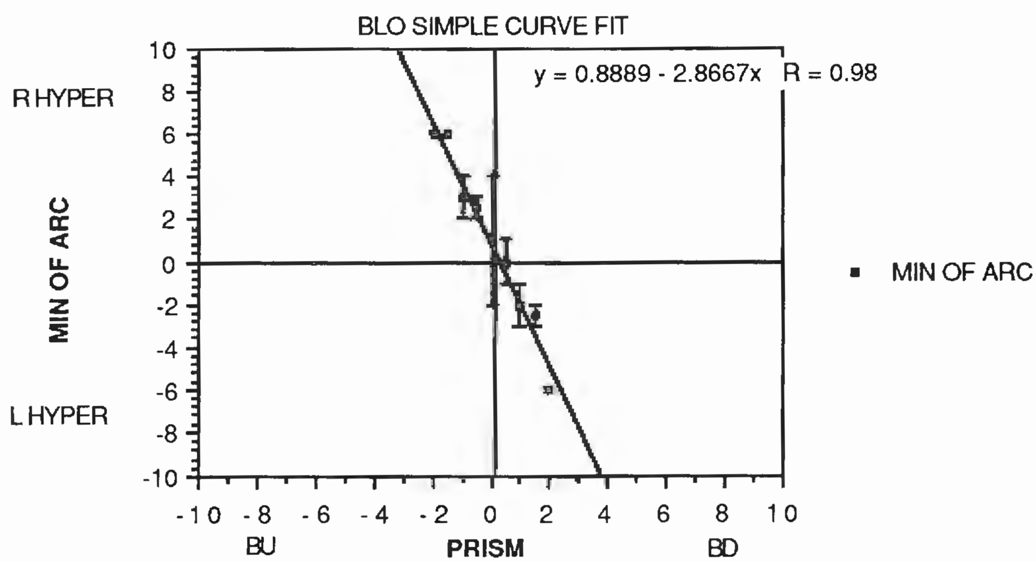
BU
PRISM
BD
MIN OF ARC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-8
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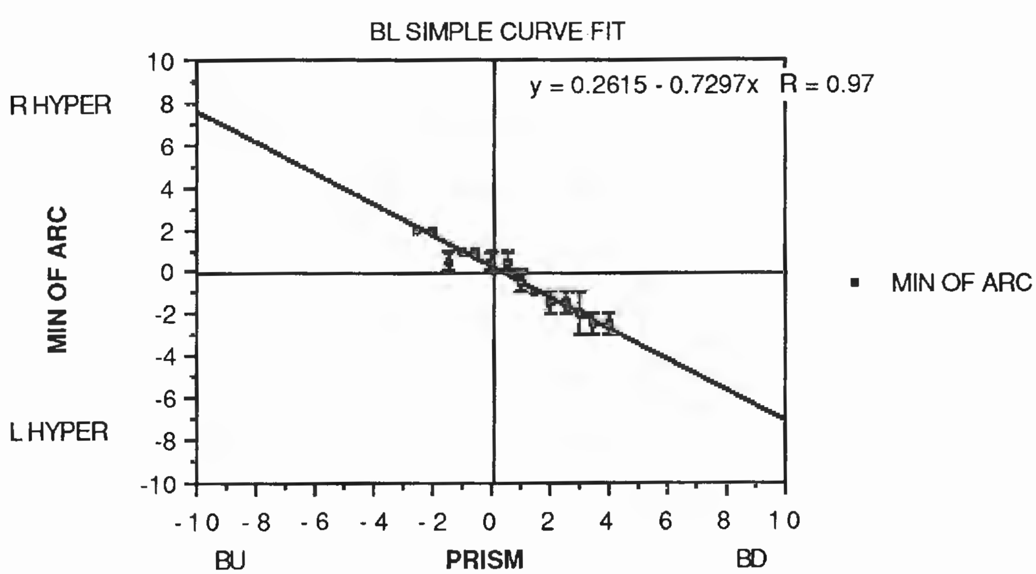
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC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8
6
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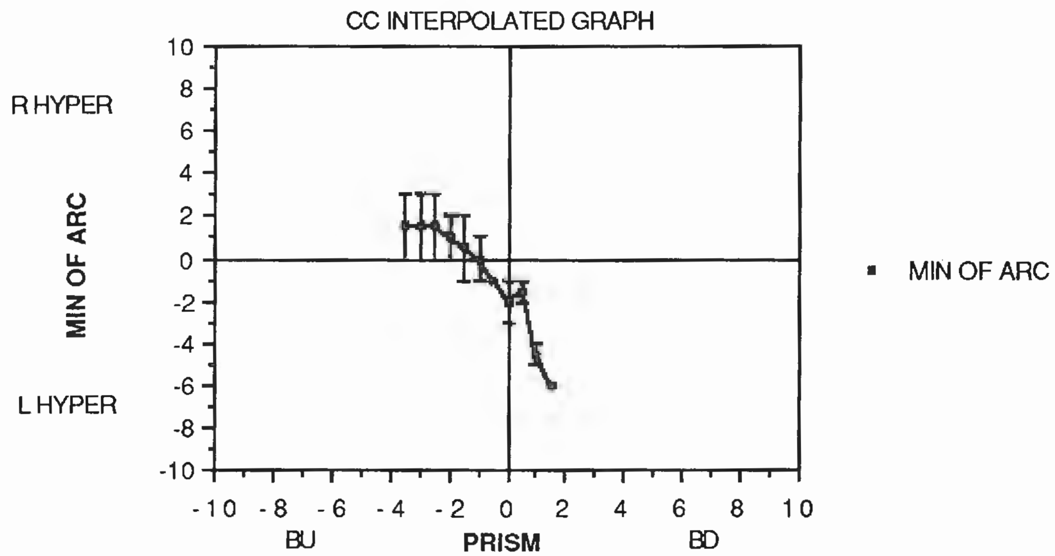
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC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MIN OF ARC
L HYPER
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6
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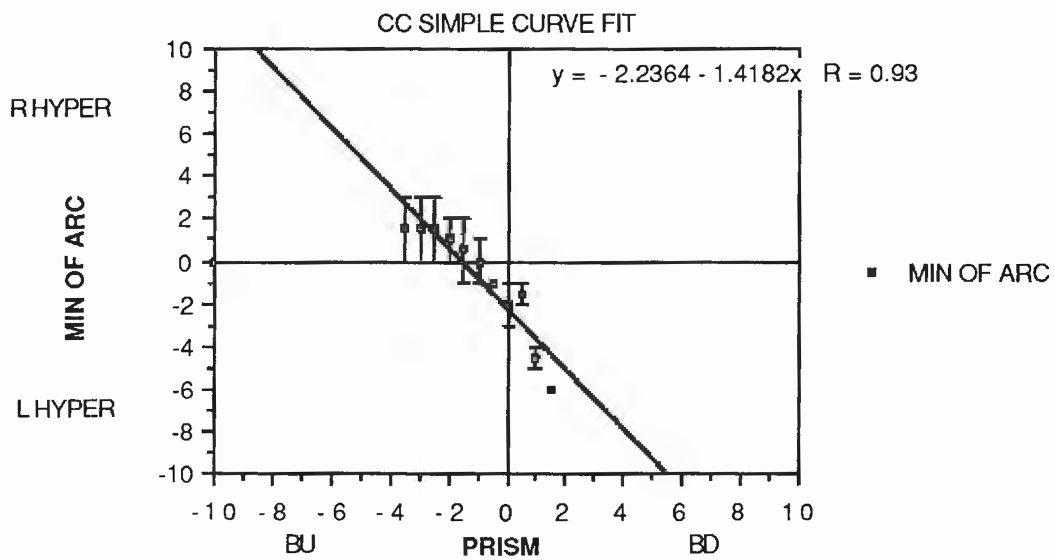
BU
PRISM
BD
MIN OF ARC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PRISM
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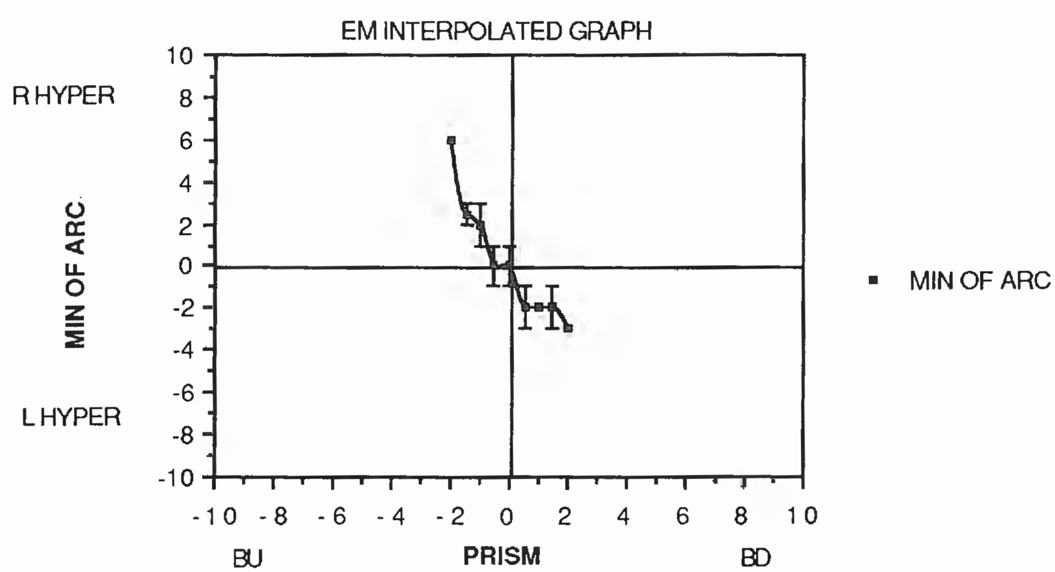
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L HYPER
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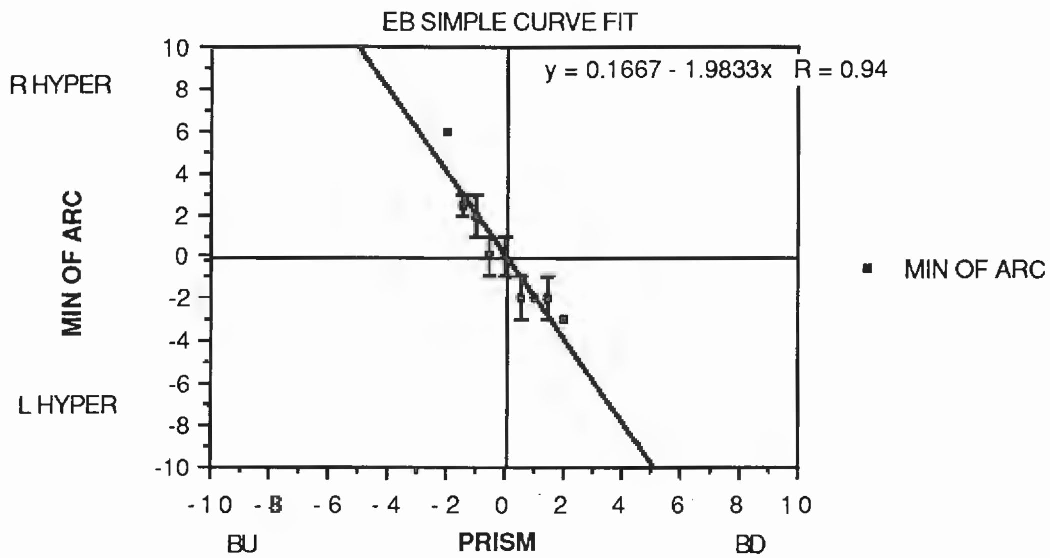
BU
PRISM
BD
MIN OF ARC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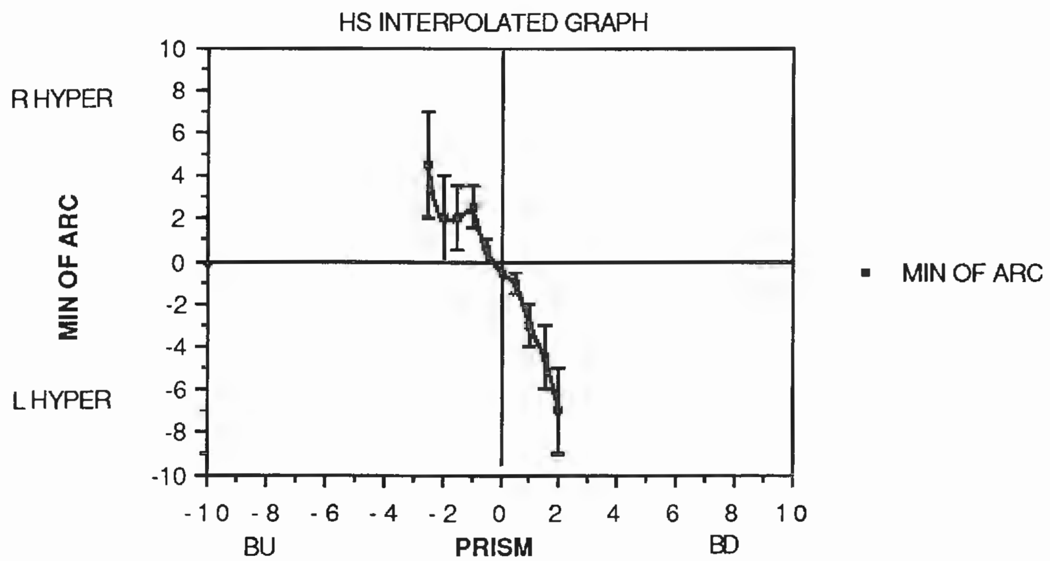
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BU
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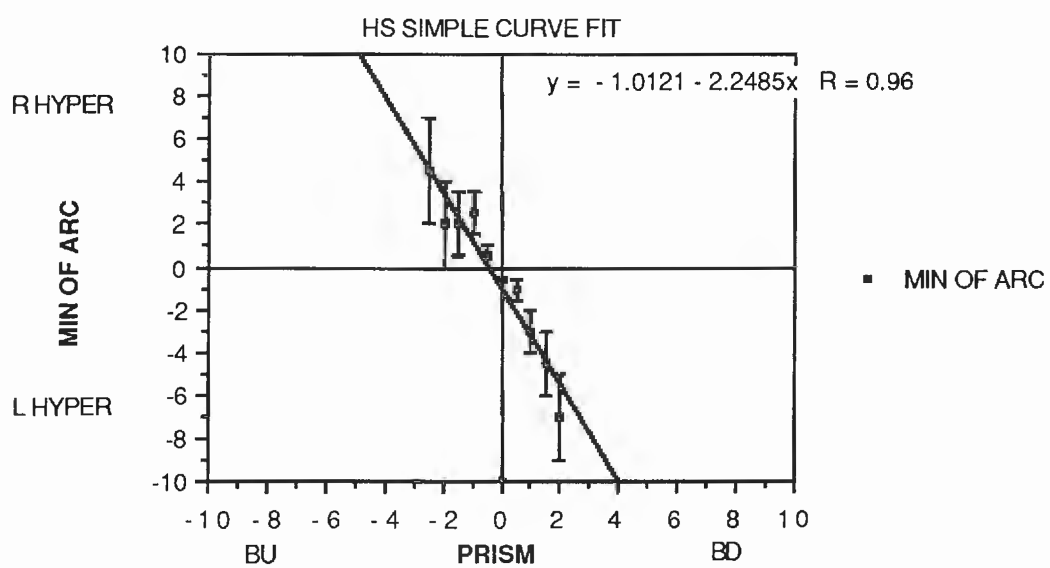
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BU
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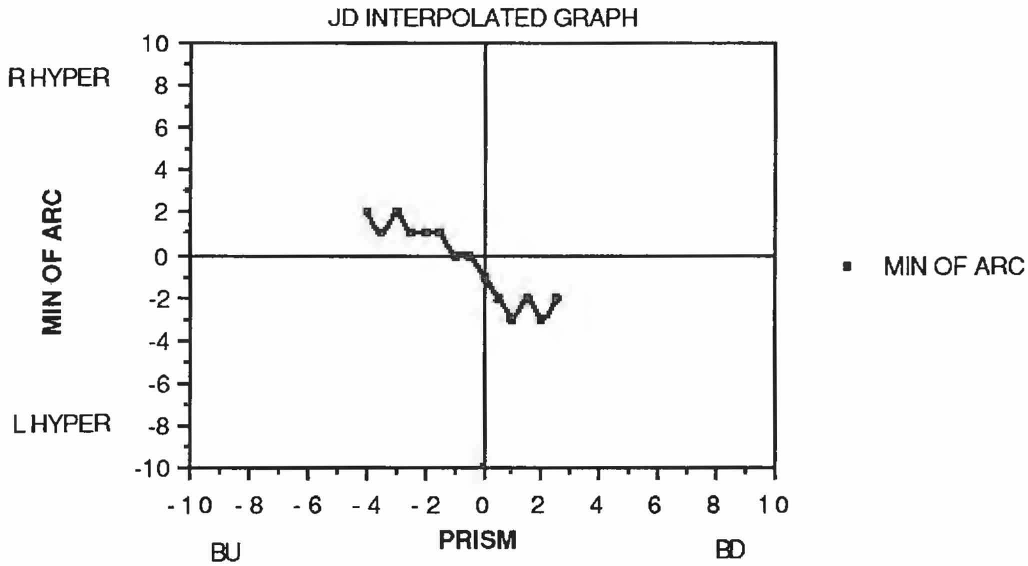
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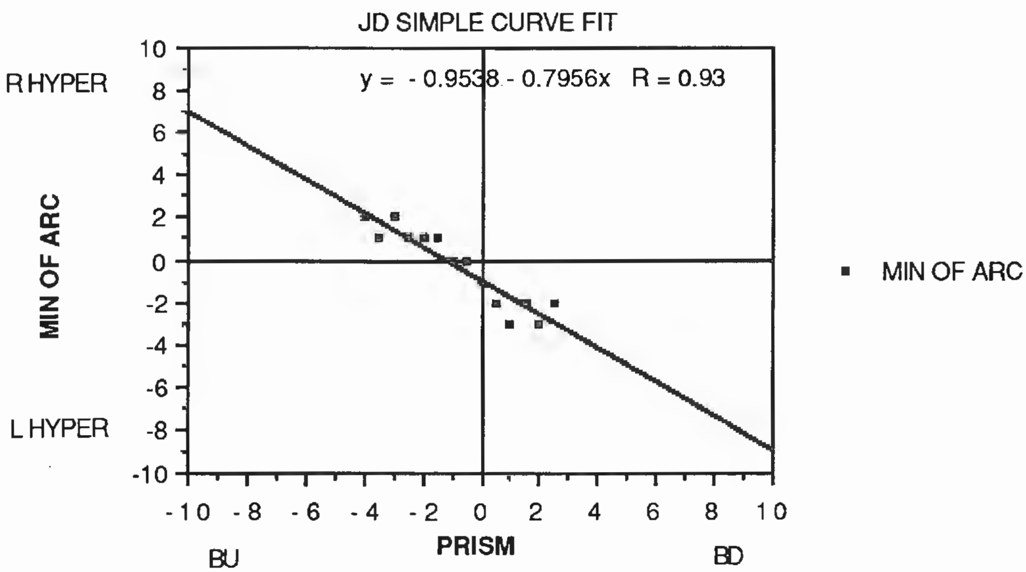
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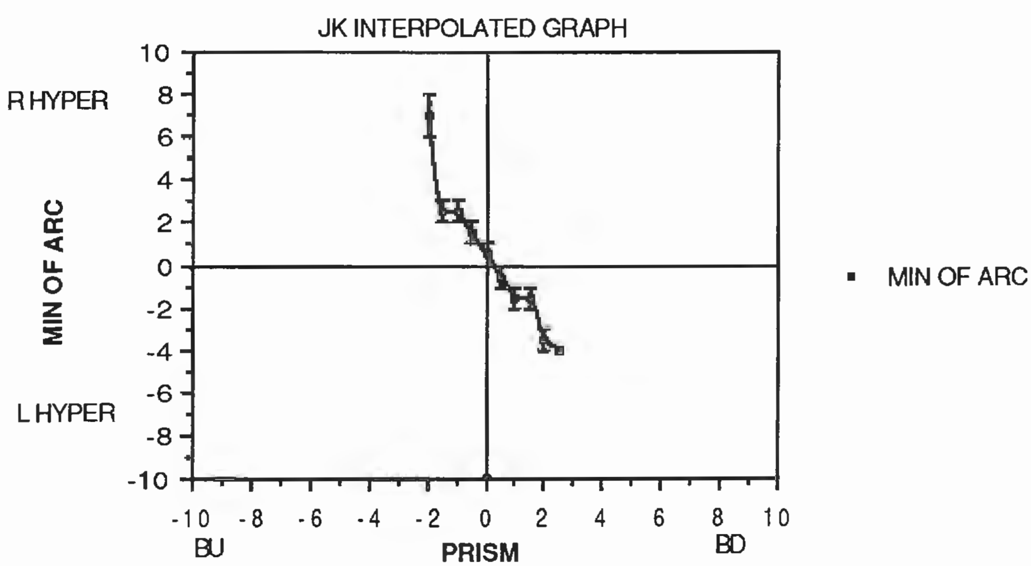
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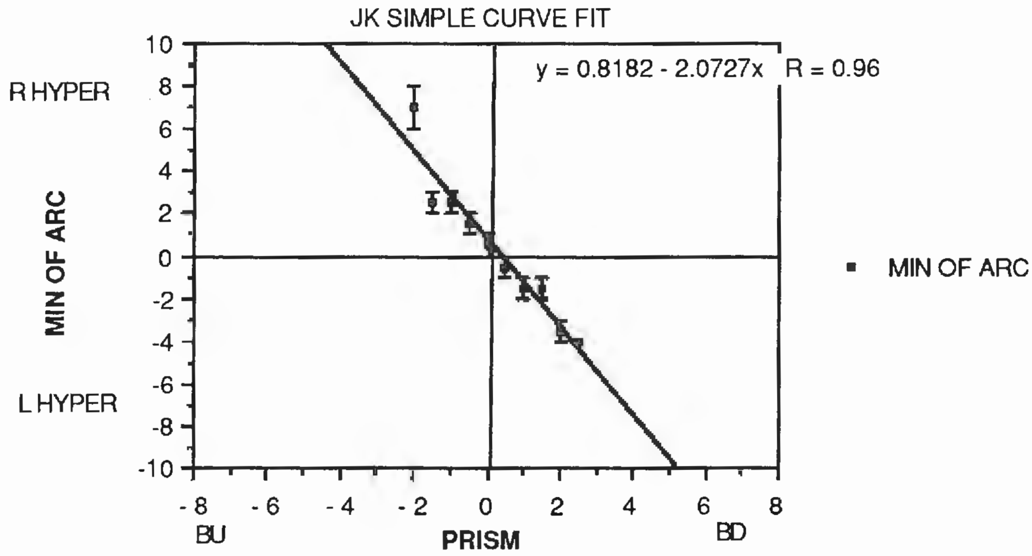
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PRISM
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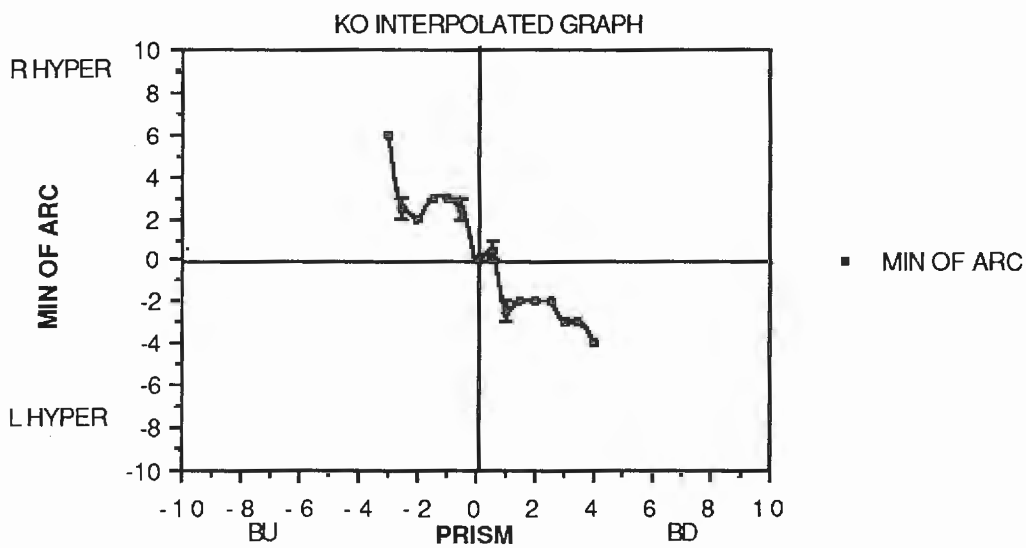
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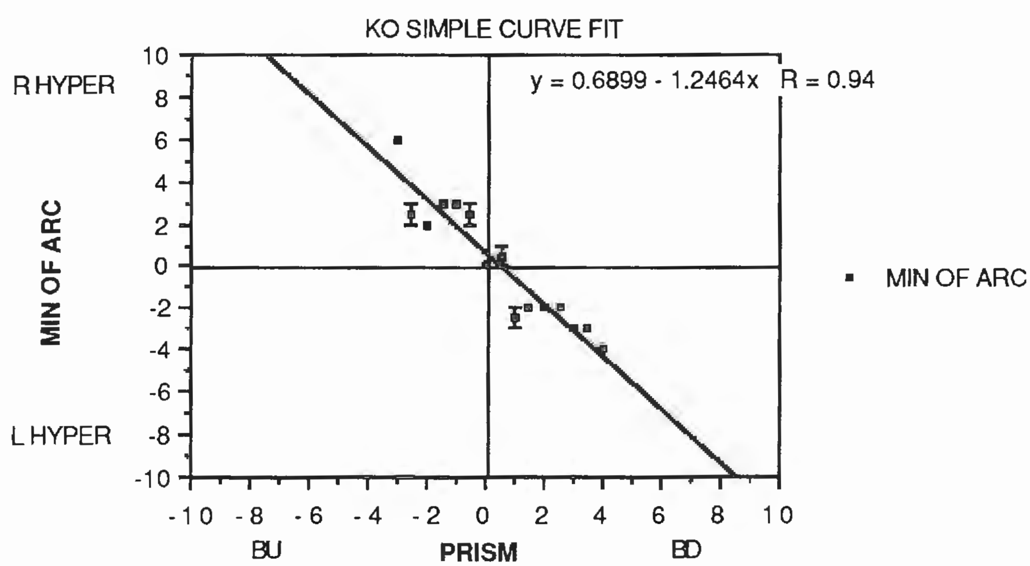
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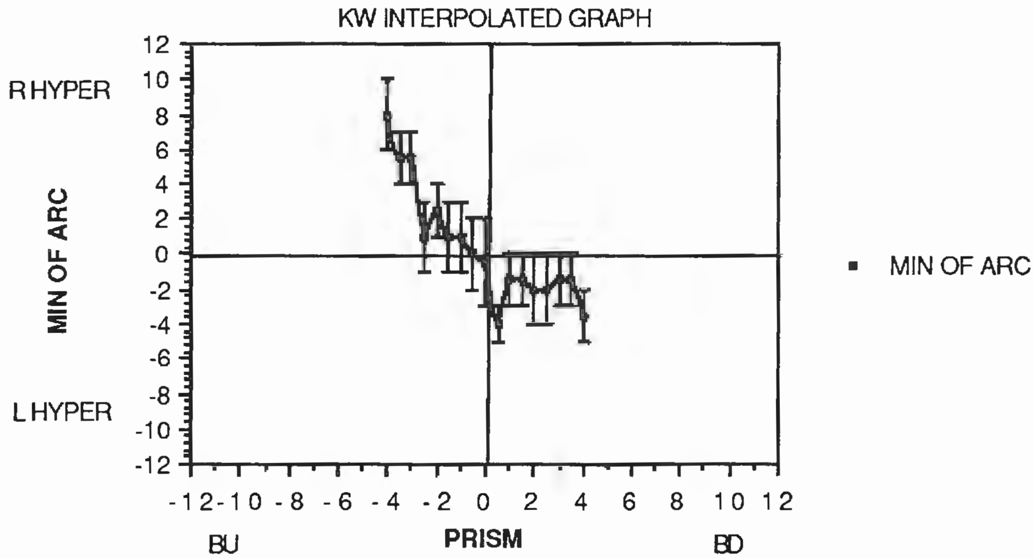
MIN OF ARC



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PRISM
BD
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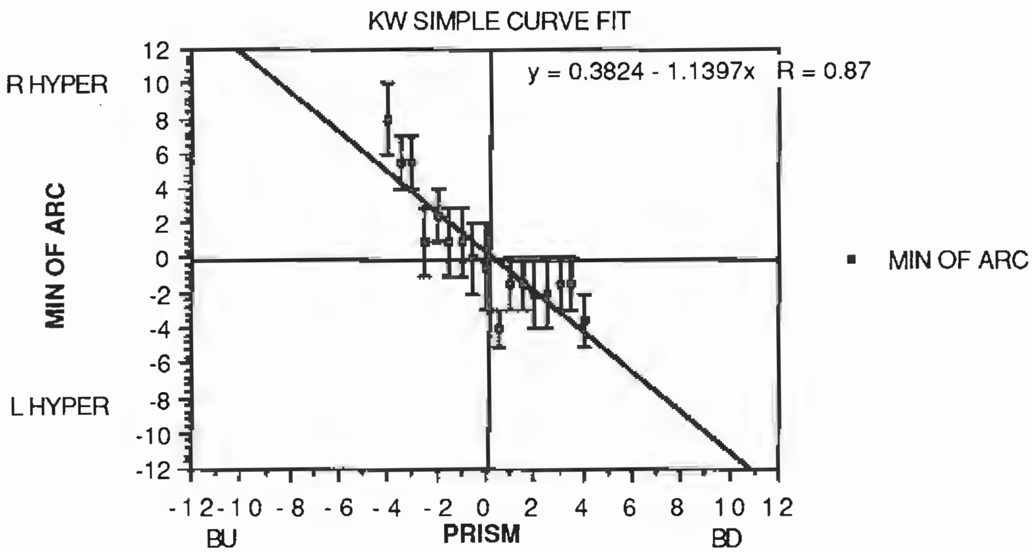

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12
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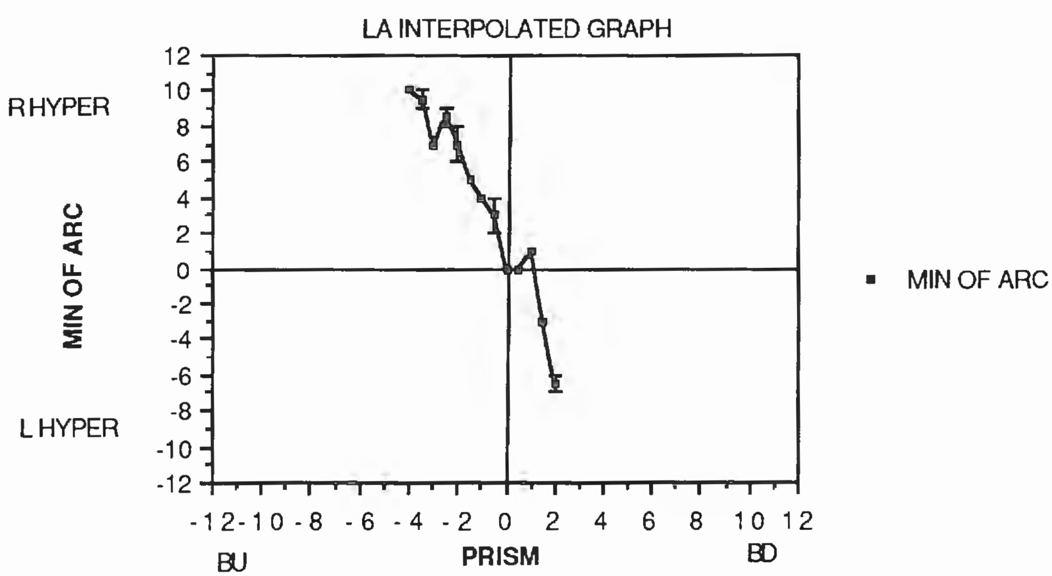
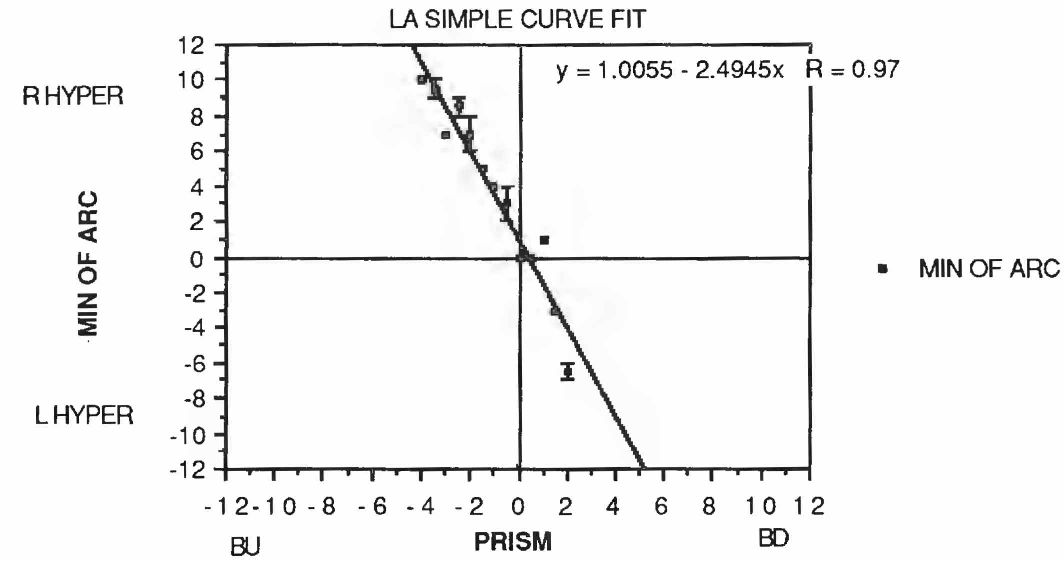
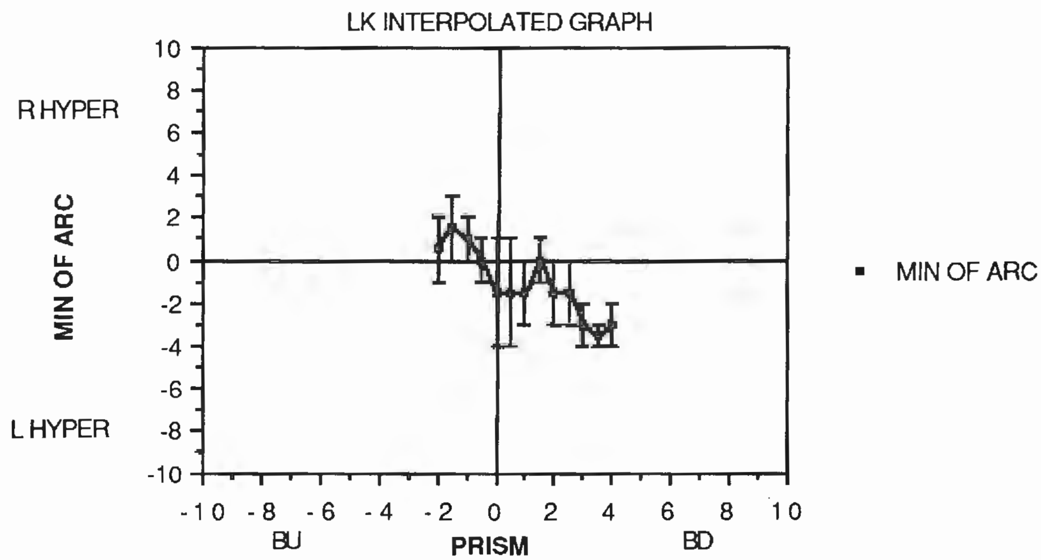
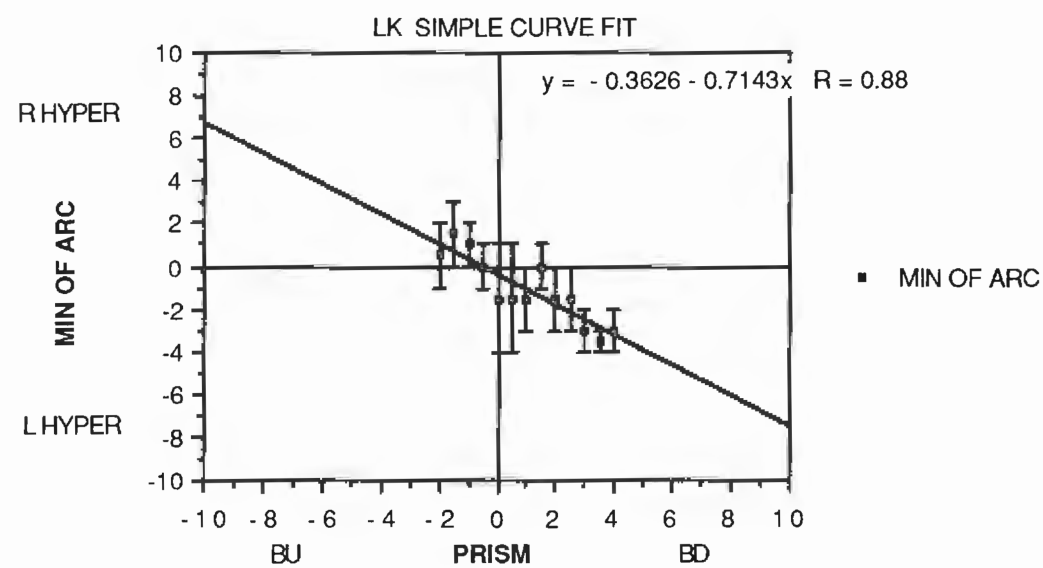
-10
-12
-12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12
BU
PRISM
BD
MIN OF ARC

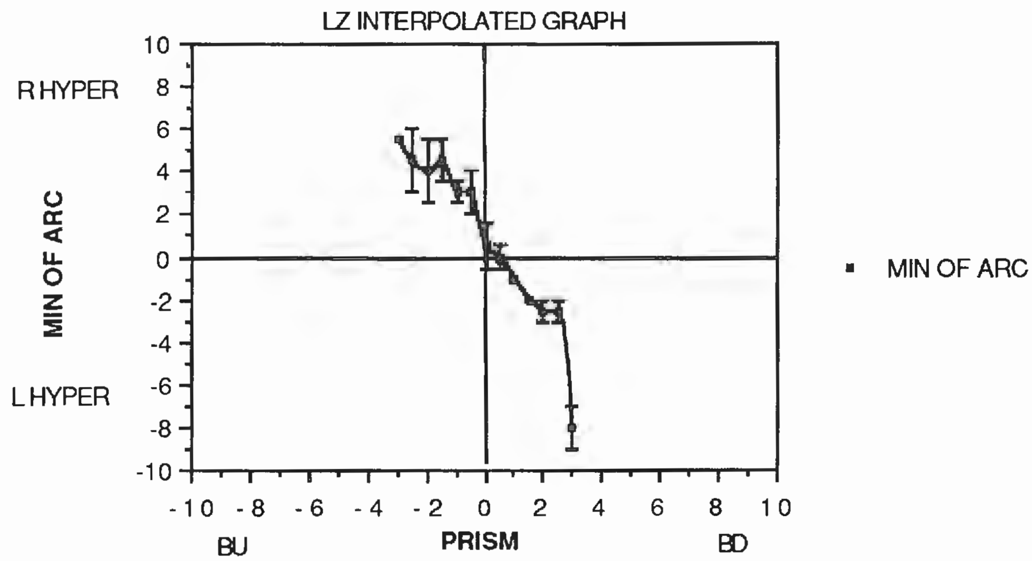


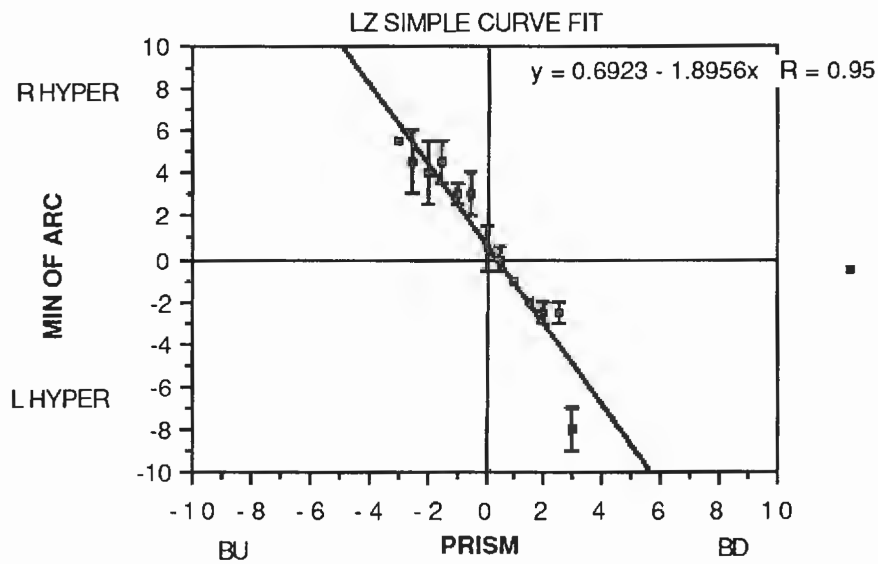
LA INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12
BU
PRISM
BD
MIN OF ARC

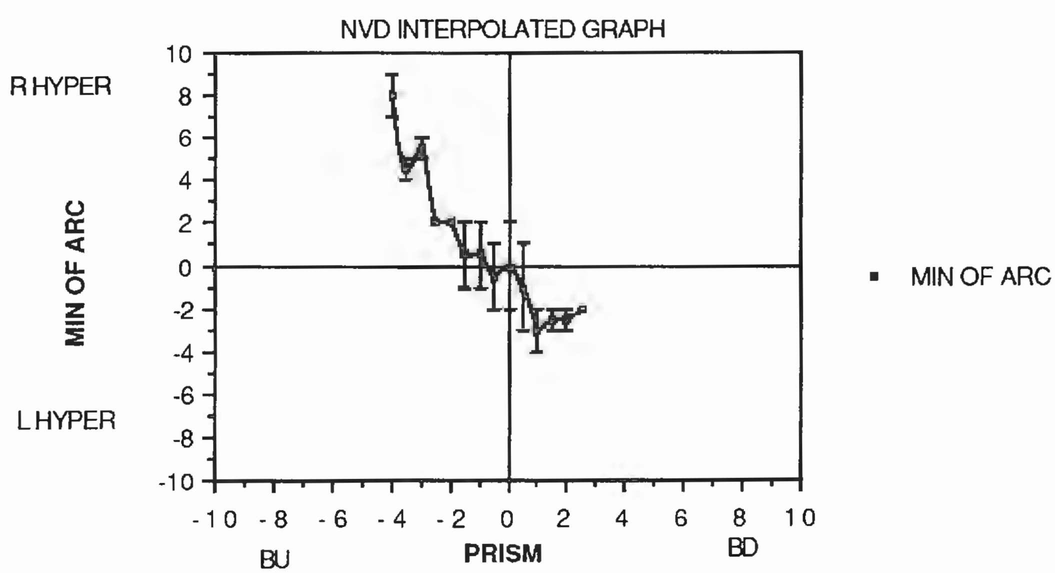

LA SIMPLE CURVE FIT
y = 1.0055 - 2.4945x R = 0.97
R HYPER
MIN OF ARC
L HYPER
PRISM
BU
BD
MIN OF ARC

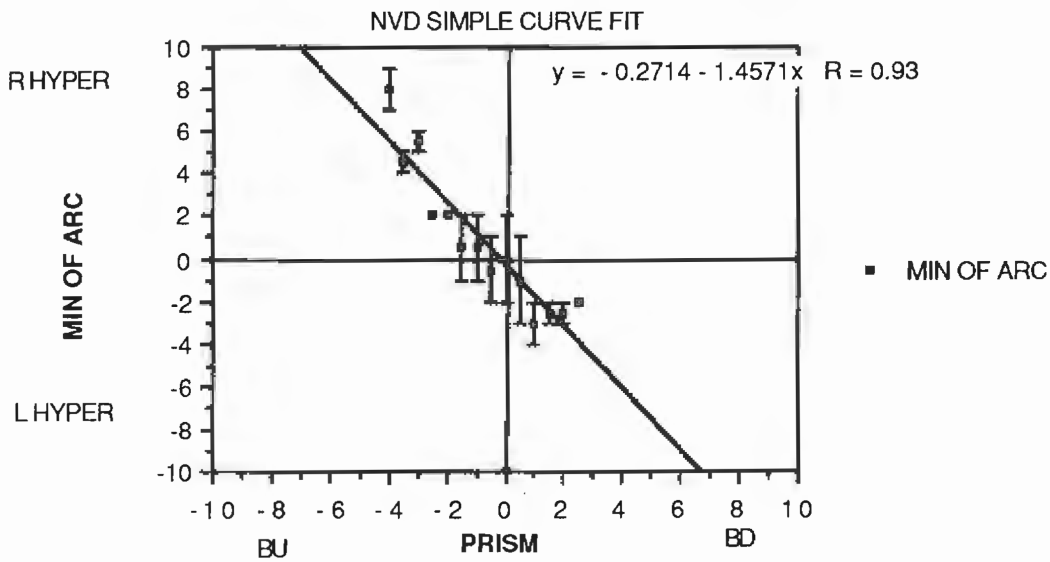

LK INTERPOLATED GRAPH
R HYPER
MIN OF ARC
L HYPER
PRISM
BU
BD
MIN OF ARC

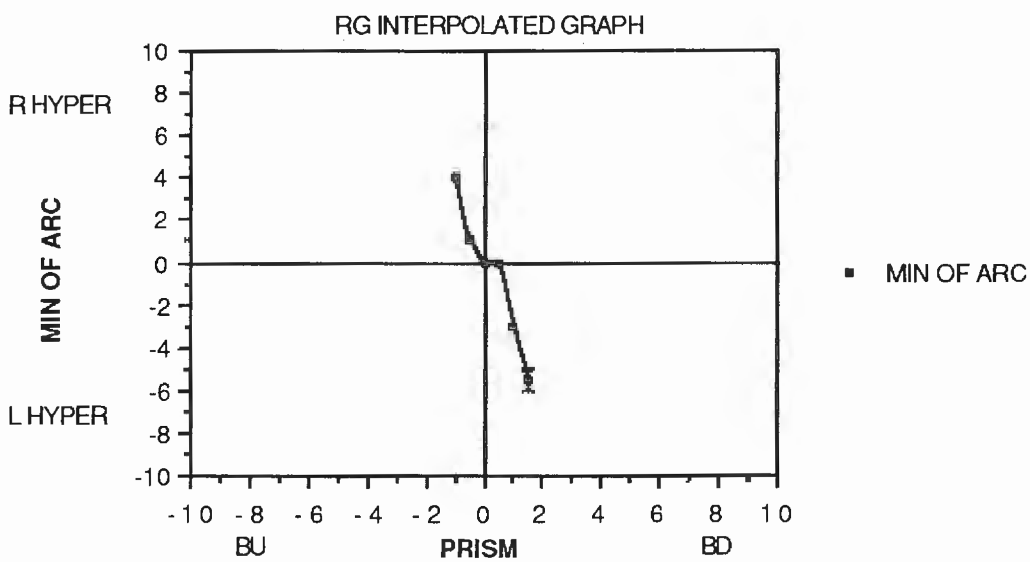

LK SIMPLE CURVE FIT
y = - 0.3626 - 0.7143x R = 0.88
R HYPER
MIN OF ARC
L HYPER
PRISM
BU
BD
MIN OF ARC

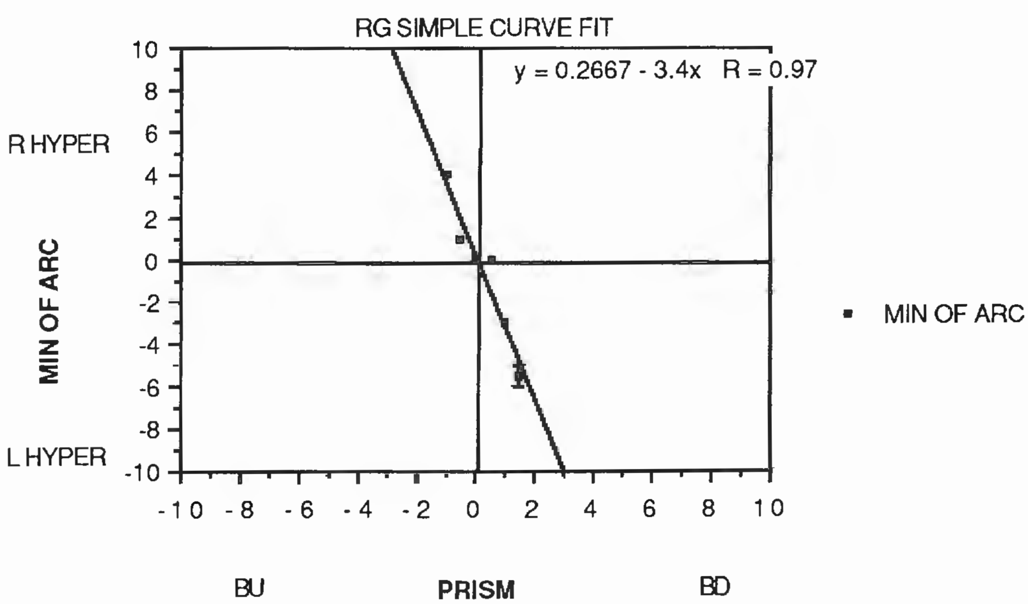

LZ INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC

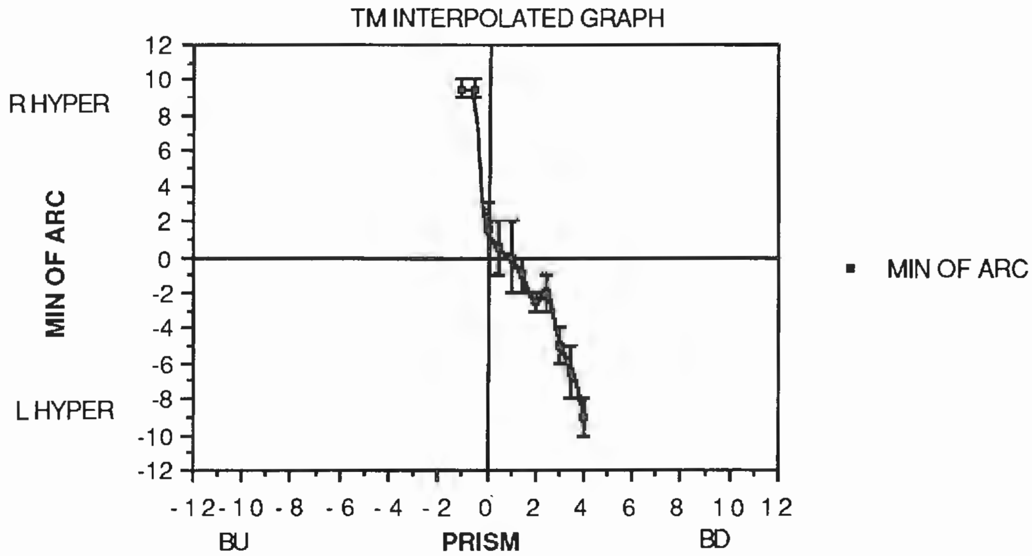

LZ SIMPLE CURVE FIT
y = 0.6923 - 1.8956x R = 0.95
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC


NVD INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC


NVD SIMPLE CURVE FIT
y = - 0.2714 - 1.4571x R = 0.93
R HYPER
L HYPER
MIN OF ARC
10
8
6
4
2
0
-2
-4
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


RG INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
10
8
6
4
2
0
-2
-4
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


RG SIMPLE CURVE FIT
y = 0.2667 - 3.4x R = 0.97
R HYPER
L HYPER
MIN OF ARC
10
8
6
4
2
0
-2
-4
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC



TM INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
12
10
8
6
4
2
0
-2
-4
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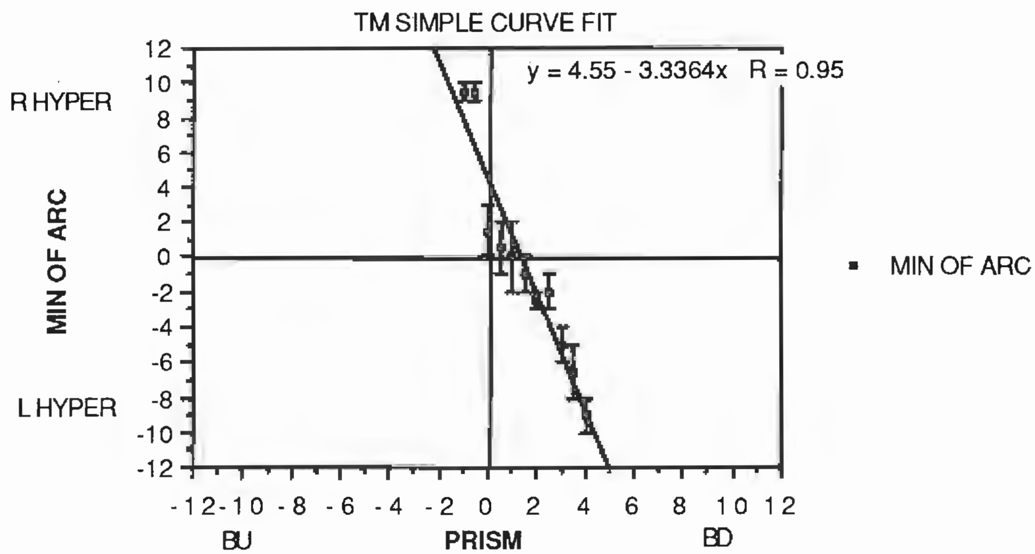
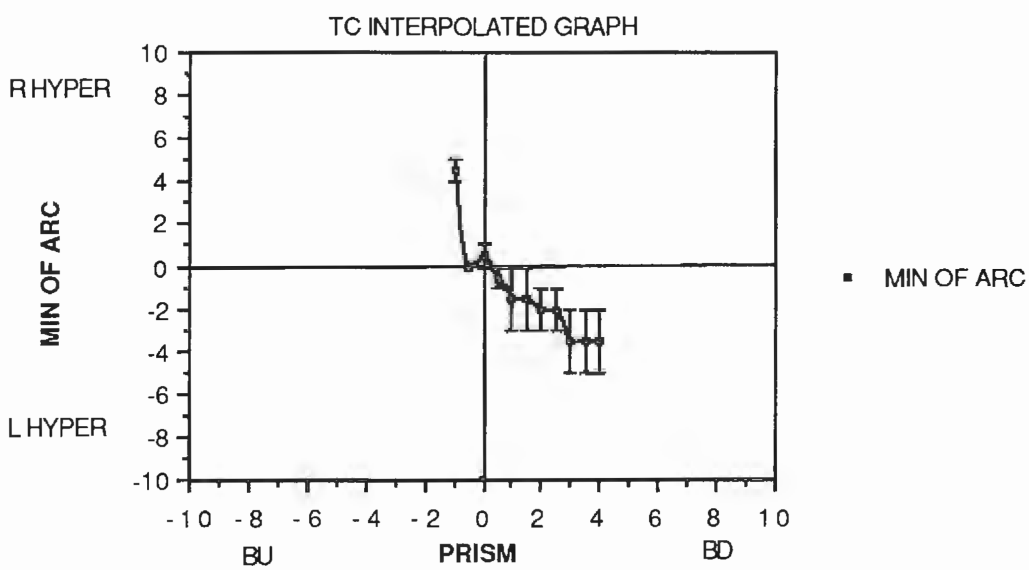
-8
-10
-12
-12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12
BU
PRISM
BD
MIN OF ARC



TM SIMPLE CURVE FIT
y = 4.55 - 3.3364x R = 0.95
R HYPER
L HYPER
MIN OF ARC
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
-12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12
BU
PRISM
BD
MIN OF ARC



TC INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
10
8
6
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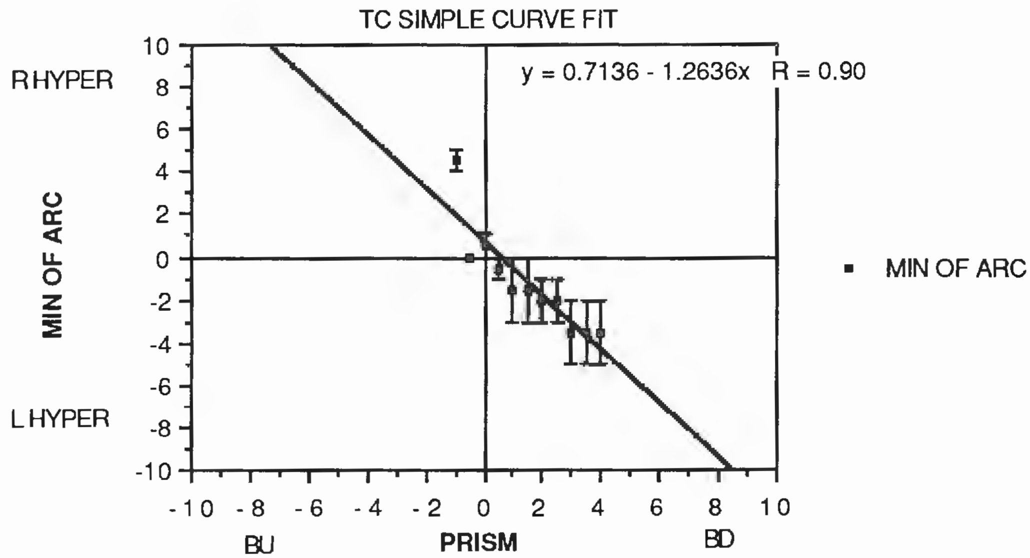
-4
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


TC SIMPLE CURVE FIT
y = 0.7136 - 1.2636x R = 0.90
R HYPER
MIN OF ARC
L HYPER
10
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6
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-2
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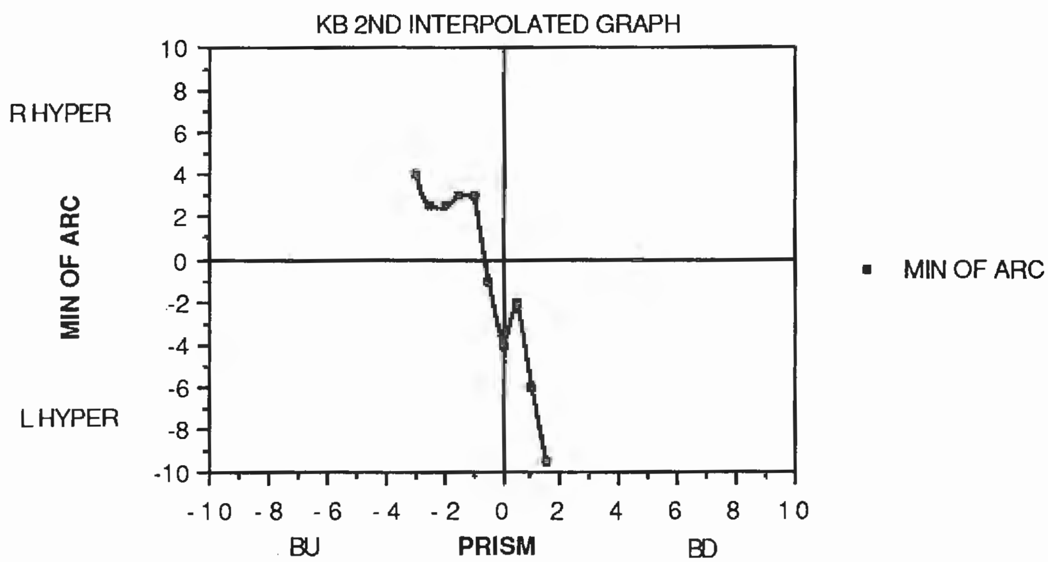
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


KB 2ND INTERPOLATED GRAPH
R HYPER
MIN OF ARC
L HYPER
10
8
6
4
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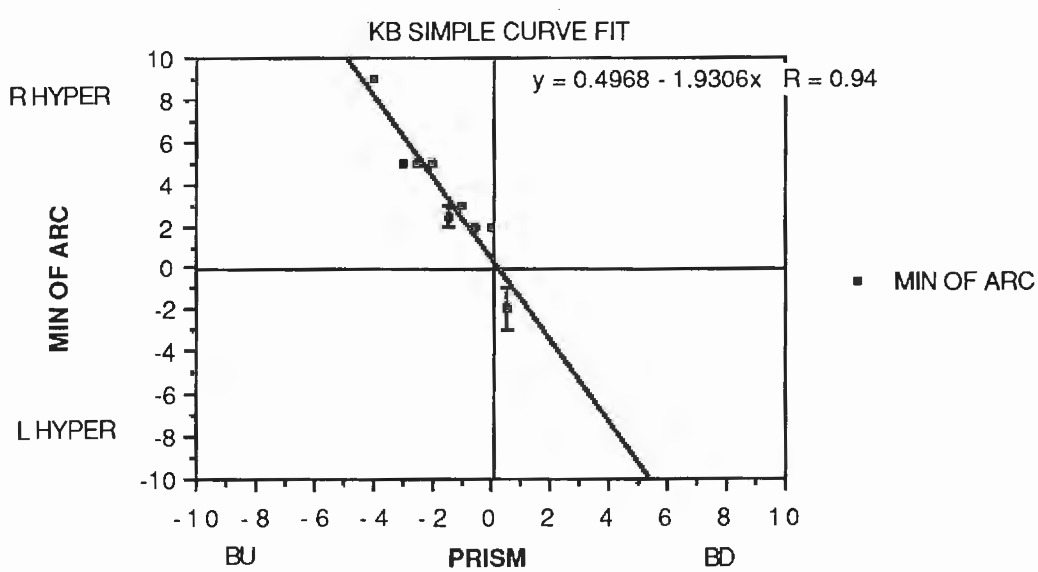
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


KB SIMPLE CURVE FIT
y = 0.4968 - 1.9306x R = 0.94
R HYPER
MIN OF ARC
L HYPER
10
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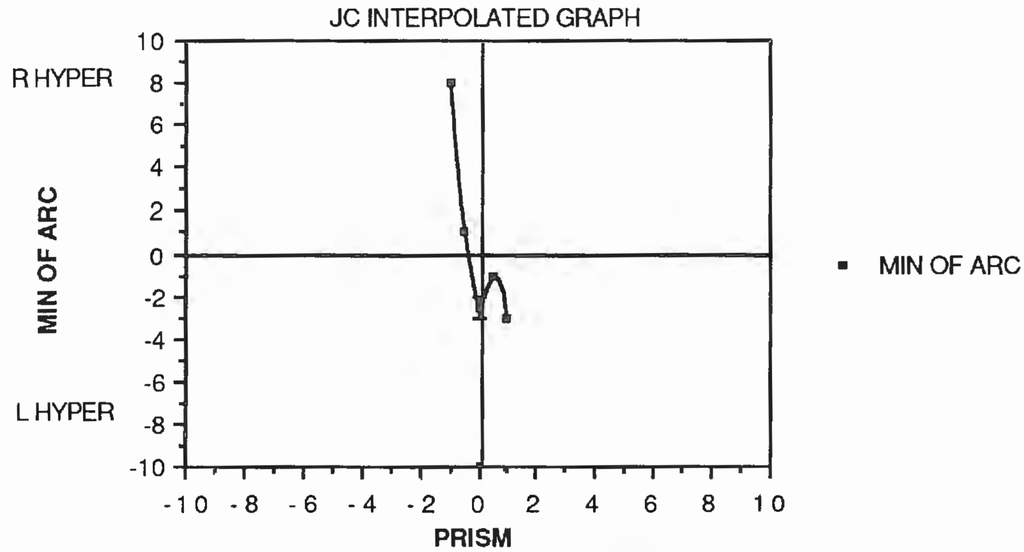
-2
-4
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


JC INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
PRISM
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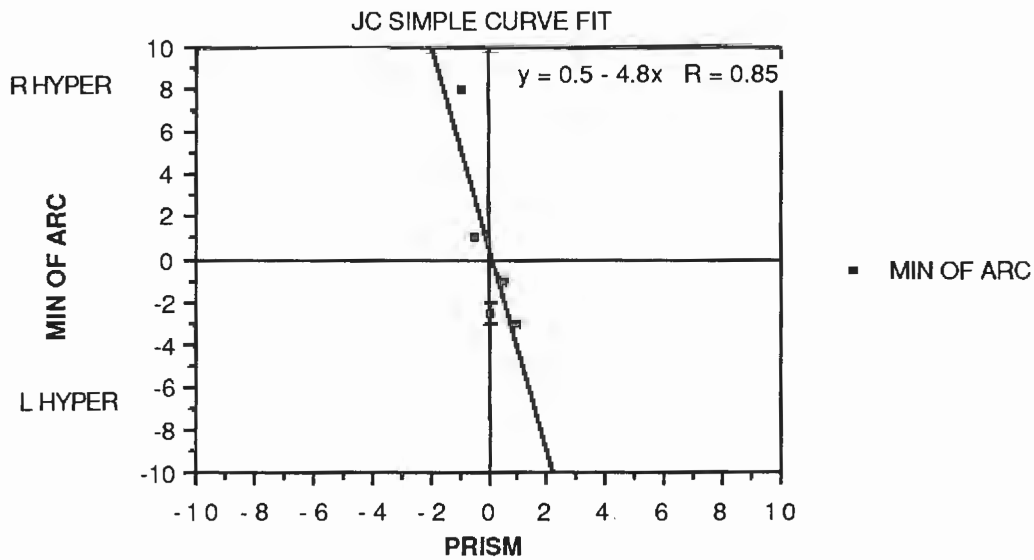
-2
-4
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
▪ MIN OF ARC


JC SIMPLE CURVE FIT
y = 0.5 - 4.8x R = 0.85
R HYPER
L HYPER
MIN OF ARC
PRISM
10
8
6
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-2
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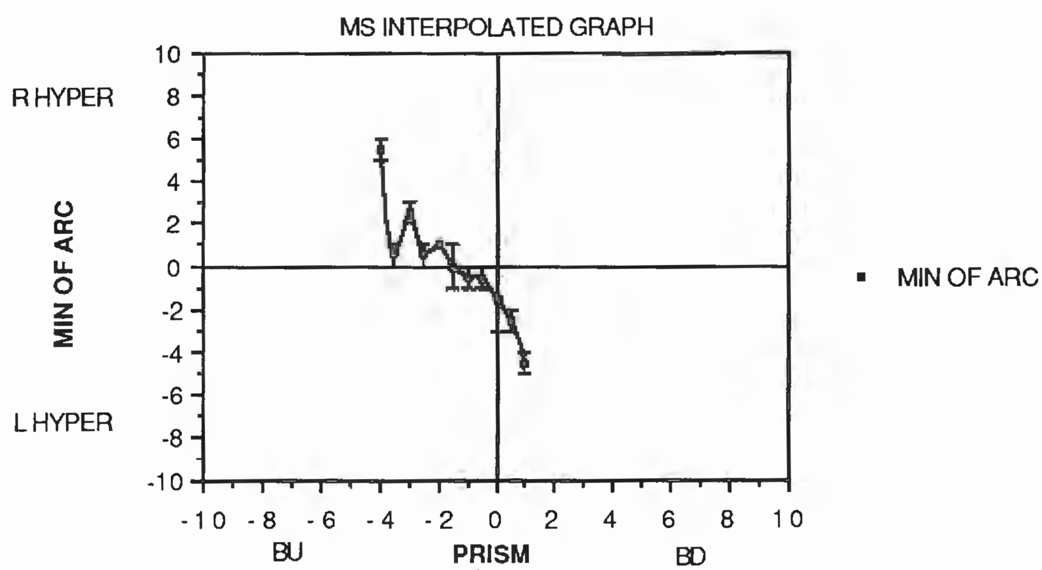
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
▪ MIN OF ARC


MS INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
10
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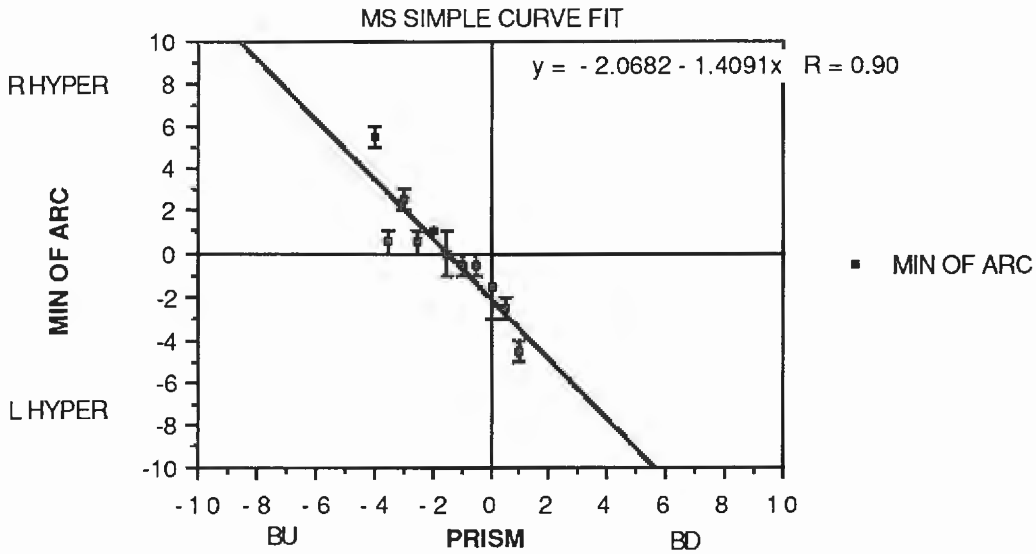
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
▪ MIN OF ARC



MS SIMPLE CURVE FIT
y = - 2.0682 - 1.4091x R = 0.90
R HYPER
L HYPER
MIN OF ARC
MIN OF ARC
BU
PRISM
BD
10
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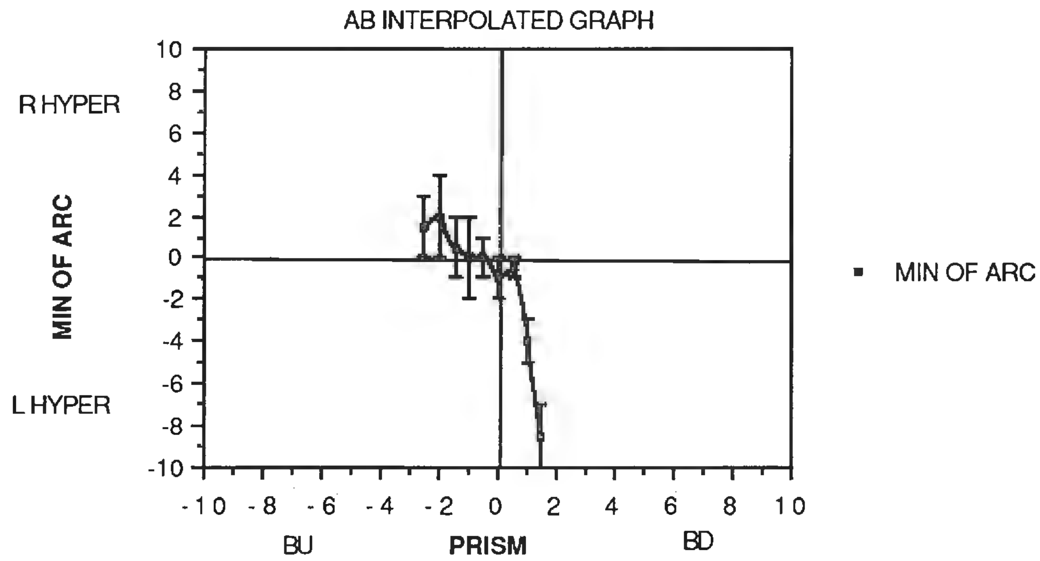
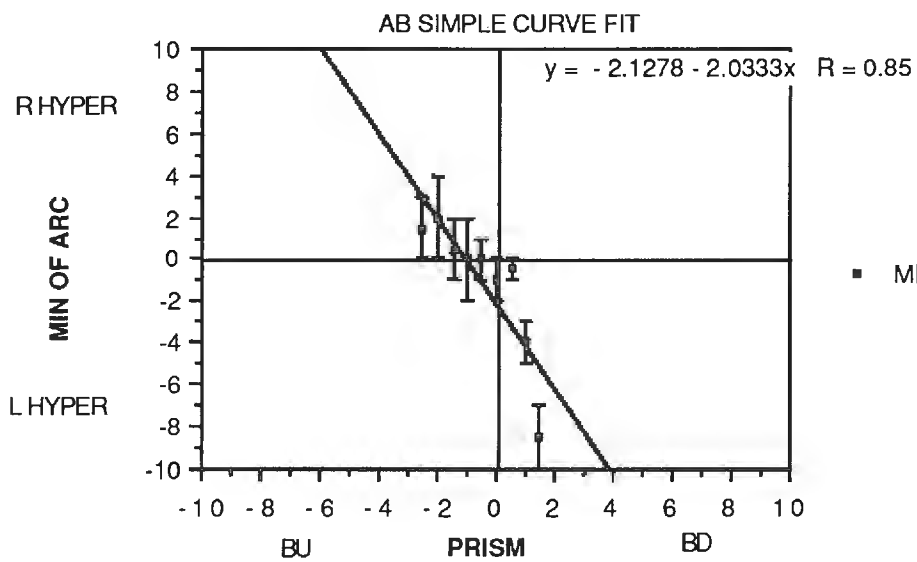
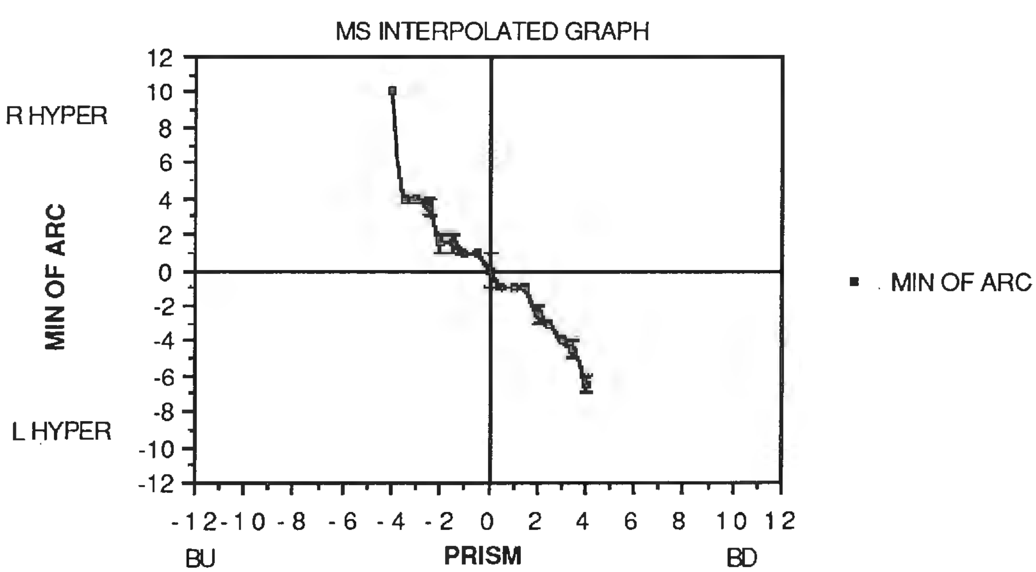
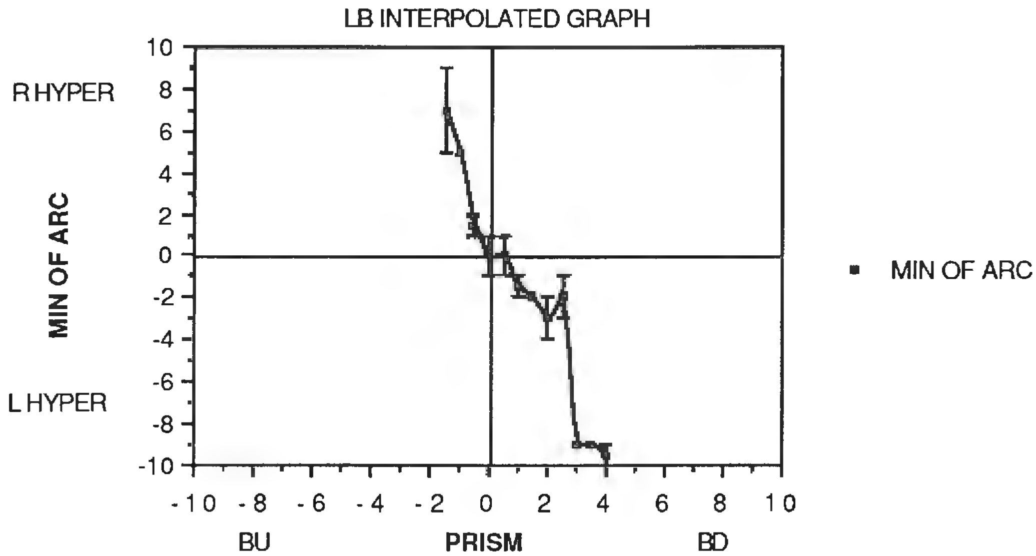
6
8
10

SIGMOIDAL SHAPED CURVES


AB INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC


AB SIMPLE CURVE FIT
y = - 2.1278 - 2.0333x R = 0.85
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC


MS INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC


LB INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
10
8
6
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-4
-6
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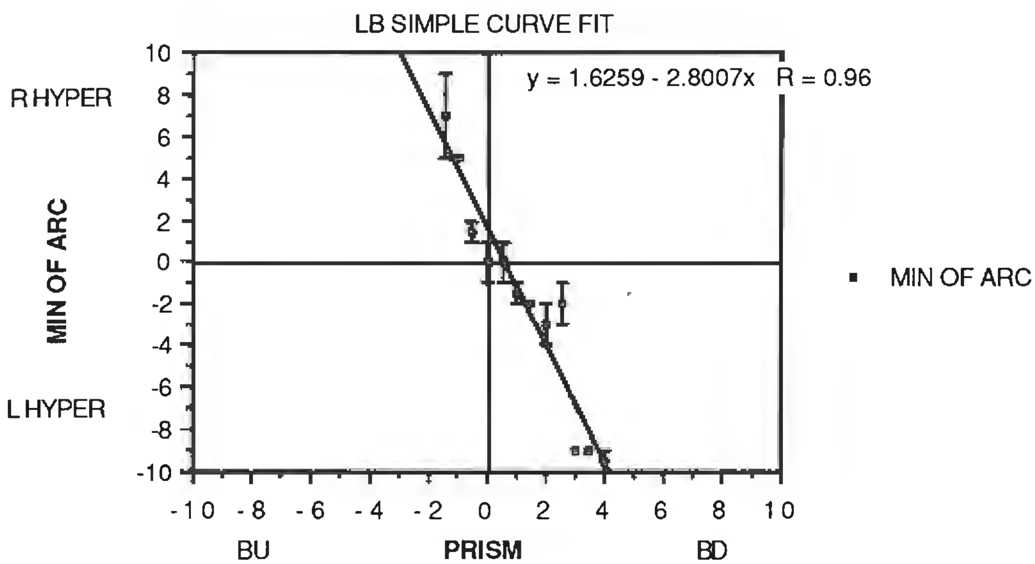
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


LB SIMPLE CURVE FIT
y = 1.6259 - 2.8007x R = 0.96
R HYPER
L HYPER
MIN OF ARC
10
8
6
4
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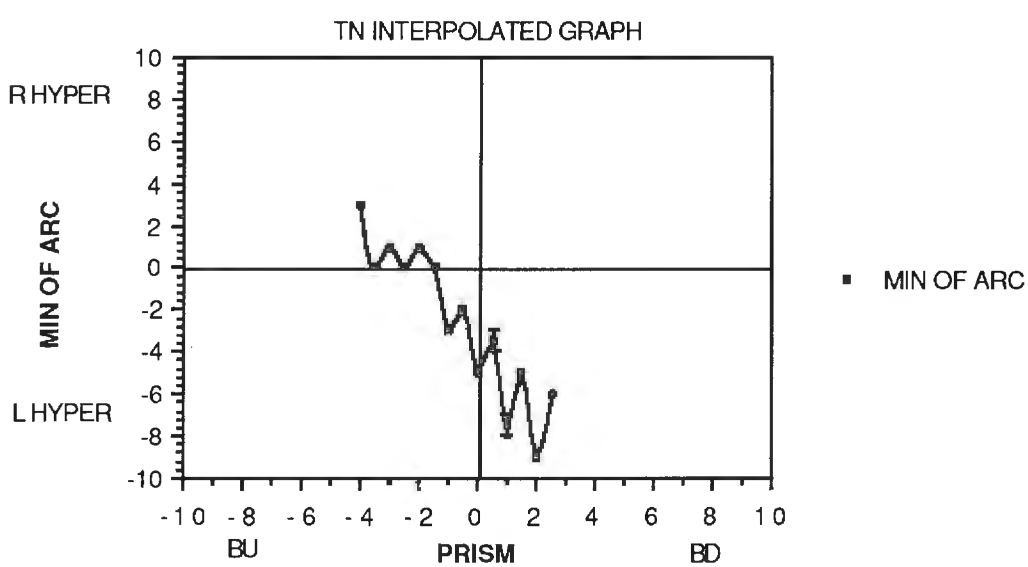
0
-2
-4
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


TN INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
10
8
6
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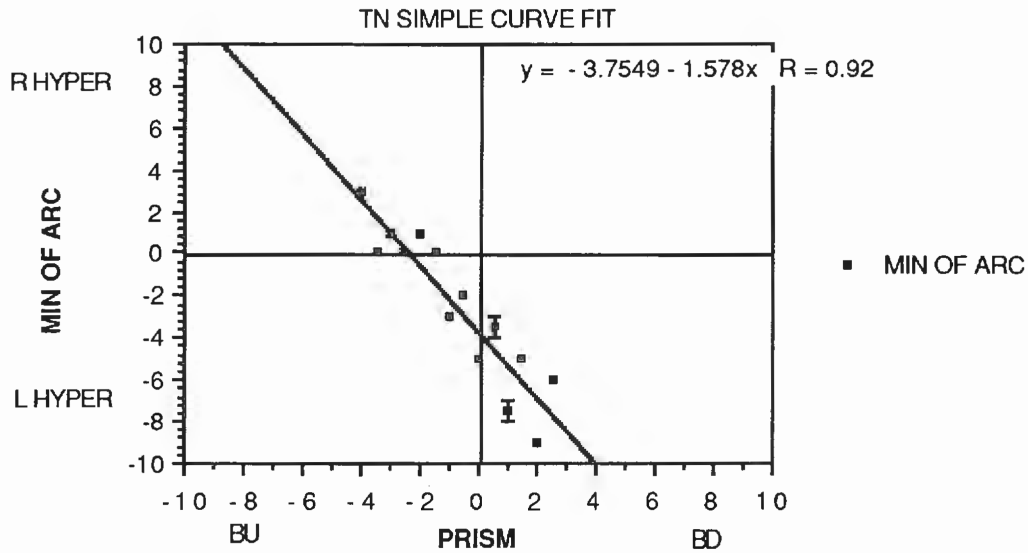
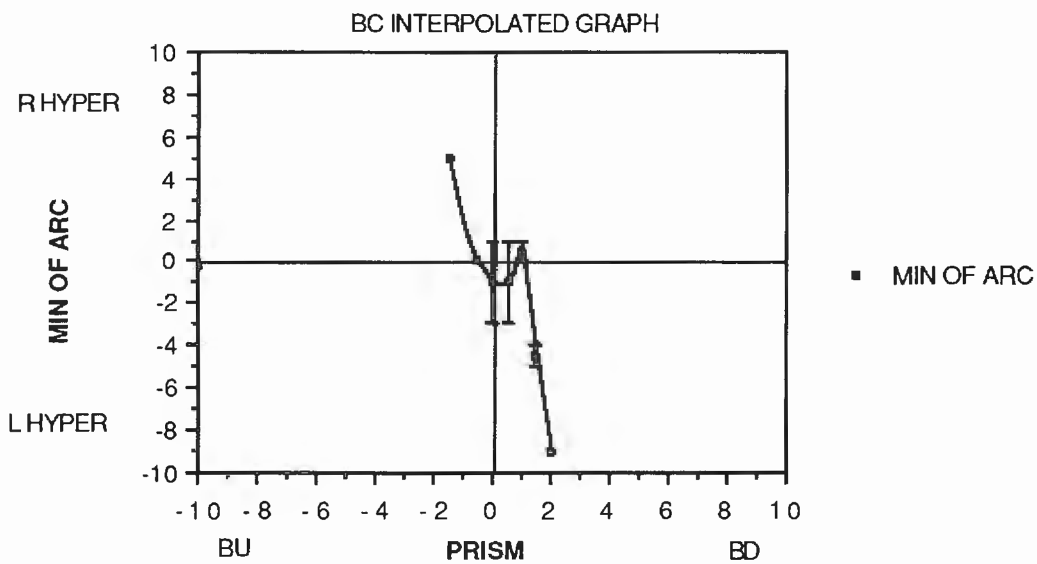
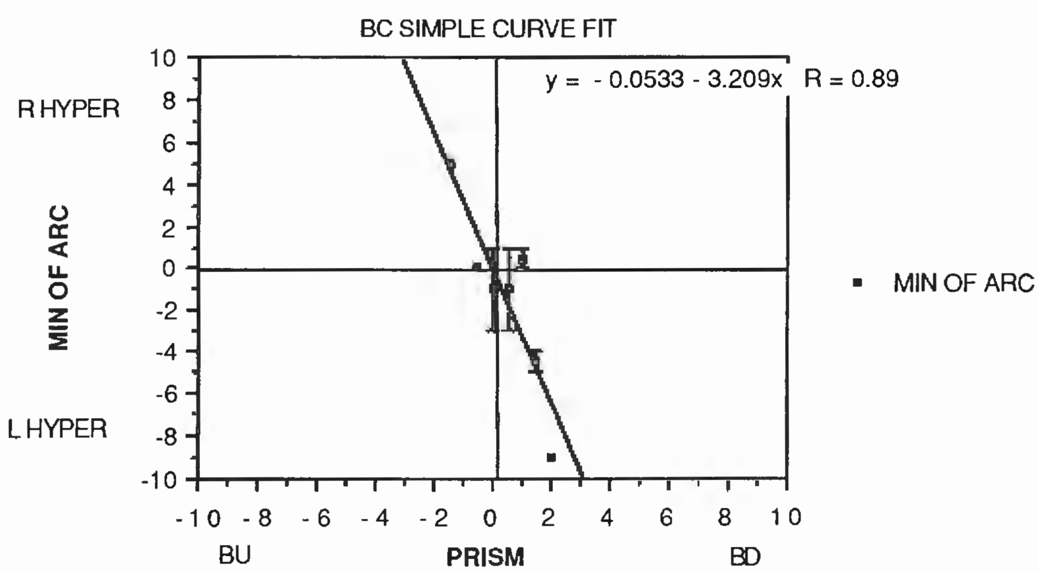
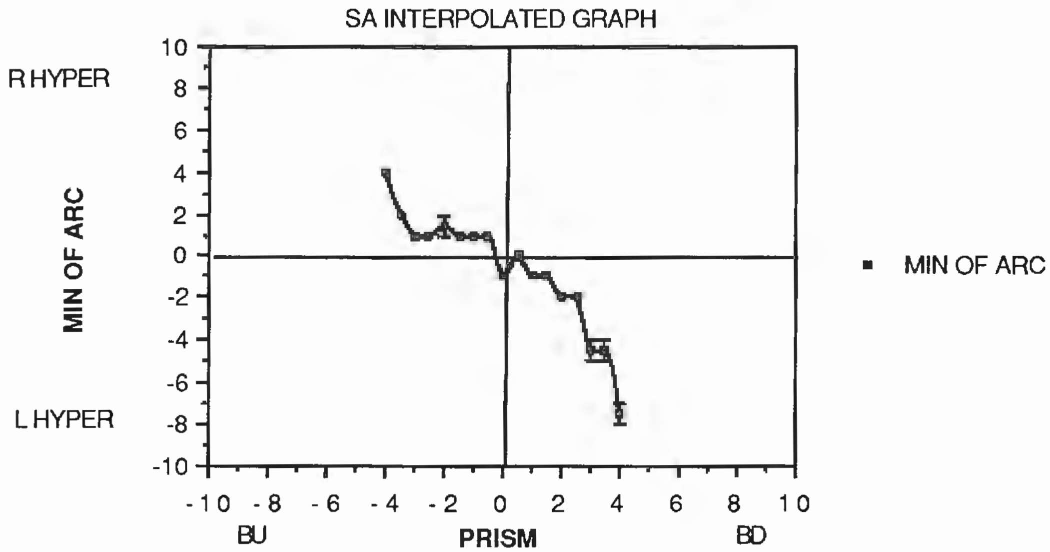
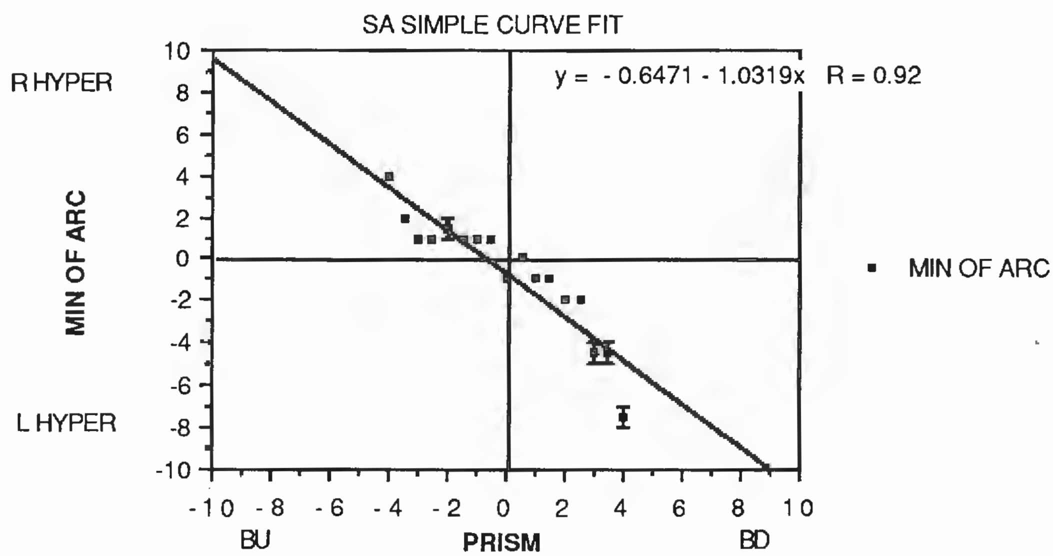
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC

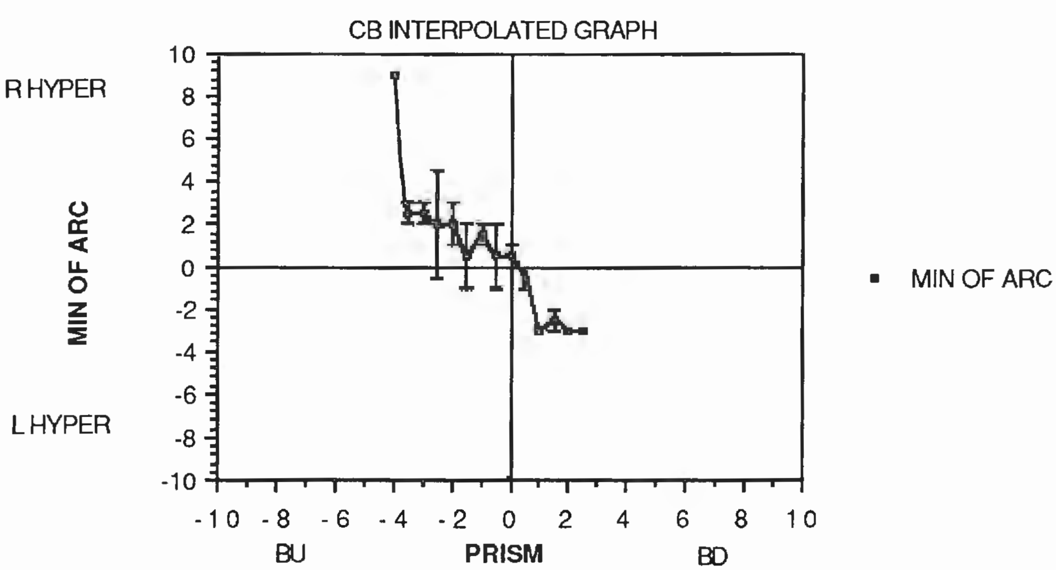

TN SIMPLE CURVE FIT
y = - 3.7549 - 1.578x R = 0.92
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC

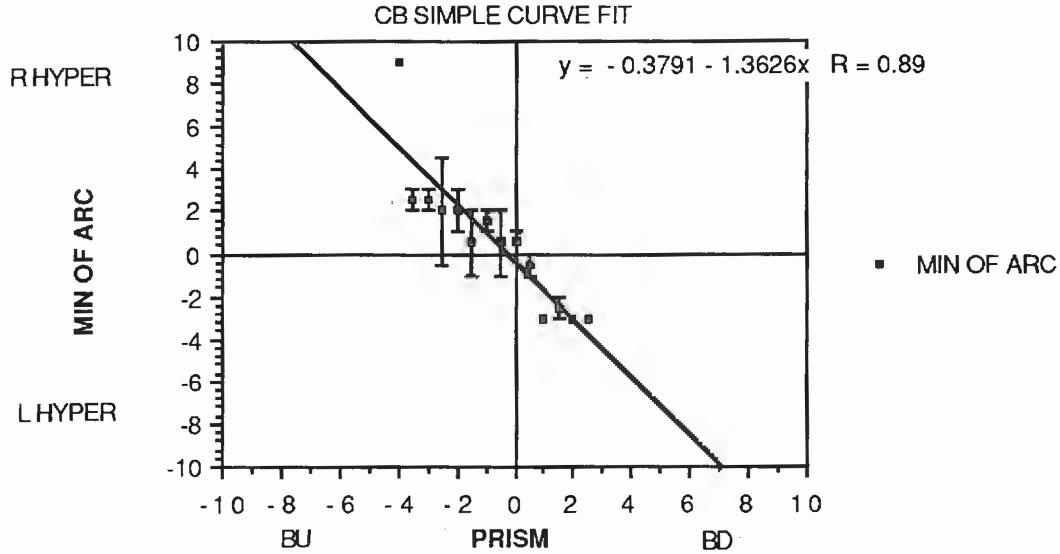

BC INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC


BC SIMPLE CURVE FIT
y = - 0.0533 - 3.209x R = 0.89
R HYPER
L HYPER
MIN OF ARC
PRISM
BU
BD
MIN OF ARC


SA INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
BU
PRISM
BD
MIN OF ARC


SA SIMPLE CURVE FIT
y = - 0.6471 - 1.0319x R = 0.92
R HYPER
L HYPER
MIN OF ARC
BU
PRISM
BD
MIN OF ARC


CB INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
BU
PRISM
BD
MIN OF ARC


CB SIMPLE CURVE FIT
y = - 0.3791 - 1.3626x R = 0.89
R HYPER
MIN OF ARC
L HYPER
10
8
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-2
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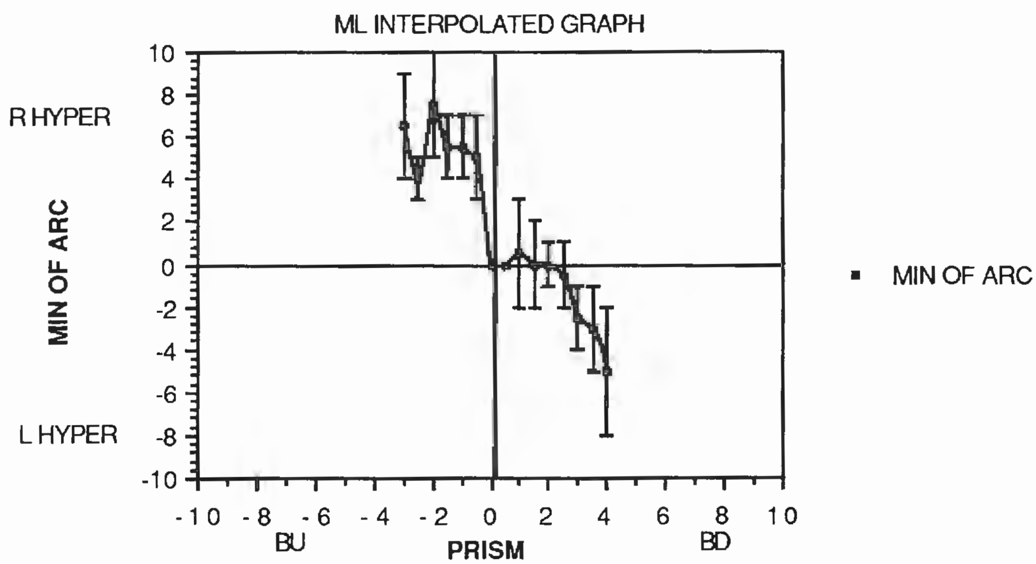
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


ML INTERPOLATED GRAPH
R HYPER
MIN OF ARC
L HYPER
10
8
6
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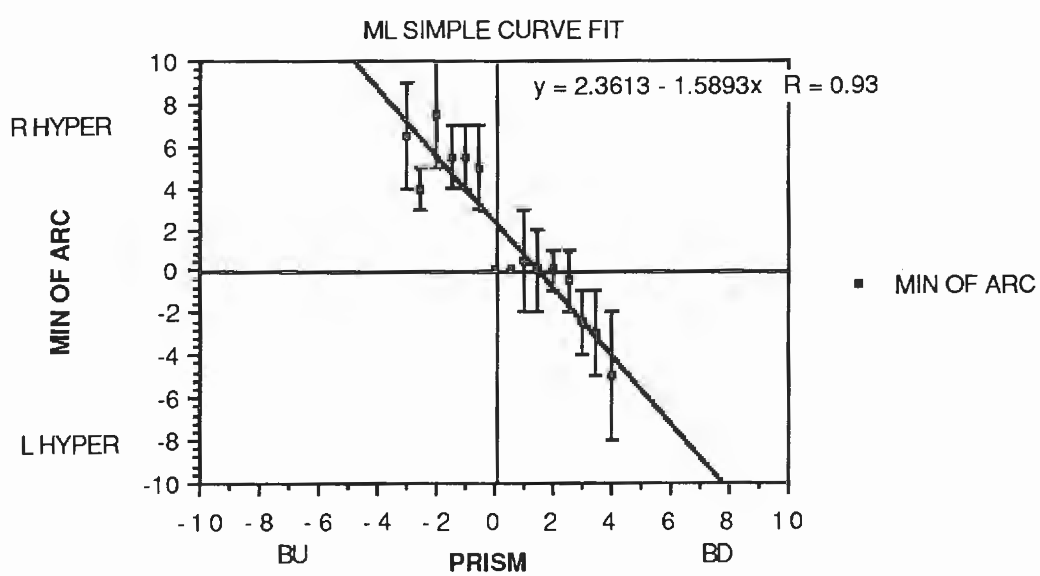
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


ML SIMPLE CURVE FIT
y = 2.3613 - 1.5893x R = 0.93
R HYPER
MIN OF ARC
L HYPER
10
8
6
4
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-2
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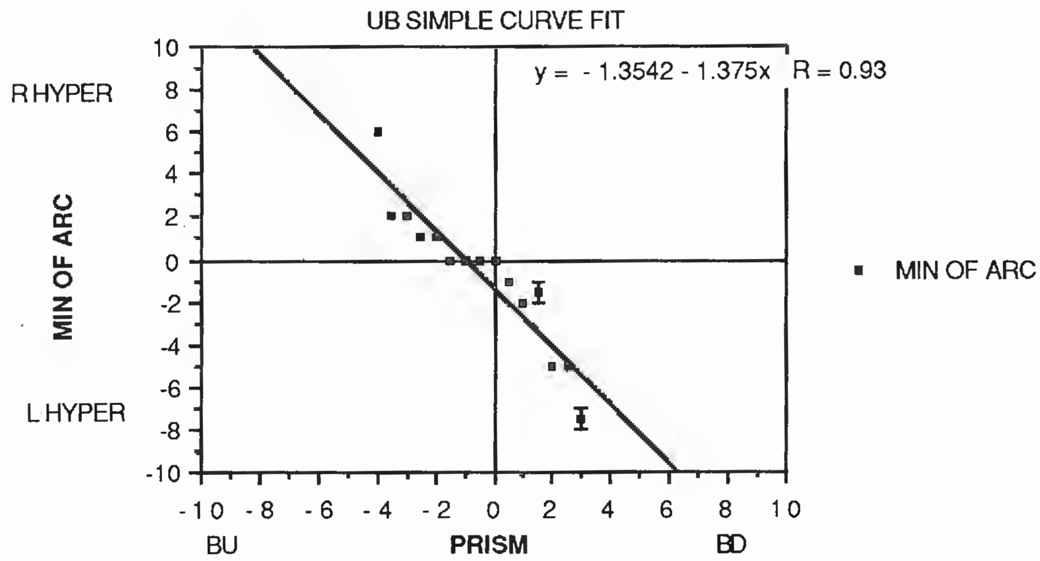
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


UB SIMPLE CURVE FIT
y = - 1.3542 - 1.375x R = 0.93
R HYPER
L HYPER
MIN OF ARC
10
8
6
4
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0
-2
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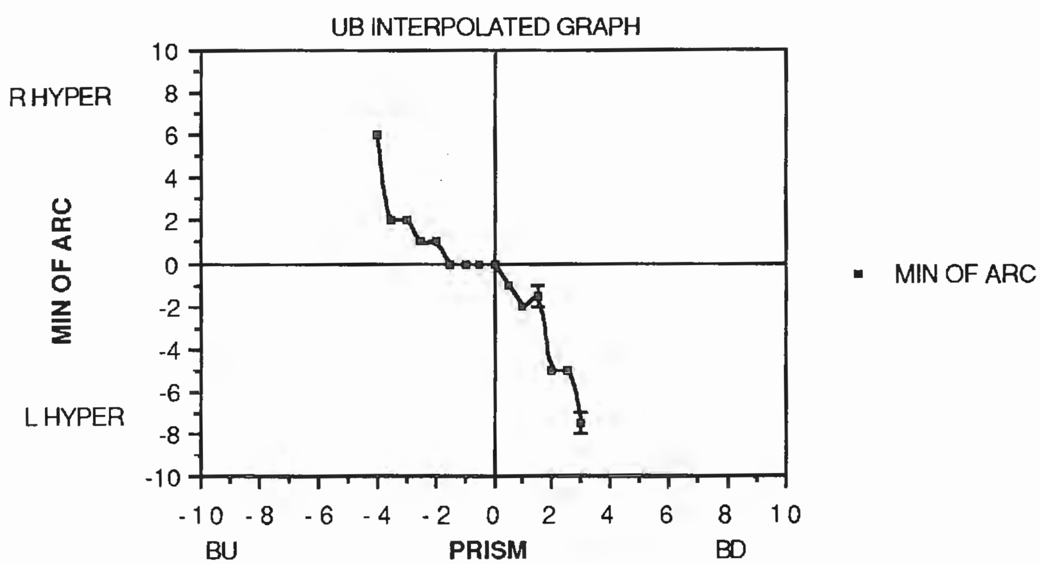
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


UB INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
10
8
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4
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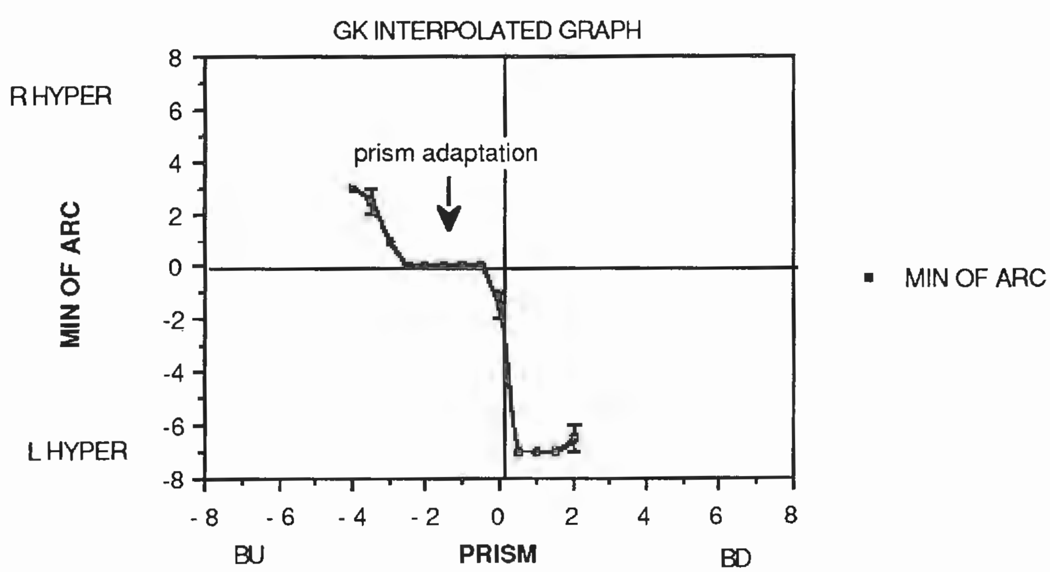
-2
-4
-6
-8
-10
-10 -8 -6 -4 -2 0 2 4 6 8 10
BU
PRISM
BD
MIN OF ARC


GK INTERPOLATED GRAPH
R HYPER
L HYPER
MIN OF ARC
prism adaptation
8
6
4
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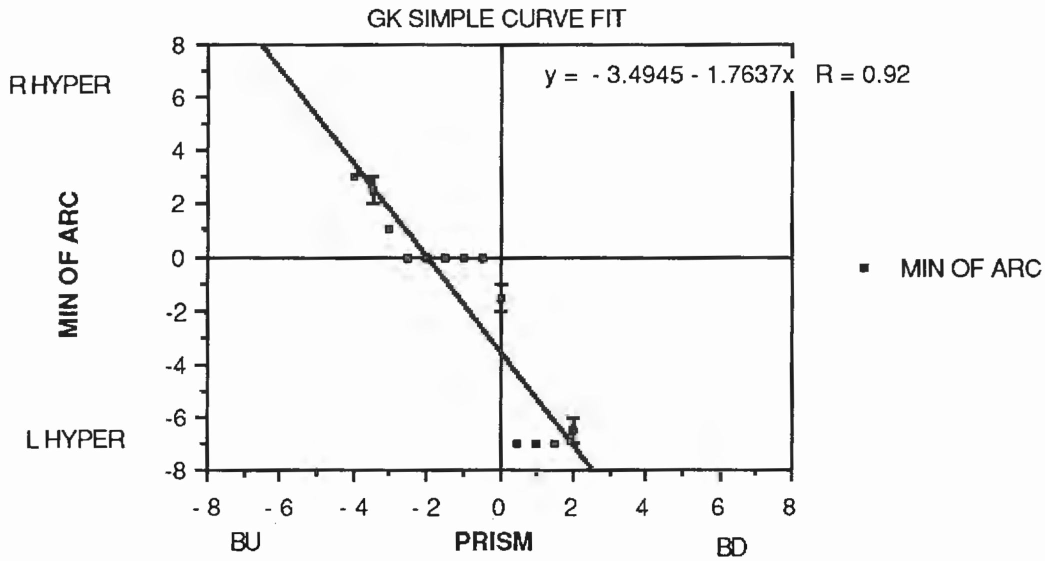
-2
-4
-6
-8
-8 -6 -4 -2 0 2 4 6 8
BU
PRISM
BD
MIN OF ARC


GK SIMPLE CURVE FIT
y = - 3.4945 - 1.7637x R = 0.92
R HYPER
L HYPER
MIN OF ARC
8
6
4
2
0
-2
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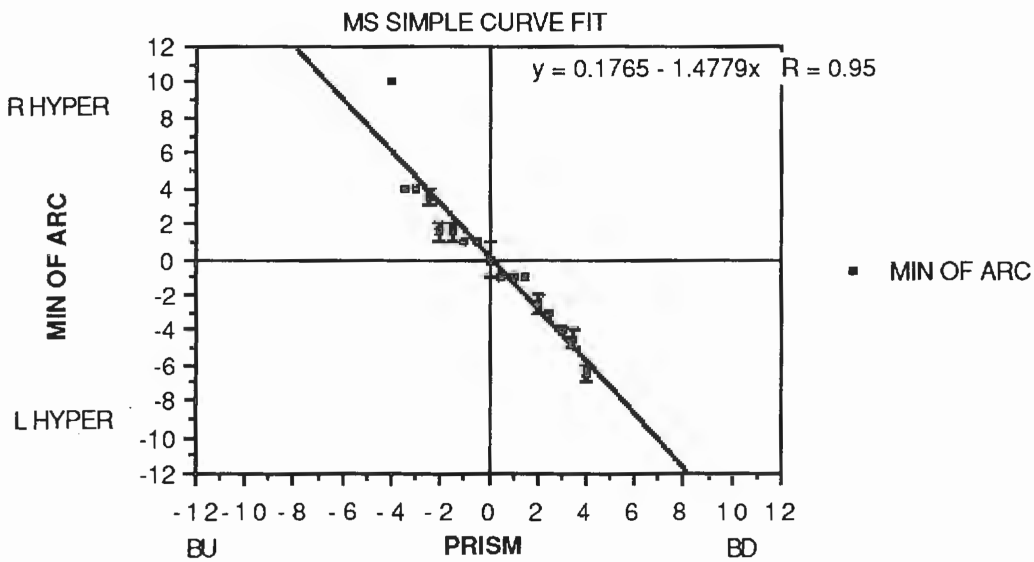
- 8
- 6
- 4
- 2
0
2
4
6
8
BU
PRISM
BD
MIN OF ARC


MS SIMPLE CURVE FIT
y = 0.1765 - 1.4779x R = 0.95
R HYPER
L HYPER
MIN OF ARC
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
-12
- 12
- 10
- 8
- 6
- 4
- 2
0
2
4
6
8
10
12
BU
PRISM
BD
MIN OF ARC