A Modified Method for Measuring Unicocular Fields of Fixation

Reliability in Healthy Subjects and in Patients With Graves Orbitopathy

Helen Haggerty, BSc; Sarah Richardson, DBO; Keith W. Mitchell, PhD; A. Jane Dickinson, FRCOphth

Objective: To assess the intraobserver and interobserver reliability of recording unicocular fields of fixation using a modified perimeter technique in healthy subjects and patients with Graves orbitopathy (GO). Patients with restrictive myopathies, particularly GO, require accurate measurement of monocular excursions. These excursions are recorded in 4 to 12 directions of gaze using a perimeter, producing a plot known as a unicocular field of fixation. While 4 direction plots give limited information on vertical muscles, recording 12 directions is time consuming and uncomfortable. This modified technique uses the 6 directions of gaze corresponding to the primary field of action of each muscle.

Methods: A single observer measured modified unicocular fields of fixation in 35 healthy subjects aged 20 to 60 years to establish normal and age-related ranges for all excursions. Fifteen subjects underwent measurement on 5 separate occasions by the same observer to establish intraobserver reproducibility. A second observer independently performed measurements in 10 of the subjects to determine interobserver reproducibility. Reliability was compared with that measured in 29 patients with GO.

Results: The technique was reproducible to within 4° for healthy subjects undergoing assessment by a single observer. When results of 2 observers were compared, the coefficient of repeatability was 7.9°. For subjects with GO, however, maximal variability was 7.8°. For clinical purposes, only a change of 8° or more can be assumed to be significant.

Conclusions: This technique offers advantages for assessing any restrictive myopathy, including GO, to within 8°. This level of accuracy is likely to be similar in other centers, and has implications for interpreting GO outcome measures, where 5° was previously taken to represent significant change.


I

N ASSESSING RESTRICTED EYE movements in patients, the measurement of monocular excursions (ductions) remains essential. In the clinical setting, ductions are commonly graded using simple scales, eg, −4 to 0 to 4. Such methods are, however, prone to standardization errors and are less suitable for accurate quantification. This is particularly true in Graves orbitopathy (GO), in which quantified motility change is an important outcome measure.1,2 The most common techniques for measuring monocular excursions use an arc or a Goldmann perimeter. Excursions are measured along 4 to 12 directions of gaze to produce a unicocular field of fixation (UFOF).1,3-6 Measurement in all meridians on a perimeter3 is time consuming and tiring and uncomfortable for the patient, and hence potentially inaccurate. Conversely, assessment limited to 4 directions of gaze (0°, 90°, 180°, and 270°)1,6 can be performed rapidly, but interpretation of individual vertical muscles is limited. In particular, small but significant changes in inferior rectus restriction commonly seen in GO may be less apparent if upgaze in abduction is not assessed.

A compromise is to measure in 6 cardinal directions, improving on assessment of individual vertical muscles with little extra time. However, gaze directions chosen previously,1,6 ie, 0°, 45°, 135°, 180°, 225°, and 315°, still reflect function of more than 1 muscle for 4 of the 6 directions. A more logical approach would therefore be the measurement of UFOF in the 6 directions of gaze that reflect the primary field of action of each of the extraocular muscles. This allows direct association between each measurement and 1 particular muscle in conditions where the action of that particular

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muscle is at fault. In conditions where movement restriction is due primarily to the failure of relaxation of the ipsilateral antagonists (eg, GO), then the 6 chosen gaze directions will still reflect dysfunction of more than a single muscle. However, these 6 axes can be justified. First, the measurement of individual muscle excursions still allows comparison over time, regardless of whether the muscle or its antagonists are abnormal. Second, in view of the variable and asymmetrical involvement of muscle restriction in GO, no measurement axes will invariably reflect the influence of only 1 muscle. Hence, a single method is suitable for all patients with restricted motility regardless of etiology. The proposed modification simply allows the association between a measurement and a particular muscle to be improved.

The Clinical Activity Score (CAS) devised for the assessment of GO scores a change in motility of 5° as one of its 10 points.7 Whether 5° represents significant change depends on the reproducibility of the measurement technique used when tested in patients with GO. Previous studies report conflicting evidence as to whether 5° is a valid cutoff point.1,6 There is therefore a need for further data to guide appropriate interpretation of sequential measurements in such patients.

Vertical ductions are thought to decline with age, although the extent of this phenomenon is debatable.1,6,8,9 Graves orbitopathy tends to be more severe in older patients; therefore any age-related decline is of relevance when performing assessments of such patients.

We developed a modified technique for the assessment of UFOF using the Goldmann perimeter, with the 6 directions of gaze reflecting the primary field of action of each of the extraocular muscles to assess the UFOF. The study then consisted of 2 parts (A and B). The principal aims of study A were to ascertain the normal range of excursions in these 6 directions of gaze and to measure the intraobserver and interobserver reproducibility when assessing healthy subjects. We also sought to determine whether an age-related decline in motility was observed in healthy subjects 60 years or younger. In study B, the reproducibility of the method was assessed in patients with GO.

METHODOLOGY

The local ethical committee of the United Newcastle Hospitals Trust, Newcastle upon Tyne, United Kingdom, approved this study. All healthy volunteers and subjects with GO freely gave written informed consent before recruitment, and the authors declare that this research followed the tenets of the Declaration of Helsinki.

TECHNIQUE

Standard Goldmann perimeter charts were premarked with 6 axes (Figure 1). These cardinal axes corresponded to the primary field of action of each muscle10 as follows: in the right eye, the lateral rectus corresponded to 0°; superior rectus, 67°; inferior oblique, 141°; medial rectus, 180°; superior oblique, 216°; and inferior rectus, 293°. Measurement axes and charts in the left eye mirrored those in the right. The head position on the chin rest and headband of the Goldmann perimeter were standardized with care. A headband was fastened to ensure that the head and eyes remained at a fixed distance from the perimeter bowl, head tilt was eliminated, and head rotation was minimized. Before testing, the foveal light threshold was established by selecting the dimmest, smallest light discernible at the fovea. Commencing with 01e at the dimmest setting, target size was increased before brightness until threshold was established, and this target was then used to measure the whole UFOF. The difference between central and peripheral fixation was clarified to maximize the accuracy of subjective measurements. To plot the UFOF, the patient followed the illuminated target along each of the 6 axes and indicated when central fixation was lost. The observer verified this loss of fixation via the central telescope; if subjective responses were unreliable, the objective measurements of maximal excursions could be taken. In practice, all of the measurements were recorded subjectively in both parts of the study, emphasizing the easiness of the technique.

The excursion of each muscle was measured, based on 12 mm on the Goldmann perimeter charts being equivalent to 10° of excursion. Individual muscle scores were recorded in degrees, as were summed scores from antagonist muscle pairs and scores from all 6 muscles, giving a total movement score per eye. Muscles were always tested in the same order, and each horizontal rectus was checked twice to assess consistency (within 5°). Hence, 7 measurements per eye were recorded for each UFOF. A single observer (H.H.) performed all assessments apart from those used to calculate interobserver reliability.

STUDY A

Normal Excursions

To establish normal ranges for each muscle, the UFOF of the right eye was plotted for 35 healthy volunteers aged 20 to 60 years with no ocular pathology. All measurements were subjective. By calculating the mean and standard deviation for each muscle, 95% confidence intervals (CI) were established for the healthy population.

Reproducibility

To establish intraobserver reproducibility, 15 healthy subjects underwent testing on 5 different occasions a minimum of 3 hours apart by the same observer (H.H.), who was masked to the previous results. From these data, the mean intertest variation for...
the 5 measurements was calculated. To try to ensure that head position was not a significant source of inaccuracy, the calculations were repeated for antagonist muscle pairs (medial and lateral rectus, superior and inferior rectus, and inferior and superior oblique) and compared with the reproducibility measurements for individual muscles.

To ensure validity in a clinical environment, 2 independent observers (H.H. and S.R.) assessed the right UFOF in a group of 10 healthy subjects on separate occasions. The measurements were analyzed independently (K.W.M.) using the strategy of Bland and Altman.11

Age-Related Variability

For analysis of age-related variation, these subjects were divided into 10-year age cohorts.

STUDY B

In study B, 29 patients with GO were recruited from the combined thyroid eye clinic of a tertiary care referral center. This aspect of the study was not concerned with the influence of the disease and any previous treatments on the UFOF, but rather with ensuring that the method was suitable for all patients with GO regardless of severity or activity. Sequential recruitment ensured that a wide range of severity and activity was indeed represented.

Each subject underwent assessment twice on the same day (a minimum of 1 hour apart) to minimize the chance of any real change in motility, and all measurements were performed subjectively. To reduce the risk of observer bias toward an identical score, several subjects underwent assessment randomly at each session, and no numerical scores were calculated until the second measurements had been taken. The standard deviation was calculated for each muscle in each subject and averaged to establish the mean standard deviation. To compare these data with those of healthy subjects, 2 measurements were randomly chosen from the 5 available for each healthy subject. The analyses of these 2 measurements from healthy subjects were then compared with those from the patients with GO.

REPRODUCIBILITY

Fifteen healthy subjects, including 3 men and 12 women (age range, 23-50 years; mean, 32.1 years) underwent measurement on 5 occasions. The mean standard deviation was similar for all individual muscles (Table 2). Based on the greatest degree of variability (mean SD, 1.9°) the intrasubject (single-observer) variability was calculated as 3.7° for a single muscle with 95% confidence. For paired muscle analysis (Table 2), maximum intrasubject variability was 4.5°. Hence for clinical purposes, a change in excursion of 4° in a single muscle or 5° in paired muscles is necessary before it can be deemed to be a significant change.

Ten healthy subjects, including 2 men and 8 women (age range, 23-50 years; mean age, 33.1 years) underwent assessment to analyze interobserver variation. The Bland-Altman strategy was applied, comparing the differences between 2 independent measurements with the average of both. All muscles were analyzed, typified by the example shown in Figure 2 pertaining to the right medial rectus. The mean difference between observers was 0.67°, with 95% confidence limits of -2.22° and 3.56°. The zero difference line lies within these confidence levels, confirming that mean interobserver differences were not significant. There was no evidence of a systematic bias between observers; however, there was considerable variability, the coefficient of repeatability (calculated as 2 × SD of the differences) being 7.9°.

Age-Related Variability

The number of subjects assessed in each age cohort is shown in Table 1, together with the mean excursion of each muscle. Individual muscle and total (per eye) muscle scores were similar for each age group. No age-related decline was apparent for any muscle. Scattergram analy-
sis of superior rectus excursion vs age suggested a slight trend toward age-related decline (Figure 3), but with one-way analysis of variance, this was not significant (P = .11).

STUDY B

The 29 patients with GO were aged 31 to 74 years (mean age, 54.0 years). Table 3 summarizes the age, sex, GO severity (maximum category for classification of eye changes), and GO activity (CAS) for each patient. All patients with class V disease also had muscle restriction. There was a wide range of disease activity at the time of assessment; however, most were judged to have active disease, and 17 (59%) had a CAS of at least 3. The disease severity also varied considerably over the group, but 23 (79%) had evidence of restricted motility, and 15 of these (65%) complained of gaze-evoked pain.

Figure 4 and Table 4 compare reproducibility data for healthy subjects with those for patients with GO. As only 2 measurements were available for each patient with GO, only 2 of the 5 available measurements for healthy subjects were randomly chosen to compare these 2 groups (this explains why the standard deviations and CIs that relate to the healthy subjects in Table 4 are not identical to those of the same healthy subjects in Table 2).

The spread of data in the GO group appears to have a wider distribution than in healthy subjects, particularly for 3 of the 6 muscles, although the difference in variance does not achieve significance for any muscle. Analysis of the CI shows that normal variation of measured excursions is larger in patients with GO than in healthy subjects. Therefore, a change of 8° is required to detect statistically significant change in a single muscle in patients with GO.

To ensure that this difference in reproducibility was not age-related variability and was indeed related to GO, the data were further analyzed by dividing the GO group into 2 cohorts with the respective age ranges of 31 to 55 years (14 patients) and 56 to 74 years (15 patients). The mean difference between these cohorts was tested for significance (2-tailed t test) for each muscle and was found to be insignificant in each one (eg, for the medial rectus, mean difference in the cohort aged 31-55 years, −1.50° [SD, 3.52°]; mean difference in the cohort aged 56-74 years, −1.27° [SD, 3.65°]; P = .86; df, 28).

COMMENT

We herein present data on the reliability of measuring ocular excursions using a modified method for plotting UFOF. In contrast to previously described techniques, this can give information on all individual muscles, while taking less than 5 minutes per eye to perform. This has allowed us to establish normal ranges for all extraocular muscle excursions, establish the reproducibility of such measurements, and compare the reproducibility of measurements between healthy subjects and patients with GO.

Table 2. Intrasubject Reproducibility in Healthy Subjects (Study A)*

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Mean SD of Individual Muscle</th>
<th>Intrasubject Variation, 95% CI†</th>
<th>Mean SD of Paired Antagonist Muscles</th>
<th>Intrasubject Variation of Paired Muscles, 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial rectus</td>
<td>1.9</td>
<td>3.7</td>
<td>2.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Lateral rectus</td>
<td>1.8</td>
<td>3.5</td>
<td>2.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Superior rectus</td>
<td>1.4</td>
<td>2.7</td>
<td>2.9</td>
<td>4.3</td>
</tr>
<tr>
<td>Inferior rectus</td>
<td>1.5</td>
<td>2.9</td>
<td>2.2</td>
<td>4.3</td>
</tr>
<tr>
<td>Inferior oblique</td>
<td>1.6</td>
<td>3.1</td>
<td>2.3</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval.
*Unless otherwise indicated, data are given as degrees and represent measurements of excursion.
†Given as the difference between the upper and lower values.

Figure 3. Scattergram analysis of superior rectus excursion for different ages.

Figure 2. Interobserver reproducibility for measurement of the right medial rectus by 2 observers (H.H. and S.R.), assessed by using the strategy of Bland and Altman.11 CI indicates confidence interval.

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When muscle restriction within the ipsilateral antagonist(s) is the main cause of motility limitation, as for example in GO, then no measurement axis can ever reliably show the action of a single vertical muscle. All axes will be a compromise. This does not, however, invalidate the method for useful sequential assessment. For other patients whose limitation derives solely from the muscle being assessed rather than its antagonist, the axes reflect a single muscle, and it is more logical to use this method than one using 45° axes. Hence this modified technique is suitable for all patients regardless of the origin of their motility restriction and now forms part of routine motility assessment, including that in patients with blowout fractures, mitochondrial cytopathies, and GO.

Ocular excursions may be assessed subjectively or objectively, depending on whether the subject or the observer, respectively, defines the limit of excursion. Objectively, methods are of the following 2 basic types: those that measure the movement of the limbus or corneal light reflex on maximal excursion using a handheld or a slitlamp-mounted ruler, and those that use a handheld or fixed perimeter. The former are subject to significant parallax errors and standardization difficulties. Although useful in the clinical setting, they have limitations for accurate assessment of excursions as an outcome measure. Fixed perimeters used objectively are much easier to standardize, but difficulties can still arise when the eyelid obscures the end point of downgaze. Subjective methods eliminate most of these variables, but accuracy depends on foveal fixation being reliably maintained by the subject. This is not always realistic, particularly with discomfort and fatigue; hence a rapid test with few axes is more likely to be reliable. This is particularly pertinent in GO, where gaze-evoked discomfort is common. Excellent reproducibility has been reported.

Table 3. Characteristics of the GO Patient Group (Study B)

<table>
<thead>
<tr>
<th>CAS</th>
<th>I</th>
<th>IIA</th>
<th>IIB</th>
<th>IIC</th>
<th>IIa</th>
<th>IIb</th>
<th>IIc</th>
<th>IVa</th>
<th>IVb</th>
<th>IVc</th>
<th>Va</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>43/F, 74/F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>31/F</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>50/M</td>
<td>58/F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>68/F</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>34/F, 40/F</td>
<td>59/F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>54/F</td>
<td>31/F, 49/F, 63/F, 56/M, 58/M</td>
<td></td>
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<td>6</td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>7</td>
<td>47/M</td>
<td>48/F</td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

Abbreviations: CAS, Clinical Activity Score; F, female; GO, Graves orbitopathy; M, male; NOSPECS, category for classification of eye changes in GO (no signs or symptoms, only signs, soft tissue involvement with symptoms and signs, proptosis, extraocular muscle involvement, corneal involvement, and sight [visual acuity] loss).

*Data are given as years of age/sex.

Figure 4. Scattergram of differences between observers in measurement of muscle excursions for healthy subjects and patients with Graves orbitopathy (GO). Abbreviations of muscles are explained in the legend to Figure 1.
for objective assessment of 4 axes using a perimeter, and although it seems likely that subjective methods are more accurate in reliable subjects, published comparisons are scarce. The results reported by Mourits et al and Gerling et al are similar to those reported herein and confirm that perimeter methods are an appropriate way of assessing muscle function for normal clinical assessment and research. Although only subjective results are reported herein, patient inconsistency is readily observed via the central telescope, and the test can then easily be performed objectively.

Minor differences in head position between assessments will reduce the accuracy of any technique, and summed scores from antagonist muscle pairs in healthy subjects were analyzed to assess this. Reproducibility of paired scores was slightly better than summed reproducibility of 2 individual muscle scores, suggesting that head rotation and misalignment are potential sources of inaccuracy, albeit of low magnitude. These findings are similar to those reported by Gerling et al, who compared total vertical and horizontal ranges with single-muscle ductions. Such errors are minimized by careful positioning of the head, use of a headband, and sequential comparison of the muscle excursion least likely to be affected by pathology before moving on to assess other muscles, eg, repeating medial rectus excursion in GO, where lateral rectus restriction is least common. These errors due to head position are obviated by the total movement score, which offsets the gains and losses of rotation. This is rapidly calculated from the sum of the 6 ductions. Alternatively, the 6 points on the UFOF plot could be used to determine an area score, which would have the same advantages in negating the effects of head misalignment. This study did not, however, evaluate this.

The effect of interobserver variation on results was also analyzed in this study. There was no overall effect, as the mean difference between observers was not significantly different from zero. Nevertheless, there was substantially more interobserver than intraobserver variation. Gerling et al found no significant difference between interobserver and intraobserver reproducibility and stated that “it is not necessary to insist on the same examiner in follow-up studies.” Our findings do not support this, and in practice we attempt to use the same observer for sequential assessment whenever possible.

The mean horizontal muscle excursions reported herein are similar to those reported previously using objective perimeter techniques. Although no vertical muscle comparisons can be made with other studies, we were unable to demonstrate a significant age-related decline in superior rectus excursion. Chamberlain examined subjects 94 years and younger and reported progressive decline in elevation throughout life, whereas Clark and Isenberg examined subjects 84 years and younger and noted 0.5% to 1% per year decline in all versions beginning in the third decade, with upgaze the most affected. Similar results have been noted in subjects aged 60 and 70 years or younger, using objective perimeter methods. This phenomenon has been attributed to disuse, a theory supported by the finding that grossly kyphotic elderly patients can show remarkable preservation of elevation. It is not clear why age-related decline was not noted in this study. The number of older subjects was small; hence, small differences could have been missed, and had a group of subjects much older than 60 years been examined, a decline in versions might have been observed.

The most important result from this study, however, concerns the reliability of the technique in patients with GO, and this was not due to the older age of the subjects with GO. Gerling et al found the reliability of patients with GO to be marginally better than that of healthy subjects. Using the coefficient of variation, they concluded that for GO, the mean coefficient of variation was 2.3%. Therefore, in 95% of patients, the repeated measurement would be ±4.6% of the original, a total variation of 9.2%. From those data, this equated to a change of 2° to 4.6° for patients with GO depending on the muscle assessed, whereas for healthy subjects it equated to a change of 3.6° to 5.2°. They therefore concluded that for patients with GO, the passive resistance of the orbital tissues had a greater effect on the maximal excursion than the voluntary effort of the patient. The data presented herein are remarkably similar to those reported by Mourits et al, who also reported a maximum coefficient of repeatability of 8° between observers. It is difficult to know whether the results of Gerling et al differ significantly, but a possible explanation lies in the disease phase of the patients studied. Patients with active disease commonly experience significant pain on excursions, and this was true of 15 (52%) of the patients described herein. Pain likely influenced voluntary effort and affected reliability; however, to investigate this effect with adequate statistical power would require in excess of 200 patients, and

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Healthy Subjects</th>
<th>Patients With GO</th>
<th>Mean (SD) Difference*</th>
<th>P</th>
<th>Healthy Subjects</th>
<th>Patients With GO</th>
<th>95% CI Difference*</th>
<th>F Test of Variance, P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial rectus</td>
<td>2.00 (2.39)</td>
<td>-1.27 (3.52)</td>
<td>-1.27 (3.52)</td>
<td>.21</td>
<td>4.68</td>
<td>6.90</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Lateral rectus</td>
<td>1.27 (2.69)</td>
<td>0.70 (3.99)</td>
<td>0.53 (2.10)</td>
<td>.29</td>
<td>5.27</td>
<td>7.82</td>
<td>.06</td>
<td></td>
</tr>
<tr>
<td>Superior rectus</td>
<td>0.13 (2.10)</td>
<td>0.93 (2.64)</td>
<td>0.53 (2.61)</td>
<td>.08</td>
<td>4.12</td>
<td>5.17</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td>Inferior rectus</td>
<td>1.40 (1.84)</td>
<td>-0.40 (2.28)</td>
<td>1.00 (2.73)</td>
<td>.06</td>
<td>3.61</td>
<td>4.47</td>
<td>.20</td>
<td></td>
</tr>
<tr>
<td>Inferior oblique</td>
<td>0.53 (2.61)</td>
<td>-0.73 (3.76)</td>
<td>-0.73 (3.76)</td>
<td>.42</td>
<td>5.12</td>
<td>7.37</td>
<td>.08</td>
<td></td>
</tr>
<tr>
<td>Superior oblique</td>
<td>1.00 (2.73)</td>
<td>-1.53 (3.41)</td>
<td>1.00 (2.73)</td>
<td>.29</td>
<td>5.34</td>
<td>6.68</td>
<td>.19</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; GO, Graves orbitopathy.

*Data are given as degrees.
CONCLUSIONS

This modified technique for measuring UFOF gives additional quantified information on the vertical extraocular muscles. Its reliability is equivalent to that of other measurement methods in healthy subjects and in those with restricted motility. It can be performed rapidly, minimizing patient discomfort, and may be particularly helpful in the sequential assessment of GO. The data on patients with GO suggest that a difference of 8° is required to detect significant change, particularly where several observers are involved, and this has important implications for the monitoring of GO, especially when using the CAS.

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REFERENCES

2. Gorman CA. The measurement of change in Graves’ ophthalmopathy. Thyroid. 1998;8:539-543.

Correction

In the article titled “Sunlight and the 10-Year Incidence of Age-Related Maculopathy: The Beaver Dam Eye Study,” published in the May issue of the ARCHIVES (2004;122:750-757), the “Results” section of the abstract contained some errors. These sentences should have read as follows: “While controlling for age and sex, we found that participants exposed to the summer sun for more than 5 hours a day during their teens, in their 30s, and at the baseline examination were at a higher risk of developing increased retinal pigment (risk ratio [RR], 2.99; 95% confidence interval [CI], 1.18-7.60; P=.02) and early ARM (RR, 2.20; 95% CI, 1.02-4.73; P=.04) by 10 years than those exposed less than 2 hours per day during the same periods. . . Participants who experienced more than 10 severe sunburns during their youth were more likely than those who experienced 1 or no burn to develop drusen with a 250-µm diameter or larger (RR, 2.52; 95% CI, 1.29-4.94; P=.01) by the 10-year examination.” The ARCHIVES regrets the error.