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TECHNICAL REPORT

# Have We Misinterpreted the Study of Hoogerheide et al. (1971)?

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## ABSTRACT

In 1971, Rempt et al. reported peripheral refraction patterns (skiagrams) along the horizontal visual field in 442 people. Later in the same year, Hoogerheide et al. used skiagrams in combination with medical records to relate skiagrams in emmetropes and hyperopes to progression of myopia in young adults. The two articles have spurred interest in peripheral refraction in the past decade. We challenge the understanding that their articles provide evidence that the peripheral refraction pattern along the horizontal visual field is predictive of whether or not a person develops myopia. First, although it has been generally assumed that the skiagrams were measured before the changes in refraction were monitored, Hoogerheide et al. did not state that this was the case. Second, if the skiagrams were obtained at an initial examination and given the likely rates of recruitment and successful completion of training, the study must have taken place during a period of 10 to 15 years; it is much more likely that Hoogerheide et al. measured the skiagrams in a shorter period. Third, despite there being many more emmetropes and hyperopes in the Rempt et al. article than there are in the Hoogerheide et al. article, the number of people in two types of "at risk" skiagrams is greater in the latter; this is consistent with the central refraction status being reported from an earlier time by Hoogerheide et al. than by Rempt et al. In summary, we believe that the skiagrams reported by Hoogerheide et al. were taken at a later examination, after myopia did or did not occur, and that the refraction data from the initial examination were retrieved from the medical archives. Thus, this work does not provide evidence that peripheral refraction pattern is indicative of the likely development of myopia.
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Key Words: emmetropization, hyperopia, myopia, myopia progression, peripheral refraction, skiagrams

Hoogerheide et al. wrote two articles on the subject of peripheral refraction in the journal *Ophthalmologica* in 1971. Rempt et al.[1] used retinoscopy to determine refraction out to 60 degrees in both directions of horizontal visual fields of both eyes of 442 young adult Dutch subjects. They divided their skiagrams, plots of peripheral refraction as a function of visual field angle, into five patterns. The patterns varied from type I, in which refractions in both the horizontal and vertical meridians of the pupil showed hyperopic (positive) shifts into the periphery, to type V, in which there was little change of the refraction into the periphery along the vertical meridian and a large myopic (negative) shift into the periphery along the horizontal meridian.

In the context of determining whether emmetropes should be accepted for pilot training because of the risk that they would become myopic, Hoogerheide et al.[2] reported changes in refraction of 222 commercial and 153 fighter pilots, 375 in total, during an unspecified period. They attempted to determine whether "the development of real myopia in pilots, being at first hyperopes, or emmetropes can be predicted at the initial examination" (page 211). For this purpose, they considered the skiagrams that were determined for 214 of these pilots.

Hoogerheide et al. reported that emmetropic and hyperopic people who went on to develop myopia "during the following years" tended to have different patterns from those of the emmetropic and hyperopic people who did not develop myopia. The majority of the former had the type I pattern (17/26 cases, 65%), and the majority of the latter had the type IV pattern of relative hyperopia along the vertical meridian and relative myopia along the horizontal meridian (109/188 cases, 58%).[a] They concluded

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[a]For further analysis, an odds ratio can be calculated using the number of skiagrams showing the more relative peripheral hyperopia patterns (types I, II, and III) and the number of skiagrams showing relative peripheral myopia patterns (types IV and V), combined with the number of participants who did or did not become myopic. The odds ratio, the proportion of types I–III participants who became myopic relative to the proportion of types IV and V participants who became myopic, is 14.8 with a 95% confidence interval of 4.3 to 51.4.

"the skiagram may reveal an indication as to whether a candidate belongs to a group in which the shift of the refraction towards the myopic side is a greater or lesser probability" [page 214].

Attention was drawn to the work of Hoogerheide et al. in 2004 by review articles of Stone and Flitcroft[3] and by Wallman and Winawer.[4] Stone and Flitcroft wrote:

"In a prospective study of Dutch trainee pilots, a refractive shift toward myopia occurred in 25% of subjects, half of whom actually became myopic. The presence of peripheral hyperopic astigmatism *at the initial examination* was the refractive pattern most predictive for a myopic shift during the course of training. This study suggests that eye shape may be an important determinant of future refractive errors ..." ("peripheral hyperopic astigmatism" refers to the type I pattern).

Wallman and Winawer wrote:

"Differences in peripheral refractions may explain why only some children become myopic and why rates of progression vary. Hoogerheide et al. (1971) have shown that, among pilots in training, of those emmetropes and hyperopes who *had* the peripheral pattern of refractions characteristic of myopes (hyperopic in periphery, low peripheral astigmatism; ...), 77% shifted in the myopic direction, compared to 6% of those who had the peripheral pattern characteristic of hyperopia."

The articles by Stone and Flitcroft and by Wallman and Winawer led to interest in the peripheral refraction pattern being predictive of myopia development, as well as in preventing or slowing the progression of myopia by prescribing corrections with additional peripheral positive power to counteract refractive peripheral hyperopia. For the former, there has been the opposing view that the peripheral refraction pattern is a consequence, rather than a cause, of myopia. Charman and Jennings[5] demonstrated that elongating an emmetropic eye to produce myopia, without any change in equatorial size, changes the refraction pattern. In the far periphery the refractions have to converge, so a peripheral myopic pattern for an emmetrope becomes a relative hyperopic refraction pattern at some level of myopia. Of course, an axial elongation of the retina in myopia is an oversimplification,[6] and the optics of emmetropic and myopic eyes may differ in other ways. Mutti et al.[7] reported that relative peripheral hyperopia had little consistent influence on the risk of myopia onset in children. Sng et al.[8] performed a 1-year longitudinal study in which the peripheral refraction at baseline was not predictive of the development of myopia, with the children who became myopic having relative peripheral hyperopia at follow-up and the children who did not become myopic retaining relative peripheral myopia.

Hoogerheide et al. gave information on changes of central (foveal) refractions for 375 pilots, 214 of whom had skiagrams. As far as we are aware, following the Stone and Flitcroft and the Wallman and Winawer articles, it has always been assumed that the Hoogerheide et al. skiagrams were taken about the time of the initial examination. *However, this was not explicitly stated by the group*. As a matter of fact, few details on the actual study protocol were given in the article. We believe that the skiagrams were taken at a later examination, after myopia did or did not occur, and that the refraction data from the initial examination were retrieved from the medical archives.

In the late 1960s, it took 28 months to educate a Dutch fighter pilot (personal communication, Quirijn van der Vegt, Netherlands Institute of Military History). Of the candidates who started between 1964 and 1968, 95 fighter pilots graduated. For the skiagrams to have been obtained at the time of the initial medical examinations, the investigations for the 153 graduated fighter pilots studied by Hoogerheide et al. must have taken place 10 to 15 years before the publication. It is more likely that Hoogerheide et al. measured the skiagrams in a separate study, initiated by the study of Rempt et al., on pilots who came to the National Aeromedical Centre for medical examination to have their licenses renewed. This would explain the much lower number of skiagrams (214) compared with the number of pilots with known refractive state change (375).

It is probable that the majority of subjects with skiagrams reported in Hoogerheide et al. were also part of the data in Rempt et al. who "selected our testees out of the persons who applied for the regular aeronautical examinations" (plus supplementation with others to get) "higher degrees of myopia and hyperopia." Given that the two articles were published in the same year, it seems unlikely that Rempt et al. would not have reported all available data. Despite there being many fewer people in the Hoogerheide et al. article (214) than there were emmetropes and hyperopes in the Rempt et al. article (301), the number of initially hyperopic and emmetropic people in skiagram types I and III was greater in the Hoogerheide article than in the Rempt et al. article (36 compared with 16 for type I and 14 compared with 9, as shown in Table 1). This is consistent with the initial refraction status being reported at an earlier time by Hoogerheide et al. than by Rempt et al., with some of the initially hyperopic/emmetropic subjects in Hoogerheide et al. having changed to myopes in Rempt et al.

One inconsistency in the above argument is that the number of hyperopes and emmetropes in Hoogerheide et al. in types I and III, after the consideration of shifts in central refraction, are bigger than the numbers in these categories in Rempt et al. (19 and 11 vs. 16 and 9, mentioned in Table 1), but one can conceive that there were a few additional subjects whose skiagrams were measured after the Rempt et al. work was completed.

In conclusion, the work of Hoogerheide et al., which provided the catalyst for the current interest in peripheral refraction, probably did not provide evidence that peripheral refraction pattern is indicative of the likely development of myopia. Although it might seem that they should have indicated when peripheral refractions were measured relative to the initial visits, they may not have considered this important as they stated "it may be presumed and certain indications do exist that the general appearance of the skiagram is inborn and does not change very much during lifetime, especially with regard to its type." Unfortunately, they did not share any of their evidence about this.

**TABLE 1.**
Number of combined hyperopic and emmetropic subjects in each peripheral refraction type as given by Rempt et al.[1] and by Hoogerheide et al.[2]

| Refraction pattern | **I** | II | **III** | IV | V | Total |
|---|---|---|---|---|---|---|
| Rempt et al. | **16** | 47 | **9** | 196 | 33 | 301 |
| Hoogerheide et al. | **36** | 43 | **14** | 112 | 9 | 214 |
| | **(19)** | (40) | **(11)** | (109) | (9) | (188) |

The bolded numbers indicate the types for which Hoogerheide et al. had more subjects than Rempt et al. The numbers in brackets indicate the hyperopic and emmetropic subjects in Hoogerheide et al. following "shifts in central refraction."

Our conclusion should not be used to mean that peripheral refraction pattern (or even retinal shape[9]) is neither the predictive of the likely development of myopia nor that providing an "addition" in the peripheral field with contact or spectacle lenses will not prevent or slow myopia progression. Although two recent studies indicate that relative peripheral hyperopia is a consequence rather than a cause of myopia development,[7,8] there is some evidence that retinal shape,[9] which is closely related to peripheral refraction, is predictive of myopia development, and limited success has been obtained with "anti-myopia" spectacle and contact lenses.[10,11]

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