Effect of a Novel Osteopathic Technique on the Axial Length of the Eye

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Osteopathy, Unitec New Zealand, 2010
Abstract

Introduction: This thesis is divided into three sections: I) Literature review; II) Manuscript (in the format specified for submission to the International Journal of Osteopathic Medicine); and III) Appendices.

Objective: To investigate the short term effect of a novel osteopathic technique on the axial length of the eye.

Methods: A single-blinded pre-test post-test experimental design was adopted. Two experiments were conducted to investigate two types of intervention: i) muscle energy technique (MET) targeted at the medial and lateral recti; and ii) MET targeted at all six extraocular muscles. The axial length of the eye was objectively measured using partial coherence interferometry (IOLMaster, Carl Zeiss Meditec, Germany) operated by qualified optometrists. Phoria was measured with a Maddox wing to determine whether there was any change in extraocular muscle tension. Tests for stereo acuity and the near point of convergence were conducted to give indications of subjects’ state of binocular vision. Two tailed paired t tests were undertaken to compare both mean axial length, and mean phoria, pre and post-intervention. The pre and post-intervention data for axial length were also compared for individual subjects.

Subjects: Two groups of 10 adults (n=20) between the age of 18 and 35 with refractive error between -1 and -6 D were recruited from the general community. Volunteers with strabismus, active ocular disease, heart disease, or diabetes were excluded.

Results: Analysis of group data showed insufficient statistical evidence to support either method of intervention in effecting a clinically important change in axial length. Analysis of data from individual subjects revealed two eyes (in two different subjects) out of 40 eyes that underwent a change of ≥ 0.093 mm (equivalent to 0.25 D). Statistical analysis of phoria failed to find sufficient evidence to validate the efficacy of the intervention in effecting changes in relative muscle tension in the extraocular muscles.

Conclusion: MET targeted at the extraocular muscles was ineffective in altering the axial length of the eye. Further development work in application of the intervention techniques is necessary if further work is to be conducted in this area.
Declaration

Name of candidate: Janice Hsin-I Huang

This thesis titled

Effect of a Novel Osteopathic Technique on the Axial Length of the Eye

is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

CANDIDATE’S DECLARATION

I confirm that:

- This thesis represents my own work.
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.

Research Ethics Committee Approval Number: 2008.916

Candidate Signature: ........................................... Date: ...........................................

Student ID Number: 1228475
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Section I - Literature Review
1. INTRODUCTION

Along with its rising prevalence in the industrialised countries, myopia (nearsightedness) has received much research attention in the past century. Research in this field includes epidemiological studies reporting investigations into aetiology, and controlled trials to investigate various interventions for myopia. Research to investigate myopia interventions has included both human and animal experiments including factors such as lens design, pharmaceutical agents, and to the lesser degree, vision training.

Despite a considerable body of investigation in this field, the cause of myopia and the mechanism of its development are still less than definitive. An effective way to intervene the rate of myopia progression is yet to be found. The mainstream management of myopia remains correction using optical aids. A novel manual therapeutic approach for myopia management is interesting to consider since successful cases have been reported in pre-1970 literature employing classical osteopathic management.

In part 2 of this literature review, the current knowledge in myopia is reviewed. Myopia and its relationship with ocular dimension are summarised in parts 2.1 to 2.3. The methods of measuring myopia severity are explained in 2.4, and epidemiology studies reviewed in 2.5. Parts 2.6 and 2.7 present discussion regarding the aetiology of myopia. The discussion includes considerations for the extraocular muscles and their anomalies. Lastly, orthodox and other methods of myopia management are reviewed in parts 2.8 and 2.9. In part 3 of this literature review, osteopathic approaches in myopia, classical and modern, are examined. In part 4, a commonly applied osteopathic manual technique, with its vintage applications for ocular disorders, is reviewed. Finally in part 5, a research question is derived that establishes the subsequent aim of the research investigation reported in Section II of the thesis.
2. **MYOPIA**

2.1. What is Myopia

Myopia is also commonly known as nearsightedness, or short-sightedness. It is the condition in which light rays from distant objects are focused in front of the retina when the ciliary muscle is fully relaxed (Guyton & Hall, 2000). This condition is usually due to the anterior-posterior dimension (the axial length) of the eye being too long compared to an emmetropic (normal) eye, as demonstrated in Figure 1. The cardinal symptom of myopia is that distant objects appear blurry. This blurriness can be corrected by concave lenses, because concave lenses diverge light bringing the focal point further away. In contrast, hyperopia is the condition in which light rays from distant objects are focused behind the retina when the ciliary muscle is fully relaxed (Guyton & Hall, 2000). However, by contracting the ciliary muscles, the image for a distant object can be focused on the retina. If the object is moved closer and close to the point that the ciliary muscles has contracted to its limit, objects any closer in will become blurry. Hyperopia is usually due to the axial length of the eye being too short compared to an emmetropic eye, as demonstrated in Figure 1.

![Illustration of emmetropia, myopia, and hyperopia.](image)

An adequate understanding of myopia necessitates the understanding of accommodation. Accommodation is defined as “the process by which the crystalline lens varies its focus in response to changes in the vergence of incident light” (p6, Grosvenor, 2007). For near objects, the contraction of the ciliary muscles causes the lens to assume a more spherical shape to powerfully converge light. For distant objects the relaxation of the ciliary muscles allows the lens to adopt a thinner shape to weakly converge light (Snell, 2004). In an emmetropic eye, the effect of accommodation is that the image is focused clearly on the retina irrespective of the distance of the object.

2.2. Axial Length and Myopia

The refractive power of the cornea, the refractive power of the crystalline lens, and the length of the eye all contribute to the overall optical clarity. However, it is the axial length of the eye that is most closely correlated to refractive error in myopia. From theoretical calculations, an increase in the axial length of 1 mm equates to an increase of refractive error of approximately 2.7 dioptries (D) (Bennett & Rabbetts, 1989). The axial length of the eye is commonly used as an objective outcome measure in myopia research, for example, in the studies of Gwiazda et al. (2003), Phillips (2005), and Ojaimi et al. (2005). Axial length is also widely used in clinical ophthalmology to calculate the optimum power of a replacement lens after a cataract lens removal.

2.3. Classifications of Myopia

There are a number of classifications of myopia, reflecting the aetiology, severity, or the course of the condition. However, as the exact aetiology is not clear, Grosvenor (1987) proposed a classification based on the age of onset, which has high face validity, instead of a classification with labels that are suggestive of a definitive aetiology. The age of myopia onset offers some information about the possible aetiology. For example, for myopes with onset at birth and remaining myopic throughout life, a greater genetic contribution is believed to be at play. For myopes with onset between the age of 6 ~ 40 years, environmental influences are thought to be of greater importance. For those with onset after 40 years old, myopia is associated with age-related cataracts and systemic conditions such as diabetes mellitus.
Myopia tends to progress rapidly through schooling years, and stabilize in the third decade. Therefore the earlier the onset of myopia, the greater the severity when the condition reaches a stable phase. Myopia of more than 6 dioptres (D) are classified as high myopia (Edwards, 1998), and generally considered to have a stronger genetic basis.

2.4. Measuring Myopia

Myopia is measured by the degree of visual acuity one possesses. Visual acuity can be measured both subjectively and objectively as explained in this section.

2.4.1. Visual acuity

Visual acuity is defined as “the resolving power of the eye, or the ability to see two separate objects as separate” (Grosvenor, 2007). Early astronomers found that it was possible to discern two stars as being separate if the distance between the stars was at least 1 minute of arc. The “normal” resolving power of the eye was thus defined as the ability to detect a gap with a width of 1 minute of arc.

2.4.2. Subjectively measuring myopia - The Snellen chart and the Snellen fraction

To test for visual acuity, the subject attempts to identify the orientation of the gap between pairs of Konig bars and the gap in a Landolt ring (as shown in Figure 2), which are projected on the wall at a distance. The projection has Konig bars and Landolt rings of decreasing size going down the wall.

![Konig bars and Landolt ring](image)

The Konig bars can only be orientated in two directions, so the subject has 50% chance of guessing correctly. The gap of Landolt ring can be orientated in 8 directions, top, down, left, right, and 4 obliques, reducing the chance of guessing correctly to 12.5%. Konig bars and Landolt rings are not widely used today due to the high probability of guessing the correct answer. The universal method of measuring visual acuity today adopts the use of the Snellen acuity chart, which is composed of letters of decreasing size going down the chart as shown in Figure 3, and the subject is asked to read out the letters.

![Snellen Chart](image)

**Figure 3. The Snellen chart.** From *Primary care optometry* (p10), by T. Grosvenor, 2007, St. Louis, MO: Butterworth-Heinemann. Copyright 2007 by Butterworth-Heinemann. Reprinted with permission from the publisher.

Visual acuity is usually tested with the subject at a distance of 6m (or 20 feet) from the chart, and the test result is denoted as the Snellen fraction:

\[
\text{Snellen fraction} = \frac{\text{testing distance}}{\text{designation (or size) of the smallest line of letters read}}
\]

The designation of the letters is labelled on the Snellen chart, and is the shortest distance at which a person with normal visual acuity is able to read the same letters. For example, if the smallest readable line is composed of size 6 letters, in the metric system the visual acuity
would be denoted as 6/6, which is equivalent to 20/20 in the imperial measuring system. This is considered normal visual acuity.

Although the Snellen fraction is denoted in a numerical fraction, the fraction is a notation, not a real number. Hence, performing arithmetic operations such as addition, subtraction, multiplication and division on Snellen fractions has no meaning.

2.4.3. The Dioptre

Since the refractive error in myopia can be compensated with concave lenses, a common measure of the severity of myopia is the strength of the lens that must be used to restore the visual acuity to 20/20 as measured with a Snellen chart.

The optical power of spherical lenses is measured in dioptres. Concave lenses diverge light, and are designated a negative sign. Convex lenses converge light, and are given a positive sign in dioptres. A convex lens capable of converging parallel light rays to a focal point 1 cm beyond the lens has a refractive power of +1 D. A concave lens that diverges light at the same rate that a 1 dioptre convex lens converges light has a refractive power of -1 D (Guyton & Hall, 2000).

Optical powers as measured in dioptres are real numbers, and therefore arithmetic operations such as addition, subtraction, multiplication and division can be applied. For example, the effect of a lens of -1 D can be cancelled by a lens of +1 D.

With the use of a trial spectacle frame (known in the industry as a ‘trial frame’), which has slots to insert lenses of different power, refractive error of the eye can be measured to the nearest 0.125 D. The smallest increment in a trial lens kit is usually 0.125 D. However, in New Zealand, lenses are ground to the nearest 0.25 D and an error of ± 0.125 D can be expected. Optometrists in New Zealand routinely prescribe lenses to the nearest 0.25 D (J. Phillips, personal communication, April 8, 2009).

As mentioned in section 2.3, myopia of more than 6 D is considered as high myopia. This is denoted as myopia > -6 D, e.g. -7 D, -10 D. According to the theoretical conversion
between refractive error and axial elongation as discussed in section 2.2, an axial elongation of just over 2.2 mm would make a difference between perfect vision and high myopia.

2.4.4. Objectively measuring myopia - measuring the ocular dimensions

Visual acuity as measured using a Snellen chart is a subjective measurement because it involves the active involvement of the subject’s perception. This is a valid measure because what is important clinically is how well the subject can see, however, the perception of the subject can involve factors other than purely refractive power of the eye. For example, psychological stress and environmental factors such as lighting may also play a part. It is also possible for the subject to cheat by squinting the eyes, or memorizing the chart. Moreover, the subjective measure of myopia is only accurate when the test is performed with accommodation fully relaxed. If the ciliary muscles are not fully relaxed, the test will give a result that is more severe than the real refractive error of the eye. For this reason, cycloplegic eye drops are used in myopia research to fully relax the ciliary muscles before subjective visual acuity tests are performed. Cycloplegic agents, such as Atropine and Tropicamide, also have the side effect of relaxing the sphincter muscles of the iris causing light sensitivity, which may pose safety issues in driving.

The close relationship between ocular dimensions and refractive error enables the refractive error to be measured objectively using instrumentation such as ultrasonography and coherence interferometry. The IOLMaster (manufactured by Carl Zeiss Meditec, Germany) is generally considered as the criterion standard or ‘gold standard’ measurement for ocular dimensions and refractive error. This device emits a low intensity light into the eye and calculates the axial length from the reflected light waves (partial coherence interferometry). Unlike ultrasound, no physical contact between the eye and the instrument is necessary. Unlike subjective methods for measuring myopia, no cycloplegic agent is needed. Figure 4 shows IOLMaster and patient positioning.
IOLMaster allows fast, accurate measurements of eye length and surface curvature. It was designed for the purpose of determining the power of an intraocular lens to be implanted after the extraction of a cataractous lens. It is claimed by the manufacturer to be consistently accurate to within ±20 µm, equivalent to 0.054 D based on the theoretical calculations (Bennett & Rabbetts, 1989). Comparing with the smallest increment of 0.125 D with trial lenses, IOLMaster would be 2.3 times more precise. However, it can be expected that in practice the measurement error will be greater than 0.054 D due to human errors and the fact that the eye is a living organ so its dimension may not stay absolutely static.

2.5. Epidemiology of Myopia

The prevalence and severity of myopia varies greatly with different geographical area, time period, lifestyle, age, race, education, occupation, and the amount of nearwork performed. Comparison between different studies or combining data from different studies is difficult because different studies involve subjects of different age group, lifestyle, ethnicity and geographic location. Also, some studies define myopia as refractive error greater than -0.75
D (Mutti, Mitchell, Moeschberger, Jones, & Zadnik, 2002), whereas others adopt -0.5D (Saw et al., 2007), -0.25 D (Lin, Shih, Hsiao, & Chen, 2004) or “any myopia” (Vitale, Sperduto, & Ferris, 2009) as the criterion. Nevertheless, these studies and a number of large scale literature reviews have revealed some clear trends and risk factors for myopia, as discussed in the following section.

2.5.1. Age

The prevalence of myopia varies substantially with age. Grosvenor (1987) collated a number of studies conducted in Europe and North America to show the prevalence of myopia at different ages. These studies found that approximately 25% of infants were myopic and 50% were hyperopic. These deviations from emmetropia are attributed to the immaturity of the eye at birth. By the time children reached 5 or 6 years old, about 2% were found to be myopic and 90% emmetropic. Emmetropization is the process in which the eye grows in such a manner that it tends to become emmetropic by the age of five or six years.

As shown in Figure 5, the prevalence of myopia increases during the school years, reaches a peak at about 40 years of age (approximately 28%). After 40 years of age, there is a tendency for the eyes to become hyperopic, and so the prevalence of myopia declines (Grosvenor, 1987).
During the school years, not only does the prevalence of myopia increase, the severity of myopia progresses also. The mean rate of progression ranges from -0.4 to -0.8 D per year as shown by various studies collated by Grosvenor and Goss (1999), and higher rates of progression are associated with earlier age of myopia onset. The progression typically slows or stops in the mid to late teenage years, and hence individuals who develop myopia after late teens tend to be mildly myopic.

2.5.2. Time period

The prevalence of myopia appears to have risen over time in the industrialised countries of North America and East Asia. In the United States the prevalence of myopia increased from 25.0% to 41.6% over a 30 year period, based on the data from the 1971-1972 National Health and Nutrition Examination Survey and the 1999-2004 National Health and Nutrition...
Examination Survey. For white individuals, the prevalence increased from 26.3% to 43.0%. For black individuals, the prevalence increased from 13.0% to 33.5% (Vitale et al., 2009).

This increasing prevalence of myopia is also reported in East Asia. In a large scale study with surveys conducted in 1983 (n = 4,125), 1986 (n = 10,500), 1990 (n = 8,667), 1995 (n = 11,175) and 2000 (n = 10,878), it was revealed that in Taiwan the prevalence of myopia in 15-year-old school children increased from 64.2% to 81% during 1983 and 2000. The mean refractive error increased from -1.49 D to -2.89 D during these 17 years (Lin et al., 2004).

This trend of increasing myopia prevalence in developed and developing countries across different races indicates factors associated with environmental influence rather than genetic inheritance. Urbanisation, lifestyle changes, increasing amount of time engaged in near activities and watching television or computer screens, are possible factors. Neither Vitale et al. (2009) nor Lin et al. (2004) explored the possible cause of the increasing prevalence.

2.5.3. Genetic and environmental factors

The wide difference in myopia prevalence in different geographical regions led to the study of factors involving genetic predisposition, environmental influence, or a combination. The prevalence of myopia is much higher in East Asia than in Europe or North America. Comparing school children of 15 years old in Taiwan, the prevalence was reported to be around 70 ~ 80% (Lin et al., 2004). In California and Finland, the figure is around 15 ~ 20% (Laatikainen & Erkkila, 1980; Peters, Blum, Betman, Johnson, & Fellows, 1959), and in Vanuatu about 4% (Garner, Chung, Grosvenor, & Mohidin, 1991).

In these three regions many factors are different, for example the ethnicity of the residents, the lifestyle, diet, education, physical activities, the culture, and the natural environment. These factors can be broadly divided under two groups: genetic factors; and environmental factors. In this section the involvement of each of these two groups is examined.
A. Genetic predisposition

It has been shown that children of myopic parents are more likely to be myopic. Mutti et al. studied 366 eighth grade (14 year-old) school children who participated in the Orinda (California) Longitudinal Study of Myopia in 1991 to 1996 (Mutti et al., 2002). They found the percentage of myopia in children with no-myopic parents was 6.3%. The prevalence was as much as 18.2% in children with one myopic parent, and 32.9% in children with two myopic parents. These data clearly indicate a connection between myopia and inheritance. However, it is less clear whether this inheritance is more strongly determined by genetics (‘nature’) or the upbringing (‘nurture’).

Twin studies offer a way to distinguish the relative contribution from genetics and upbringing. In one study involving 361 pairs of twins between the age of 10 and 15 in Taipei (Chen, Cohen, & Diamond, 1985), the authors found that the concordance of refractive error (defined as difference < 0.5 D) was greater in monozygotic twins (89.1%) than dizygotic twins (51.2%). The marked difference in concordance shows that genetic inheritance is a strong determinant of myopia development.

In the above two studies however, it was found that genetics did not entirely explain the risk factors for developing myopia. For example, 6.3% of non-myopic couples (n=95 couples) had myopic children, and 67.1% of myopic couples (n=85 couples) had non-myopic children (Mutti et al., 2002). These figures indicate that the environmental factors also play a role in myopia development.

B. Environmental influence

One method of assessing the influence of lifestyle and environmental factors is to investigate whether the prevalence of myopia is comparable in the same genetic pool across a large time span. The studies of Vitale (2009) in the United States and Lin et al. (2004) in Taiwan are examples of such studies. As discussed in section 2.5.2, both these studies showed a clear trend of increasing myopia prevalence, indicating the involvement of lifestyle factors in myopia development.

Garner, Owens, Kinnear, and Frith (1999) examined the extent of environmental influence by investigating the prevalence of myopia in groups that shared a common genetic pool but
lived different lifestyles. Garner et al. (1999) compared the prevalence of myopia in Sherpa children that lived in isolated villages in the Himalayas, and the Tibetan children that lived in the modern city of Kathmandu with rigorous schooling. These children shared a common genetic background: the Sherpas migrated from Tibet over centuries and the Tibetans arrived in Nepal more recently. Garner et al. reported the prevalence of myopia in Sherpa children as being approximately 3% and for Tibetan children 22%. The finding of this study suggested a strong lifestyle influence on the prevalence of myopia. One of the major differences in lifestyle between the Sherpa and Tibetan groups is the extent of close-up activities (such as studying) that the Tibetan children were engaged in.

C. Summary
To summarise, both genetic and environmental factors appear to contribute to the development of myopia. The amount of nearwork appears to be an important environmental factor that is associated with myopia.

2.5.4. Nearwork

Studies have revealed a close association between sustained nearwork and myopia. Myopia is correlated with a greater volume of reading or near-point activities (Zadnik & Mutti, 1998). There is a higher education achievement in myopes than emmetropes and hyperopes (Sperduto, Seigel, Roberts, & Rowland, 1983). Myopia is less prevalent in populations with minimum compulsory schooling, and highly prevalent in societies with highly competitive school entrance examination (Garner et al., 1999) (Lin et al., 2004). Nearwork seems to be a common factor in groups with high myopia prevalence.

In a 1968 study (as cited in Zadnik & Mutti, 1998), it was reported that myopia prevalence in the occupation category “mainly university students” was 30%, “mainly clerks” 12%, and “farm and unskilled labourers” 3%. Sperduto, Seigel, Roberts, and Rowland (1983) found that myopia prevalence rose with family income and educational level, as shown in data collected from the 1971 to 1972 National Health and Nutrition Examination Survey in the United States. In Saw and colleagues’ study of 740 Singapore school children aged 10–12 years old (Saw et al., 2007), they found that children with average grades in the
highest quartile were 2.5 times more likely to be myopic compared with children with average grades in the lowest quartile. According to these studies it appears that larger volumes of nearwork, and higher academic achievement, are closely associated with myopia.

2.5.5. Summary

In summary, both genetic and environmental factors contribute to the likelihood of developing myopia. Children with myopic parents are more likely to be myopic. Identical twins are more likely to have similar refractive error than non-identical twins. The prevalence of myopia has shown an increasing trend in the North America and South East Asia where cross-sectional studies had been carried out spanning 17 to 30 years. The prevalence of myopia is substantially lower in societies with minimum school education. In societies where demand for education is high, myopia progresses rapidly during the school years and slows or stops in the late teens. “It appears that the environmental element that has the most impact is nearwork” (Grosvenor & Goss, 1999, p51).

2.6. Causes of Axial Length Alterations

As discussed in section 2.2, refractive error in myopia is closely correlated to the axial length of the eye. The cause of the eye’s abnormal elongation has been the centre of much research attention. Theories postulated can be broadly divided into three concepts: accommodation deficit, mechanical stretching of the sclera, and hereditary traits.

2.6.1. Accommodation deficit

During the process of emmetropization, the refractive error at birth is normalised by the time most children reach 5 or 6 years old. The current hypothesis is that the clarity of retinal images provides feedback to modulate the growth of the eye in the correct direction to reach emmetropia. For example, if the images focus behind of the retina, the feedback
stimulates the eye to grow longer in order to have a clear image. However, for children who have decreased ability to accommodate for near objects, this failure also results in images behind the retina when viewing near objects. If these children are engaged in nearwork for sufficient amount of time, the images will be behind the retina for sufficient amount of time to set up the feedback mechanism to grow a longer eye. Prolonged nearwork is thought to be the cause of excessively long eyes in myopia.

This theory is supported by Gwiazda, Thorn, Bauer, and Held (1993). In their study (n=64 children), the authors concluded that myopic children accommodated significantly less than emmetropic children for near objects, while their accommodation for far objects was normal. The theory is also supported by the study of Lin et al. (2004), in which high myopia prevalence was found in societies where children were under pressure to achieve academically from a very young age. However, it has been shown that 12-minutes-per-day of myopic defocus (image focused in front of the retina) prevents myopia which is caused by daylong hyperopic defocus (image focused behind the retina) in baby chickens (Zhu, Winawer, & Wallman, 2003). If human eyes respond in a similar way to chicken eyes during their growth, the reasoning follows that unless children were in a constant state of hyperopic defocus (e.g. with constant nearwork, or with an inability to accommodate for most distances), myopia would not occur. Furthermore, since wearing under-corrected lenses is not effective in controlling myopia progression (Chung, Mohidin, & O’Leary, 2002), it implies that apart from insufficient near accommodation, other factors also play a role in the elongation of the eye.

2.6.2. Mechanical stretching of the sclera by the extraocular muscles

The shape of the eye is contained by the fibrous sclera. On the sclera there are attachment sites for six extraocular muscles, which can exert mechanical force on the sclera. Applying engineering principles, Greene (1980) calculated the mechanical stress experienced on the sclera as a result of a number of factors: accommodation, convergence, vitreous pressure, and the extraocular muscle contraction, based on their anatomical orientation. Greene’s theory indicates that myopia might result from stretching of the posterior sclera induced by
a combined influence of the extraocular muscles, especially the internal and external obliques, and the increased pressure within the globe associated with convergence (and hence the medial rectus muscles). The increased prevalence and progression of myopia with nearwork as discussed in section 2.5.4 supports the association of convergence with axial elongation.

The extraocular muscles as the cause of axial elongation was also discussed by Gottlieb (1982). As cited by Gottlieb (1982), Bates attributed myopia as a result of children undertaking prolonged period of concentration at school. Bates also commented that the continual strain and psychological stress pervasive in the modern civilization may be a factor. These stressors induced aberrant neural impulses to the eyes and the extraocular muscles. The extraocular muscles became abnormally tense distorting the shape of the eyeball. Gottlieb further analysed the anatomy of the extraocular muscles and reasoned that if the inferior and superior obliques contracted simultaneously, the effect would be like placing a tight band about the equator of the globe, squeezing the eye to protrude in the axial direction.

In more recent studies, the measurement of phoria offers an insight into the relationship between the extraocular muscles and myopia. Heterophoria is the tendency of the eyes to move inwards (eschoria) or outwards (exophoria) when cues for fusion of the two retinal images are removed (e.g. by covering one eye). In a retrospective study, Chung and Chong (2000) showed that refractive error is significantly higher in the group of patients with any amount of esophoria (assessed with a Maddox wing) when viewing near objects, compared with the group with exophoria. Goss (1990) also found that through their habitual correction lenses, children with near esophoria (esophoria when viewing near objects) had greater rates of myopia progression compared with children with orthophoria or exophoria. Both studies found an association between a medial drift of the eye and myopia. Since the orientation of the eye is co-ordinated by the six extraocular muscles collectively, it is possible that an imbalance between those muscles exists, perhaps with some muscles abnormally tense or weak. Of particular interest are the medial and lateral rectus muscles, because they are the strongest medial and lateral movers of the eye.
Summary

Mechanical modelling of the eye suggests a possible contribution of the inferior and superior obliques in axial elongation. Clinical association between heterophoria and myopia also suggests the involvement of extraocular muscles, medial and lateral recti in particular, in myopia development. Functional imbalance of the skeletal muscles is commonly and successfully treated with manual therapy. There appears to be a potential in myopia management with manual therapy through influencing the extraocular muscles.

2.6.3. Hereditary traits

As discussed in section 2.5.3, studies of parental myopia and concordance of refractive errors in twins support a genetic predisposition to myopia. In Greene’s mechanical model of axial elongation (1980), he also suggested that the mechanical properties of the sclera, the geometry and the mechanics of the extraocular muscles, are largely genetically determined. These factors may account for the predisposition of some families or races to myopia in the presence of similar environmental factors such as prolonged nearwork.

2.7. Extraocular Muscles & Binocular Vision Anomalies

In section 2.6.2 and 2.6.3, the possible involvement of the extraocular muscles in myopia development was discussed. Abnormalities in the extraocular muscles often affect binocular vision. Binocular vision is a process of integrating retinal images from two eyes into a single three-dimensional perception (Wright, 1997). This process requires sensory fusion, the cortical integration of the images from each eye, and motor fusion, the corrective movements of the eyes to maintain eye alignment on a common target. To obtain binocular vision, the eyes must be in proper alignment so that the images of the two eyes fall on corresponding retinal areas that are physiologically linked to the same cortical area. Extraocular muscles therefore play a crucial role in normal binocular vision.
Anomalies in binocular vision can be considered in two broad categories:

1) Heterophoria, where binocular vision is maintained but at a considerable amount of stress
2) Heterotropia, where binocular vision is absent

2.7.1. Heterophoria

The phoria position is the position that the visual axes take with respect to one another in the absence of stimuli to fusion, e.g. when a cover is place in front of one eye. While one eye is fixating at a distant object, if the other eye deviates outward when the cover is placed, the covered eye is said to have the condition of exophoria. If it turns inward or remains in its original position, the condition is called esophoria or orthophoria respectively. Most people are orthophoric for distant objects. For near objects, a small amount of phoria (< 6 D) is considered normal (Pickwell, 1995). Phoria in the horizontal plane (as described) is more common, but it can also occur in the vertical plane. Heterophoria can be measured with a Maddox wing as illustrated in Figure 6.

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**Figure 6. Maddox Wing.** Patient is instructed to hold the handle and place the Maddox Wing close in front of the eyes. The patient then looks through the eye pieces and reads out the number that the arrow is pointed to on the scale. The reading gives the phoria in dioptres.
2.7.2. Heterotropia

Heterotropia is also known as ‘squint’, or strabismus. It is a condition where the eyes deviate even when the fusion stimulus is present. This deviation results in diplopia, which may cause confusion and headache. If strabismus is present early in life, the individual often learns to suppress images from one eye to overcome the problem of diplopia. The aetiology of strabismus is not well understood. It has been associated with genetics (Wilmer & Backus, 2009), and possibly with forceps delivery (Mallett, 1988).

The presence and the quality of binocular vision can be assessed by using a test for assessing the stereoscopic depth perception. The Titmus Stereo test is a preliminary test that is commonly used. The test consists of a series of pictures and a pair of cross-polarized lenses. While wearing the cross-polarized lenses, the subject is asked to identify a particular icon in the pictures that appear to be closer (or sticking-out from the picture) than the others. Stereo acuity of 40 seconds of arc is considered normal (Pickwell, 1995). Greater values of stereo acuity indicate potential problems with binocular vision, and some patients may notice difficulty in judging distances.

2.7.3. Extraocular muscles in binocular vision anomalies

The crucial role of the extraocular muscles in normal binocular vision suggests that binocular vision deficits may involve dysfunction of the extraocular muscles. For individuals with both myopia and binocular vision anomalies, the extraocular muscles are possibly being influenced by both mechanisms simultaneously that drive the two conditions. Neither of these mechanisms is well-understood. Clinically and as shown by research, mechanical dysfunctions in the skeletal muscles may be influenced with manual therapy. Similarly, mechanical dysfunctions in the extraocular muscles, seemingly in myopia, should also respond to manual therapy. In the presence of binocular vision anomalies however, with unknown driving mechanisms, it is difficult to predict whether extraocular muscles will respond to manual therapy in the same way.
2.8. Orthodox Corrections for Myopia

2.8.1. Glasses and contact lenses

Concave lenses diverge light. They can be used to lengthen the focal length to reach the retina therefore correcting for myopia. Lenses can be worn in the form of spectacles, or contact lenses directly over the cornea.

Depending on the personal preference of the user, glasses may not be cosmetically appealing, and can be inconvenient for social or sporting activities. Contact lenses are discrete, but they must be handled with careful hygiene practice to avoid eye infection. In New Zealand, a conservative price estimate of a pair of spectacles would be $500 or more. The cost of contact lenses varies depending on the designed lifetime of the lenses. Daily, fortnightly, and monthly lenses are the more common options. Daily disposable lenses are more hygienic and allow better gas (primarily oxygen) permeability which is important because the cornea does not contain blood vessels. The cost of daily disposable lenses is approximately $800 per year.

2.8.2. Surgical correction for myopia

Surgical correction for myopia commenced in 1950. Today, Photorefractive Keratectomy (PRK) (since 1989) and Laser in Situ Keratomileusis (LASIK) (since 1991) are the main techniques for refractive surgery (Ang, Couper, Dirani, Vajpayee, & Baird, 2009). Both techniques utilise ultraviolet laser pulses to break molecular bonds in the cornea to alter the refractive property of the cornea.

Due to the short history of these procedures, the long-term effects are not well understood. The efficacy can be unpredictable resulting in under-correction or over-correction. Over time, there is also a tendency towards myopia regression. In these circumstances, spectacles, contact lenses, or repeat surgery may be necessary. Furthermore, the best corrected visual acuity (BCVA) as corrected with lenses may not be as good as the pre-
operation BCVA due to complications from the surgery. The long term consequence to the structural integrity of the cornea is still to be investigated. Other side effects reported include ‘dry-eye’ syndrome, light sensitivity, haze, halo, and impaired night vision. Currently, the medical fee for such a procedure in Auckland is approximately $3000 per eye (Eye Institute, n.d.).

2.9. Other Methods of Myopia Management

2.9.1. Bates’ method

Ophthalmologist William Bates (1860 -1931) attributed myopia to habitual strain of the eyes. He advocated exercises to free the eye and the body from straining, and to restore the natural blinking from habitual stare. Four basic exercises described by Bates (as cited in Gottlieb, 1982) are

- Palming – Eyes covered by palms, feel the eyes giving up the tension of trying to see.
- Swinging – In the standing position, rotate the body from left to right and back. Be aware of the movement of the eyes, head and torso moving together without tension.
- Sunning – Face the sun with eyes closed. Rotate the head from side to side. Allow the sunlight to penetrate deeply into the eyes and the forehead.
- Blinking and Breathing – Blink rapidly while taking two big breaths. Avoid locking the eyes into a stare.

On face value, these exercises appear to have little direct relationship with the axial dimension of the eye. However, it is possible that with the relaxing effect on the extraocular muscles the axial dimension of the eye may be affected over time. Anecdotal stories of effective results have been documented in Huxley (1975) and Gottlieb (1982), but to the author’s knowledge, no controlled trials have been reported in the peer reviewed vision science literature.
2.9.2. Alexander technique

Alexander technique involves the conscious guidance and conscious control of one’s own body in everyday activities (MacDonald, 1999). This conscious control of the body commonly manifests in ‘poised postures’ and a sense of ease in bodily movements. Peter Grunwald (2004), an Alexander technique teacher, took this concept further into the field of vision, integrating his training in Bates’ method and his personal discoveries into a concept that he termed “Eyebody”. The Eyebody method advocates the conscious control of the process of seeing. The resulting sense of ease and anti-straining effect is in line with that advocated by Bates eighty years earlier. To the author’s knowledge, there has been no efficacy study published on the Eyebody method to date.

2.9.3. Behavioural optometry

Behavioural optometry is a relatively new division of optometry which promotes the development of a more efficient and complete visual process with vision training. Vision training may consist of the use of lenses, optical filters, eye patches, electronic targets with timing mechanisms, visual-motor-sensory integration training, and exercises to converge the eyes. The training is individualised to each patient’s condition.

There have been some anecdotal success stories of myopia regression with behavioural optometry, but little in way of formal investigation in peer reviewed literature. For example, Orfield (1994) reported a prescription reduction of more than 3 D over the period of 7 years with a combination of therapies including behavioural optometry, nutrition, yoga, Alexander technique, cranial chiropractic, and meditation. However, it was unclear what level of visual acuity she achieved with the final prescription and over what age span. As discussed in section 2.5.1, the severity of myopia tends to reduce in the forth decade of life without intervention. If the treatment span included the fourth decade of life or later, it would be unreasonable to attribute the result to the therapy alone. Moreover, the combination therapy makes it impossible to determine individual contribution. Indeed, as criticized by Barrett (2009), the paucity of controlled trials continues to challenge the validation of behavioural optometry.
3. **OSTEOPATHIC CONSIDERATIONS FOR MYOPIA**

The possible causative connection between the extraocular muscles and myopia lends itself to the exploration of myopia management from an osteopathic perspective. A systematic search of literature in the field of osteopathic research focused on myopia intervention identified only two recent studies: Etchell (1999) and Bayer (2006). Both of these studies investigated myopia control with an approach described as ‘osteopathy in the cranial field’ (sometimes known as OCF) approach. Both studies are student projects and have not been published in the peer reviewed literature.

A limited amount of older, pre-1970 literature was found to explore myopia management from a structural or systemic perspective. Specific manipulative techniques directed to the eye and the orbit have been recorded. There are successful cases mentioned in these industry magazine articles, however, no controlled trial was documented.

In the following sections, recent OCF approaches to myopia are discussed. The structural and general physical considerations in older literature are summarised.

### 3.1. Myopia and Osteopathy in the Cranial Field (OCF)

#### 3.1.1. British school of osteopathy (BSO) final year project by David Etchell (1999)

Etchell (1999) investigated the effectiveness of osteopathic interventions for treating myopia using a single system research design. The subjects were three BSO fourth year male students between the ages of twenty and thirty-five.

The interventions consisted mostly of OCF techniques but also included some functional techniques and high velocity thrust techniques (HVT) of the cervical spine. The techniques chosen were based on diagnosis following physical examination and thus varied from subject to subject. The subjects received 4 treatments spaced at one week intervals. Before and after each treatment, unaided visual acuity was measured subjectively using a Snellen
chart, and denoted in Snellen fraction. The improvement in visual acuity ranged from 0 to “71.2%” immediately after a treatment.

It should be noted that the data analysis in Etchell’s study was inappropriate. Close inspection of the raw data revealed that the improvement of “71.2%” was calculated from erroneously interpreting the Snellen fractions as numerical fractions. Furthermore, the three subjects were all Etchell’s classmates. The influence of a close association between the subjects and the researcher makes the design of the study less rigorous, especially when the outcome measure was subjectively determined. Also, unaided visual acuity test using Snellen chart is a measure of low precision. Together with the small sample size, the overall validity of these findings is questionable.


Bayer’s controlled clinical study (2006) investigated the efficacy of “orbit fluid drive” technique for treating myopia. “Orbit fluid drive” is a cranial osteopathic technique that involves the operator directing the fluid from the occipital region towards the orbit, and observing the fluctuation of the fluid to a state of “still point”.

Twenty test subjects and 22 control subjects participated in this study. The intervention was one single session of orbit fluid drive. The ocular refraction and visual acuity were measured by an independent optician using a trial frame and a Snellen chart immediately pre and post intervention. The result showed myopia reduction of 0.125 dioptres (D) in average for the test group compared with 0 D for the control group.

The use of a trial frame and trial lenses allowed more precise measure of visual acuity. It also allowed the measure to be made in dioptres instead of Snellen fraction, enabling numerical data analysis. Examining the raw data, it appeared that the visual acuity was measured in 0.25 D increments. The measuring error is therefore 0.125 D, and changes less than 0.125 D will not be detectable. The apparent average improvement of 0.125 D for the test group may therefore be a result of measurement error.
In addition, neither Etchell’s nor Bayer’s studies mentioned the use of cycloplegic agents. As discussed in section 2.4.4, subjective measures of refraction without a cycloplegic agent may be prone to inaccuracy (Edwards, 1998).

Unaided visual acuity as measured with a Snellen chart alone is inadequate in determining the degree of refractive error. Aided visual acuity test with the use of trial lenses and the Snellen chart is the most commonly used method for an optometrist to determine the correct lens prescription clinically. However, the measuring error of 0.125 D makes it impossible to pick up small changes for research purposes. Neither of these two methods of measurement offers sufficient precision. Instead of subjectively measuring refractive error, axial length of the eye can be used as an objective measure of myopia. This method also offers a finer calibration without the need for cycloplegic agents.

3.1.3. Visual somatic dysfunction

An osteopathy website (“Vision and osteopathy in the cranial field”, 2006) referenced recent concepts in lens prescription developed by James Jealous, Joe Field, and Paul Dart. There is no formal scholarly literature available in the public domain regarding these concepts. The following information is based on email communication with Dr. Paul Dart (March 11, 2010).

According to Dart, Jealous was believed to be the first who observed a physical strain (described as being palpable with OCF palpation) which commences or is augmented when light enters the eye, and diminishes or resolves when light is no longer entering the eye. This physical strain has been labelled by Jealous as “visual somatic dysfunction”. Jealous, and other practitioners using this form of palpation, have observed clinically that corrective lenses for refractive errors often induce or magnify this physical strain.

Aiming to maximise visual acuity, corrective lenses are conventionally fitted to focus the image on the fovea for central vision. However, from clinical experience, Dart asserts that
the cranial mechanism appears to be “trying to optimize peripheral vision rather than central vision”. Dart notes that as a result of this optimization of peripheral vision, physical strain increases as the cranial mechanism attempts to compensate for the effect of corrective lenses.

From these findings, Field and Dart have developed protocols for prescribing lenses designed to reduce visual somatic dysfunction rather than maximising visual acuity. Usually this “balanced prescription” is slightly weaker than the prescription that gives the patient 20/20 vision. Dart suggests that as the patient’s body improves from the reduced strain, the balanced prescription will also change. Often the new prescription is weaker than the old one and the patients’ unaided acuity improves as the process continues.

For patients that started with a mild refractive error (approximately -1 D), it is Dart’s experience that they may progress to a point where they no longer need vision correction to be in neutral balance (i.e. when no additional strain is palpated with light entering the eye). However, patients who have a greater refractive error are likely to still need corrective lenses for distant vision. As Dart stated, the goal of the therapy is to reduce physical strain in the body, not myopia reduction.

This innovative approach to visual dysfunction offers an unconventional perspective that considers vision as part of an intricate mechanism that optimises overall health of the individual, rather than an isolated quantity measured by central acuity. However, the approach is based upon the assumption that diagnosis of physical strain with OCF palpation is accurate and reliable. In fact there is a lack of investigation for the validity of OCF concepts, and few studies in this field have been published. The studies that investigated inter-practitioner reliability of OCF diagnosis found conflicting results (Moran & Gibbons, 2001), and the lack of a reliable diagnostic method continues to present a challenge for the validity of OCF research. Jealous, Field and Dart’s approach to vision would be an interesting area of research when reliable outcome measures can be defined.
3.2. Structural Osteopathy, Extraocular Muscles, and Myopia

Although osteopaths in New Zealand, Australia, and the United Kingdom today are known for their expertise in treating musculo-skeletal complaints, osteopathic philosophy is concerned with the body as a whole (Seffinger et al., 2003). Historical approaches by osteopathic physicians to myopia reflect this philosophy, and historical considerations for myopia involve structures further afield than that of the orbital content. Historical considerations and other structural considerations for myopia are discussed in the following sections.

3.2.1. Sinus infections & general physical considerations

Peppard (1942) and Gerber (1947) wrote of their experiences in successfully reducing myopia in their patients. Peppard did not give specific cases but claimed that in nearly every case the “lost vision” was restored by 25 to 75 percent. Gerber reported 7 successful cases, in one case, the visual acuity of a12-year-old-boy improved from 14/200 to 14/10 (as tested at 14 feet) after 21 treatments spaced at weekly intervals. Out of the seven cases, six had complained of sinusitis, and the remaining one patient was found to have a “pan-sinusitis” upon examination. Gerber did not explain the possible mechanisms by which sinus infection affects myopia. Both Peppard and Gerber suggested treating sinus infection as a first step in myopia management. Peppard also wrote of the importance of treating infections in the teeth, tonsils, and intra-nasal cavities due to reflex activities modulated through the trigeminal nerve.

These authors appeared to suggest a causative relationship between myopia and sinus infections, but most myopes today do not seem to have apparent sinus infections. However, it was found that infections in the head could be extremely difficult to detect (Bush, Snyder, & Reid, 1948). With modern imaging, sinus infections are easier to diagnose but it is possible that at least some myopes do have low grade sinus infections that are perhaps subclinical. It is noteworthy that the protocol of visual acuity test in these articles was not specified. The robustness of these claims is therefore questionable.
Gerber wrote highly of Ruddy’s “resistive duction” technique for the extraocular muscles as a “tremendous aid in myopia” from his clinical experience (Gerber, 1947). This technique is detailed in section 4.2. Both Gerber and Peppard suggest treating the spine, especially the upper thoracic and cervical spine to normalise sympathetic tone affecting the eye. Gerber wrote of cases where “clearer and greater range of vision” immediately followed spinal manipulation (Gerber, 1947, p. 166).

Considering the anatomical connections, according to Guyton and Hall (2000), the sympathetic innervation of the ciliary muscles, the sphincter of the iris, and the extraocular muscles all originate in the first thoracic segment of the spinal cord. From there the sympathetic fibres enter the cervical ganglion, and then spread along the surface of the carotid artery and successively smaller arteries until they reach the eye. This neurological connection offers a possible explanation for affecting vision with spinal treatments in the upper thorax and cervical spine. Furthermore, as the sympathetic fibres travel along the surface of the carotid artery, this may be a mechanism through which psychological stress may impact on the extraocular muscles and vision, as suggested by Bates (as cited in Gottlieb, 1982).

With respect to evidence, there is limited evidence from contemporary investigations that autonomic outputs can be influenced with manual therapy. For example, in an unpublished master thesis, Buchmueller (2008) found that no significant changes were detected in the heart rate variability of healthy young adults after receiving thoracic manipulation (high velocity low amplitude thrust technique). Buchmueller concluded that the autonomic output to the heart was not affected by thoracic manipulation. On the other hand, cervical spine manipulation has been reported to alter edge light pupil cycle time (Gosling, Kinross, Gibbons, & Holmes, 2005), which is the time taken for the pupil to constrict and re-dilate when exposed to a thin beam of light at the pupil’s edge. Since the iris is exclusively innervated by the autonomic nervous system (ANS), a change in edge light pupil cycle time reflects a change in the ANS. From the conflicting results of these studies, it is not conclusive whether spinal manipulation can influence the activities of the ANS.
3.2.2. Fluid health

As recorded in an article in the Academy of Applied Osteopathy Yearbook 1948, in a seminar discussion Reid stated his view of myopia as a form of juvenile glaucoma (Bush et al., 1948). Reid asserts that in myopia there is an increased osmotic pressure in the blood causing increased fluid into the eye from the ciliary processes. Modern research however, did not find a clear relationship between increased intraocular pressure (IOP) and myopia (Wildsoet, 1998).

In Packard’s opinion (1942), the eyes are very sensitive to altered fluid health, and the most important technique for the treatment of eye conditions is the ‘lymphatic pump technique’. He recommended treatment of the extraocular muscles and “deep cervical therapy” (he did not explain what constitutes “deep cervical therapy”). The technique he developed for the extraocular muscles was essentially active resisted muscle exercise involving the patient trying to roll the eyes against the therapist’s gentle resistance over the closed eyelids. This technique appeared to be similar to Ruddy’s ‘resistive duction’ technique as described by Wolf (1970). Packard (1942) did not report any specific outcome on visual acuity.

Wolf discussed fluid drainage of the eye in more detail (Wolf, 1970). He pointed out the fact that extraocular muscles insert close to the sclero-corneal junction, where the drainage sinus for the anterior chamber of the eye was found. The healthy state of the extraocular muscles therefore underpins the venous return from the eye. Wolf described Ruddy’s ‘resistive duction’ technique for releasing tension in the extraocular muscles, with an effect of decreasing abnormal tension on the sclera. He also recommended OCF manipulative procedures, as well as treating articular dysfunctions of the entire spine.

Ruddy’s ‘resistive duction’ or similar techniques appeared to be popular techniques in their era for treating a wide range of eye complaints including conjunctivitis, glaucoma, squint, and refractive error. These techniques were directed at the extraocular muscles, and it appears plausible that improved fluid health can be achieved in the orbit by exercising the extraocular muscles the same way that exercising skeletal muscles improves fluid health of tissue in their vicinity. It is important to note that no outcome data was presented in these pre-1970 articles to support any of these claims.
3.2.3. Fascial considerations

Although not specifically discussing myopia, Carreiro (2009) postulated the connection between fascia, extraocular muscles, and refractive error. She described the anatomical relationship:

A sheath of fascia covers the optic nerve and extends forwards to the back of the eye. Here it spreads out, becoming the fascia of the posterior aspect of the globe. Wherever it reaches an extraocular muscle, it turns onto the muscle, becoming the muscle sheath. Posteriorly, where the recti muscles attach to the common tendon, this same fascia merges into the tendon. (p204)

Without stating the exact mechanism, Carreiro postulates that the influence of these fascial structures on the eye may be important in understanding astigmatism and refractive errors. It appears logical that abnormal tension in this fascia sheath could influence the mechanical function of the sclera and cornea. It appears plausible that tension in the extraocular muscles may be a source of abnormal tension in this fascia sheath.

3.2.4. Summary

A review of historical literature reveals four main clinical considerations for the management of myopia:

- Resolution of sinus and head infections
- Improve fluid health of the orbit
- Address abnormal tension in the fascia of the orbit
- Resolve spinal dysfunction affecting upper thorax and the cervical spine

Ruddy’s ‘resistive duction’ technique has been described as being useful in addressing a number of these points (Gerber, 1947), (Wolf, 1970).
4. THE MUSCLE ENERGY TECHNIQUE

The muscle energy technique (MET) is described as: “a manual medicine treatment procedure that involves the voluntary contraction of patient muscle in a precisely controlled direction, at varying levels of intensity, against a distinctly executed counterforce applied by the operator” (Greenman, 2003, p101). In this section the protocol of MET is described. The historical development of MET is briefly documented in order to highlight its historical connection with Ruddy’s ‘resistive duction’ technique. Finally the theoretical mechanisms of MET are discussed.

4.1. MET Protocol

Muscle Energy Technique can be divided into five main variations, each with a slightly different protocol. These variations are (Chaitow & DeLany, 2008):

1) Isometric contraction using post-isometric relaxation
2) Isometric contraction using reciprocal inhibition
3) Isotonic concentric contraction
4) Eccentric isotonic stretch
5) Isokinetic

Each variation is considered most suitable for slightly different conditions and purposes e.g. for acute or chronically contracted muscles; Emphasis on stretching or strengthening the muscles. In general, the clinical aim of employing MET is to restore the normal length-tension relationship of the muscle and the fascia.

The first variation, isometric contraction using post-isometric relaxation, is the most widely taught variation in the education of osteopaths. A typical protocol of this variation of MET is described in Table 1.
Table 1. The MET protocol (Adapted from Chaitow & DeLany; Greenman, 2003)

1) The practitioner positions the patient in such a way that the muscle to be treated is slightly stretched. The practitioner will feel a subtle resistance (barrier) to further movement.

2) The patient is instructed to contract the muscle with 10-30% of their maximum effort for 3-10 seconds, while the practitioner resists any movement of the patient’s body. This is an isometric contraction of the muscle in concern.

3) Patient is instructed to relax for 3-10 seconds, while the practitioner prevents any movement of the patient’s body.

4) The practitioner then slowly and smoothly positions the patient further into the stretch until a new barrier is felt.

5) Step 2) to 4) is repeated for a total of 3-6 cycles or until no further gain in range of motion is possible.

4.2. Historical Development of MET

According to Chaitow (2006), the inception of MET into osteopathic work is credited to American osteopath Fred Mitchell Sr. in the late 1950s, and Mitchell’s work drew on the Ruddy’s ‘resistiveduction’ technique. Many others have contributed to the refinement of MET since then. A variety of other terms have been used to describe the technique, for example, ‘Active Muscular Relaxation Techniques’ (Liebenson, 2006). Proprioceptive Neuromuscular Facilitation (PNF) is another term referring to a variation of MET that is employed mostly by physiotherapists (Chaitow, 2006).

Compared with MET, in Ruddy’s ‘resistiveduction’ technique the patient is required to activate and relax the target muscle/s at a much faster rate (1~2 cycles per second) for the purpose of increasing blood flow and normalising neural tone to the muscle (Ruddy, 1961). Applied to the extraocular muscles, as described by Wolf (1970) and Gerber (1947),
resistive duction involved the physician placing the index fingers against the edge of the patient’s cornea over the closed eyelids and resisting the patient’s attempts to move the eyes in the direction of the six cardinal gazes, at the rate of half a cycle per second.

4.3. Principles of MET

In standard teaching texts, two main models have been proposed to explain the physiology behind MET.

1) Neurological: Afferents from Golgi tendon organ and muscle spindle relay in the spinal cord causing gamma efferents to the intrafusal fibres resetting the resting length of the extrafusal fibres. There is a slight delay after the isometric contraction before the muscle can be taken to a new resting length. “simply put, after an isometric contraction, a hypertonic muscle can be passively lengthened to a new resting length” (Greenman, 2003, p103)

2) Biomechanical: The elongation in the muscle following active stretches is suggested a purely biomechanical adaptation due to the viscoelastic properties of the muscle-tendon unit (Lederman, 1997).

The exact mechanisms of MET have not been identified, however, the effectiveness of MET on skeletal muscles is clinically evident (Fryer, 2006). As indicated in the earlier osteopathic literature documenting the use of ’resistive duction’, it appeared that the extraocular muscles also respond to MET.
5. **THE RESEARCH QUESTION**

From different perspectives, literature in optometry and in osteopathy has indicated a relationship between myopia and the extraocular muscles. To the author’s knowledge, there has been no study in the optometry field that has investigated the effect of directly manipulating the extraocular muscles. Earlier osteopathic literature has documented several successful case reports, however, these reports did not appear to have rigorous study designs or standardised outcome measures.

In Section II of this thesis, the direct and immediate relationship between the refractive state of the eye and the extraocular muscles is investigated, using axial length as a measure of the refractive state and MET as a means to manipulate the extraocular muscles. The research question addressed in Section II of this thesis is therefore:

**What is the effect of a novel osteopathic technique on the axial length of the eye?**
6. REFERENCES


Section II – Manuscript
Note to Reader

This manuscript has been prepared in accordance with the Instructions for Authors for the *International Journal of Osteopathic Medicine* (see Appendix C).

The use of square brackets in this manuscript indicates where reference is made to another section of the manuscript. The content indicated by square brackets does not constitute part of the journal manuscript.

The use of curly brackets in this manuscript indicates where reference is made to another section of the thesis. The content indicated by curly brackets does not constitute part of the journal manuscript.
Effect of a Novel Osteopathic Technique on the Axial Length of the Eye
Effect of a Novel Osteopathic Technique on the Axial Length of the Eye

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ABSTRACT

**Objective:** To investigate the short term effect of a novel osteopathic technique on the axial length of the eye.

**Methods:** A single-blinded pre-test post-test experimental design was adopted. Two experiments were conducted to investigate two types of intervention: i) muscle energy technique (MET) targeted at the medial and lateral recti; and ii) MET targeted at all six extraocular muscles. The axial length of the eye was objectively measured using partial coherence interferometry (IOLMaster, Carl Zeiss Meditec, Germany) operated by qualified optometrists. Phoria was measured with a Maddox wing to determine whether there was any change in extraocular muscle tension. Tests for stereo acuity and the near point of convergence were conducted to give indications of subjects’ state of binocular vision. Two tailed paired t tests were undertaken to compare both mean axial length, and mean phoria, pre and post-intervention. The pre and post-intervention data for axial length were also compared for individual subjects.

**Subjects:** Two groups of 10 adults (n=20) between the age of 18 and 35 with refractive error between -1 and -6 D were recruited from the general community. Volunteers with strabismus, active ocular disease, heart disease, or diabetes were excluded.

**Results:** Analysis of group data showed insufficient statistical evidence to support either method of intervention in effecting a clinically important change in axial length. Analysis of data from individual subjects revealed two eyes (in two different subjects) out of 40 eyes that underwent a change of ≥ 0.093 mm (equivalent to 0.25 D). Statistical analysis of phoria failed to find sufficient evidence to validate the efficacy of the intervention in effecting changes in relative muscle tension in the extraocular muscles.

**Conclusion:** MET targeted at the extraocular muscles was ineffective in altering the axial length of the eye. Further development work in application of the intervention techniques is necessary if further work is to be conducted in this area.

**Keywords:** myopia, osteopathy, extraocular muscle, muscle energy technique.
1. INTRODUCTION

Myopia, commonly known as ‘nearsightedness’ or ‘short-sightedness’, is a prevalent condition in which distant vision becomes ‘blurry’. Myopia affects more than 40% of the population in the United States,¹ and over 70% of 15-year-old school children in Taiwan.² The severity of myopia is closely related to the axial length of the eye. Myopic eyes are abnormally long in their anterior-posterior dimension, and the refractive error can be measured objectively from the axial length of the eyeball.³

The aetiology of myopia is unclear. The condition is thought to involve both genetic and environmental influence, with nearwork being the most important environmental factor. Abnormal muscular tension in the extraocular muscles has been postulated as the chief element leading to myopia.⁴⁻⁵ Abnormalities of convergence have also been associated with myopia development, hence pointing to the possible involvement of the medial and lateral rectus muscles in particular.⁶⁻⁷

Despite these connections between the extraocular muscles and myopia, there appear to be no published studies that have investigated the effect of manual therapy technique on refractive error. In this study, extraocular muscles were manipulated with a novel osteopathic technique, and changes in refractive error were objectively monitored by measuring changes in the axial length of the eye. The aim of this study was to investigate the effect of a novel osteopathic technique on the axial length of the eye.
2. METHODS

2.1. Subjects

Little previous data was available to assist with a priori power calculations, therefore, a sample size of 20 was recruited using a group sequential approach to sampling for this preliminary pilot study. Subjects were recruited using posters placed on local community notice boards, local optometrists, campuses of University of Auckland and Unitec New Zealand. The posters described the intervention as “resisted exercises of the eye muscles”. Respondents between the age of 18 and 35 with low to moderate myopia (-1.00 D to -6.00 D) were eligible to participate. Volunteers with any of the following conditions were excluded:

- Squint or strabismus (defined as a lack of coordination between the eyes. As a result, the eyes look in different directions and do not focus at the same time on a single point)
- Refractive error of more than 6 dioptres in any eye
- Previously history of head injury, eye surgery, retinal detachment, or any active ocular disease (e.g. conjunctivitis, retinitis etc)
- Systemic conditions that affect the eye such as diabetes, circulatory and cardiovascular disorders

After being briefed by the researcher and reading an information sheet [see Appendix A] all subjects gave written, informed consent [see Appendix B]. The study was approved by Unitec Research Ethics Committee.
2.2. Experimental Design and Protocol

A single blinded pre-test post-test experimental design was adopted for the investigation. The experiment involved two separate experiments. Both experiments followed the same protocol but differed in the number of extraocular muscles that were intended to be manipulated: Experiment 1) medial and lateral recti; Experiment 2) all six extraocular muscles.

Measures of axial length and phoria were conducted by qualified optometrists. The intervention was delivered by the researcher. The study was conducted in the research laboratory at the Department of Optometry and Vision Science, University of Auckland.

The protocol for both experiment 1 and 2 is identical except for the intervention. The protocol is described below, and illustrated in Figure 1. {Detailed experimental flow charts are included in Appendix D.}

1. First, one set of 6 axial length (AL) measurements was taken for each eye by an optometrist to obtain a mean base line value for each eye. A mean base line value for phoria was also obtained from 3 repeated measurements.

2. The researcher decided by random assignment if the subject’s right or the left eye was to be treated first. Intervention was carried out by the researcher to eye 1.

3. A second set of 6 axial length measurements was taken for each eye by the optometrist to obtain a mean value. A second set of 3 phoria measurements was also taken.

4. Intervention was carried out by the researcher to the second eye.

5. The third set of axial length and phoria measurements was taken by the optometrist.

6. A stereo acuity test and tests for the near point of convergence were conducted by the researcher.

[Insert Figure 1]
Three sets of six axial length measurements (18 measurements for each eye which is below the recommended daily maximum of 20). The subject was seated in the same room throughout the session. Both assessment and MET of the extraocular muscles were applied by the researcher while the subject was in the sitting position and the optometrist was absent from the room. Therefore the optometrist was ‘blinded’ to which eye the MET was applied.

2.3. Intervention

In experiment 1, the intervention was Muscle Energy Technique (MET) targeted at the lateral rectus (LR) and medial rectus (MR) muscles. In experiment 2, the intervention was MET targeted at all six extraocular muscles.

The subject was instructed to close both eyes throughout the intervention procedure. The operator thoroughly washed and dried their hands before performing the intervention technique through the subjects’ closed lids. First, the relative muscle resistance between the agonist and antagonist was assessed, by the operator moving the eyeball under the closed eyelids and palpating for resistance. For example, if more resistance was palpated attempting to move the eye towards the lateral direction compared with the medial direction, the lateral rectus was said to have less resistance than the medial rectus. MET was applied first to the muscle with less resistance and then to its antagonist. Applying the principles of MET as detailed in Chaitow & DeLany, procedures for the MET of the lateral rectus are described in Table 1 and illustrated in Figure 2.

The MET procedures targeted at each of the six extraocular muscles are similar but each muscle is best activated from a particular direction of gaze. For clarity, these procedures are shown as flow charts alongside their agonist in Figure 2, 3, and 4. The direction of gaze indicated in the flow charts is based on the anatomical positions of the muscle insertion and origin as described by Burde and Feldon.

[Insert Figure 2]
[Insert Figure 3]
[Insert Figure 4]
2.4. **Primary Outcome Measure**

The outcome measure was the axial length of the eye as a measure of myopic severity. Axial length was measured objectively using a patented interference optical method known as partial coherence interferometry (IOLMaster, Carl Zeiss Meditec, Germany) by qualified optometrists.

2.5. **Other Measures**

A number of binocular vision screening tests were implemented to provide some indication of possible dysfunctions in the extraocular muscles. These tests were not intended to serve as exclusion measures, but to provide additional data if closer examination is indicated for the identification of possible influencing factors. These screening tests are phoria, stereo acuity, and the near point of convergence. Phoria also served as a secondary outcome measure to determine if manipulation of the extraocular muscles resulted in any functional change in the extraocular muscles.

2.5.1. **Phoria**

Phoria was monitored for two purposes, i) as a secondary outcome measure; ii) as a screening test for binocular vision anomalies. Phoria is the deviation between the two eyes when the eyes are in their natural resting position in the absence of an adequate fusion stimulus. Changes in phoria can be an indication of changes in the relative muscle tension in the extraocular muscles, and thus may indicate whether the intervention resulted in any change in extraocular muscle function. As a screen for the state of binocular vision, a small amount of phoria (< 6 D) is considered normal. Large amounts of phoria indicate dysfunction of the convergence or divergence mechanism. A Maddox Wing, as shown in Figure 5, is used as a simple way of measuring phoria. More sophisticated tests provide more accurate data but they are outside the scope of this study.

[Insert Figure 5]
2.5.2. Stereo acuity test

The Titmus Stereo test is used to screen for the presence of abnormalities in binocular vision development. While wearing cross-polarized lenses, the subject is asked to look at various pictures and identify a particular icon that appears to be closer (or ‘sticking-out’ from the picture) than the others. Stereo acuity of 40 seconds of arc or less is considered normal.\(^\text{13}\)

2.5.3. Near point of convergence

Near point of convergence (NPC) was measured using a RAF rule as shown in Figure 6. The test is commonly used as a screening test for weakness in the convergence mechanism. Under normal conditions, single vision should be maintained from 8 cm and in further distance \(^\text{14}\). Abnormal results are indications for further investigation.

[Insert Figure 6]

2.6. Data Analysis

2.6.1. Analysis of group data

A. Analysis of phoria

Two tailed paired t tests were conducted for each experiment separately to identify any difference in either mean horizontal or vertical phoria pre and post intervention.

B. Reliability analysis for axial length measurements

To establish the reliability of axial length measurements, a test re-test reliability study was performed on Pre1 versus Pre2 measurements for all 20 subjects. This involved the calculation of the mean, Pearson correlation coefficient, intraclass correlation coefficient (ICC), 95% confidence interval for ICC, and the coefficient of variation using a spreadsheet
designed by Hopkins. The results (see Table 2) show that axial lengths measurements under the experimental set-up were almost perfectly reliable.

[Insert Table 2]

C. **Efficacy analysis for axial length**

To investigate changes in group means between pre and post intervention, a group study was conducted. Experiment 1 and 2 were analyzed separately using the same methods. Eye1 and Eye2 were also analyzed separately.

For eye1, to investigate the immediate effect of the intervention, two tailed paired t tests were conducted to compare the group mean axial length at base line versus the group mean immediately post-treatment (i.e. Post1 vs. Pre) for each experiment. To reveal any changes shortly after the intervention, two tailed paired t tests were conducted to compare the group mean axial length immediately post-treatment versus the group mean approximately 10 minutes post-treatment (i.e. Post2 vs. Post 1) for each experiment. To summarize the overall short-term effect of the intervention, two tailed paired t tests were conducted to compare the mean axial length at base line versus the group mean approximately 10 minutes post-treatment (i.e. Post2 vs. Pre) for each experiment.

For eye2, the immediate effect of the intervention was analyzed separately from eye1. The two base line measures, Pre1 and Pre2, were highly reliable as analyzed in the reliability study so they were averaged to provide an accurate baseline measure. Two tailed paired t tests were conducted to compare the group mean axial length at base line versus the group mean immediately post-treatment (i.e. Post vs. the average of Pre1 and Pre2) for each experiment.

The distribution of data was explored for normality before t tests were carried out. SPSS v17.0 (SPSS Inc., Chicago, IL.) was used for exploration of normality and conducting t tests and calculating confidence intervals. Cohen’s effect sizes ($d$) were calculated using an Excel spreadsheet. A clinically important result was concluded when the mean axial length for the group altered by greater than 0.093 mm. From theoretical calculations, 0.093 mm of change in axial length is equivalent to a change of 0.25 D in refractive error. This is the increment at which optometrists commonly prescribe corrective lenses.
2.6.2. Analysis for individual subject

A. Accuracy of axial length data

The accurate measure of axial length is not only dependent on the precision of the measurement instrument but also the ability of the subject to fix their gaze while the measurements are being taken. To study the variability of data accuracy amongst the subjects, the range and standard deviation were calculated for each of the 3 sets (baseline, outcome measure 1, and outcome measure 2) of 6 axial length measurements. The 3 sets of range and standard deviation for each eye were averaged to represent the variability in axial length measurements for each eye.

B. Efficacy analysis for axial length

Due to the small sample size, the possibility of making an incorrect conclusion based on statistical analysis is relatively high. Examining the intervention effect for each subject individually made it possible to detect changes in individuals that may otherwise be masked when considering changes in group means. The intervention effect for each individual subject was therefore analyzed. Experiment 1 and 2 were analyzed separately using the same methods.

For eye1, to investigate the immediate effect of the intervention, difference between the mean axial length at base line and immediately post-treatment was calculated (i.e. Post1 minus Pre) for each subject. To identify any changes occurring shortly after the intervention, difference between mean axial lengths immediately post-treatment and approximately 10 minutes post-treatment was calculated (i.e. Post2 minus Post 1) for each subject. To summarize the overall short-term effect of the intervention, differences between the mean axial length at base line and approximately 10 minutes post-treatment were calculated (i.e. Post2 minus Pre) for each subject.

For eye2, the two base line measures, Pre1 and Pre2, were highly reliable so they were pooled and used to provide an estimate of the baseline measure. Differences between the
mean axial length at base line and immediately post-treatment were calculated (i.e. Post minus the average of Pre1 and Pre2) for each subject.

When the subject underwent an increase or decrease in axial length, the treatment effect was defined as negative or positive respectively. A clinically important result was concluded when the axial length for the individual altered by greater than 0.093 mm. The number of subjects with clinically important results, in either positive or negative direction, was tabulated.
3. RESULTS

3.1. Analysis of Group Data

3.1.1. Efficacy analysis for phoria

A. Experiment 1

From the time baseline measures were taken to the time the first set of outcome measures were taken, the group mean of horizontal phoria became more exophoric by a difference ± SD of 0.74 ± 0.91 D from -1.42 to -2.15 D (95% CI for mean difference = -1.39 to -0.08; t = -2.55; df = 9; P = 0.031; d = 0.409). From the time the first set of outcome measures were taken to the time the second set of outcome measures were taken, the group mean of horizontal phoria became less exophoric by a difference ± SD of 0.22 ± 1.07 D from -2.15 to -1.93 D (95% CI for mean difference = -0.55 to 0.99; t = 0.64; df = 9; P = 0.537; d = 0.108). From the time baseline measures were taken to the time the second set of outcome measures were taken, the group mean of horizontal phoria became more exophoric by a difference ± SD of 0.52 ± 1.18 D from -1.42 to -1.93 D (95% CI for mean difference = -1.36 to 0.32; t = -1.39; df = 9; P = 0.197; d = 0.280).

These results indicate that there may be a small change in relative muscle tension immediately after the intervention was delivered to the first eye, but the change was not apparent after 10 minutes. The mean vertical phoria for each subject at the time of baseline, outcome measure 1, and outcome measure 2 are mostly zero as shown in Table 3, therefore t tests were not necessary. The intervention appeared to have minimal effect on the vertical phoria.

[Insert Table 3]
B. Experiment 2

From the time baseline measures were taken to the time the first set of outcome measures were taken, the group mean of horizontal phoria became more exophoric by a difference ± SD of -0.32 ± 1.72 D from -0.55 to -0.87 D (95% CI for mean difference = -1.55 to 0.91; t = -0.59; df = 9; P = 0.573; d = 0.099). From the time the first set of outcome measures were taken to the time the second set of outcome measures were taken, the group mean of horizontal phoria became more exophoric by a difference ± SD of -0.35 ± 1.26 D from -0.87 to -1.22 D (95% CI for mean difference = -1.25 to 0.55; t = -0.88; df = 9; P = 0.402; d = 0.118).

From the time baseline measures were taken to the time the second set of outcome measures were taken, the group mean of horizontal phoria became more exophoric by a difference ± SD of -0.67 ± 1.00 D from -0.55 to -1.22 D (95% CI for mean difference = -1.38 to 0.04; t = -2.12; df = 9; P = 0.063; d = 0.189).

These results indicate that there may be a small amount of change in relative muscle tension after intervention is carried out for both eyes. The mean vertical phoria for each subject at the time of baseline, outcome measure 1, and outcome measure 2 are mostly zero as shown in Table 4, therefore t tests were not necessary. The intervention appeared to have minimal effect on the vertical phoria.

[Insert Table 4]

3.1.2. Efficacy analysis for axial length

A. Experiment 1

For Eye1 (i.e. the eye that was treated first) the axial length increased immediately post-treatment by a mean ± SD of 0.008 ± 0.043 mm, from 25.225 to 25.232 mm (95% CI for mean difference = -0.039 to 0.023; t = -0.578; df = 9; P = 0.578; d = 0.007). Over the course of the time taken to treat the other eye (approximately 10 minutes), the axial length of Eye1 decreased by a mean ± SD of 0.010± 0.015 mm from 25.232 to 25.222 mm (95% CI for mean difference = -0.001 to 0.021; t = 2.041; df = 9; P = 0.072; d = 0.009). Overall, the axial length of Eye1 decreased by a mean ± SD of 0.002± 0.048 mm from 25.225 to 25.222 mm (95% CI for mean difference = -0.032 to 0.037; t = 0.142; df = 9; P = 0.89; d = 0.002). For Eye2, the eye that was treated second, the axial length showed an immediate decrease by a mean ± SD of
0.017 ± 0.024 mm from 25.221 to 25.204 mm. (95% CI for mean difference = -0.000 to 0.034; t = 2.253; df = 9; P = 0.051; d = 0.014). However, the change was not of sufficient magnitude to be clinically important (>0.093 mm).

In summary, group analysis for the 10 subjects showed that the mean axial length fluctuated during the course of the experiment. The confidence interval (in which the true value lies) for the difference in mean axial length between the three set of measurements spans either side of zero, suggesting that a real change in axial length was unlikely to have occurred. In addition, MET targeted at the lateral and medial rectus muscles did not effect a clinically important change (mean difference > 0.093 mm) in the axial length of the eye.

B. Experiment 2

For Eye1, the axial length increased immediately post-treatment by a mean ± SD of 0.004 ± 0.022 mm, from 24.924 to 24.928 mm (95% CI for mean difference = -0.019 to 0.012; t = -0.557; df = 9; P = 0.591; d = 0.004). Over the course of the time taken to treat the other eye (approximately 10 minutes), the axial length of Eye1 increased by a mean ± SD of 0.010 ± 0.013 mm from 24.928 to 24.938 mm (95% CI for mean difference = -0.019 to -0.001; t = -2.433; df = 9; P = 0.038; d = 0.009). Overall, the axial length of Eye1 increased by a mean ± SD of 0.014 ± 0.029 mm from 24.924 to 24.938 mm (95% CI for mean difference = -0.034 to 0.007; t = -1.472; df = 9; P = 0.175; d = 0.013). For Eye2, the axial length showed an immediate decrease by a mean ± SD of 0.004 ± 0.042 mm from 24.895 to 24.890 mm (95% CI for mean difference = -0.026 to 0.035; t = 0.324; df = 9; P = 0.754; d = 0.004).

The group analysis for the 10 subjects showed that the mean axial length fluctuated during the course of the experiment. The confidence interval (in which the true value lies) for the difference in mean axial length between the start and the end of the experiment spanned either side of zero, suggesting that a real change in axial length was unlikely to have occurred. In addition, MET targeted at all six extraocular muscles did not effect a clinically important change (mean difference > 0.093 mm) in the axial length of the eye. In summary, neither experiment 1 or 2 showed an average change in axial length of clinical importance across the group.
3.2. Analysis for Individual Subject

3.2.1. Accuracy of axial length data

As shown in table 5, the standard deviation and the range of the axial length measurements varied considerably from subject to subject. Across the 20 subjects, the maximum value of the average range for each eye is more than 5 times the minimum value. The maximum value of the standard deviation for each eye is also more than 5 times the minimum value.

[Insert Table 5]

3.2.2. Efficacy analysis for axial length

A. Experiment 1

In this experiment, one in the total of 20 eyes showed a clinically important change. This is Eye1 of subject 3, which underwent an axial elongation. The clinically important change was detected immediately post-intervention, and was maintained approximately 10 minutes later. The other 19 eyes involved showed minor changes that did not reach a clinically important threshold.

[Insert Table 6]

B. Experiment 2

In this experiment, one in the total of 20 eyes showed a clinically important change. This is Eye2 of subject 16, which underwent an axial elongation. The clinically important change was detected immediately post-intervention. The other 19 eyes involved showed minor changes that did not reach a clinically important threshold.

[Insert Table 7]

3.2.3. Stereo acuity test and near point of convergence raw data

Raw data from the screening tests for binocular vision is tabulated in Table 8. These tests are stereo acuity test and the near point of convergence.

[Insert Table 8]
4. DISCUSSION

The association between myopia and extraocular muscles has been made by numerous authors. However, there had been no published studies to date that have investigated the effect of manual therapy techniques on refractive error. There are a few reports in osteopathic literature that document intervention for myopia, however, they either lack rigorous study design, lack precision in measurement methods, or used inappropriate data analysis. The aim of this study was to investigate the short term effect of intervention to the extraocular muscles on the axial length of the eye. Axial length of the eye as measured with interferometry offers a precise outcome measure for refractive error in myopia. Two methods of intervention were implemented on two separate groups of subjects, i) MET targeted towards the lateral and medial recti; and ii) MET targeted towards all six extraocular muscles. There was insufficient statistical evidence from the experimental results to support either method of intervention in effecting a clinically important change in axial length.

Analysis of data from individual subjects revealed clinically important changes in two eyes (in two different subjects) in which the axial length increased by more than 0.093 mm. This is approximately equivalent to more than 0.25 D of deterioration in refractive error. The 0.093 mm of change in axial length is considerably greater than the measurement error of the respective eye, with the change exceeding 2.5 times the standard deviation. In one of these cases where 10-minute post-intervention measurements were also taken, the change was maintained. The maintenance of axial length change over the 10-minute interval is supportive of this change being more likely to be real rather than a measurement error. However, thirty-eight out of the total of 40 eyes participating in the experiments did not show a change of substantial clinical importance. If the intervention was capable of altering axial length, a greater number of responders would be expected. Examining the data obtained from tests of binocular vision, there appeared to be nothing that sets the two responding subjects apart from the other subjects. If there had been more responding cases, the binocular vision data collected may had been useful information from which predictions can be drawn regarding the likelihood of the intervention in effecting a clinically important change in axial length of a particular individual.
The single blinded pre-test post-test experimental design, and the precise, objective method of measuring outcome enabled a high degree of objectivity in data collection. However, the measurement error varied widely between subjects, and this variability presented a challenge for the valid interpretation of results. The varied ability of the subject to fixate the eye while the optometrist undertook axial length measurements is a likely cause of the variation of measurement error observed between subjects. This wide variation indicates a need for a more rigorous training for the subjects prior to data collection, however, the training of fixing eye gaze may itself introduce strain in the extraocular muscles, which may alter axial length in itself.

Axial length data collected in this study showed very small, negligible effect from the interventions. This result can be interpreted in a number of ways: i) axial length may not be affected by the extraocular muscles; ii) axial length may be affected by the extraocular muscles, but one single session of intervention is not sufficient in effecting a change of detectable size. In addition, any change in the extraocular muscles may take some time to manifest in alterations in ocular dimensions. It is useful to keep in perspective that during the school years where the severity of myopia progresses most rapidly, the mean rate of progression ranges from -0.4 to -0.8 D per year as shown by various studies collated by Grosvenor and Goss. To effect a change of 0.25D immediately from one single exposure to the intervention is perhaps over ambitious in retrospect. Future studies are suggested to increase the number of interventions, and to monitor the outcome over a longer period. iii) Finally, the intervention may not have influenced the extraocular muscles, therefore no change is detectable in axial length. Because MET targeted at the extraocular muscles is a novel technique, an effective way of ensuring that the extraocular muscles are successfully engaged in the intervention would be a valuable validation. A change in phoria may indicate a change in the state of homeostatic balance amongst the extraocular muscles, which may imply that a change had occurred in at least one of the extraocular muscles. If phoria does not change, it is unlikely that the intervention has changed the state of the targeted muscle. From the statistical analysis of phoria, efficacy of the intervention for effecting a functional change in extraocular muscles can not be validated. The lack of a significant statistical change is partially attributed to the large measurement error of phoria, which was measured in steps of 1 D with a Maddox Wing. More precise methods of measuring phoria may be employed but the procedures are technically complex and inherent variability of phoria may still present an obstacle for sufficiently reducing the measurement error.
A number of challenges have been identified in effectively performing the intervention technique on the extraocular muscles; a number of assumptions had been made due to limitations for an effective monitoring method. The limitations are: i) extraocular muscles are not readily accessible, and their contractions can not be monitored as easily as large skeletal muscles with electromyography. In this study, it is unclear to what extent the subjects were able to successfully follow instructions with regards to the intensity of muscle contraction and with regards to maintaining the muscle contraction for the required length of time. Some subjects may have experienced discomfort and thus contracted the muscles less. Some may have difficulty in generating and sustaining power in some directions. ii) It was observed by the researcher that holding the eyeball in place across the eyelids while the subject attempts to move the eye is challenging and technically difficult to achieve. The ‘slipperiness’ of the eye under the eyelids, and the consideration for patient comfort are potential reasons for inadequate fixation. Therefore, there may have been inconsistencies in the implementation of the technique attributable to both the researcher and the subjects. Further development work in application of the technique is necessary if further work is to be conducted in this area.

In conclusion, there is insufficient statistical evidence to support either method of intervention in effecting a clinically important change in axial length. However, two eyes (in two different subjects) out of 40 responded with a change of over 0.093 mm (equivalent to 0.25 D). It would be interesting to investigate whether the proportion of responding eyes would increase if the intervention is repeated on a daily to weekly basis.
5. REFERENCES


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6. FIGURES

Figure 1. Experimental protocol.
Experimental steps are shown from ① to ⑤. Firstly, baseline measurements are taken for both eyes. The measurements are named Pre and Pre1 respectively for Eye1 and Eye2. The eyes are randomly assigned. Secondly, intervention is carried out on Eye1. Thirdly, outcome measurements are taken for both eyes. The measurements are named Post1 and Pre2. Fourthly, intervention is carried out on Eye2. Finally, outcome measurements are taken again and named Post2 and Post.
Figure 2. MET procedures for (a) Lateral rectus (b) Medial rectus
Figure 3. MET procedures for (a) Inferior rectus (b) Superior rectus
Figure 4. MET procedures for (a) Superior oblique (b) Inferior oblique
Figure 5. Measurement of phoria with a Maddox Wing
The subject holds the handle placing the Maddox Wing in front of their eyes, and their eyes look into the two apertures. The numerical positions of the white and red arrows are read off the horizontal and vertical scales respectively by the subject, and these numbers determine the horizontal and vertical phorias in prism-dioptres. From the horizontal scale, esophoria is recorded with a plus sign, and exophoria is recorded with a minus sign. From the vertical scale, left and right hyperphoria is recorded with a plus sign and a minus sign respectively.

Figure 6. Measurement of near point of convergence with a RAF rule
The RAF rule is held in front of the subject by the subject (left) and the researcher (right). The white card was moved by the researcher: i) firstly from the furthest point closer in towards the subject, and the subject is asked to signal when the black line on the white card becomes double; ii) secondly from the closest point further away, and the subject is asked to signal when what appears to be double lines fuse back into one. The distance of the white card from the spectacle plane is read off the RAF rule as the NPC and the recovery distance respectively.
Table 1. **MET procedures for the lateral rectus** (Adapted from Chaitow & DeLany 11)

1) The subject was asked to move the eye as far medially as they can. The researcher then placed a finger towards the lateral border of the closed eye to resist gently any subsequent lateral movement.

2) The subject was then instructed to gently attempt moving the eye laterally, increasing to approximately 30% of maximum effort. (It is acknowledged that each subject made their own personal judgement on this figure, and the exact accuracy was immaterial). The researcher applied a counterforce with the finger so that the eyeball stayed stationary. This was an isometric contraction of the LR and was maintained for approximately 7 seconds.

3) The subject was instructed to slowly ease off their effort and then relax completely. During this process the researcher maintained the eyeball in a stationary position.

4) The subject was then asked to move the eye again as far medially as they can on an exhalation. The researcher followed this movement with the finger to gently resist any subsequent lateral movement of the eye.

5) Step 2 to 4 was repeated three more times.

6) To finish, the researcher slowly remove the finger from the subject’s closed eyelids.
Table 2. Reliability analysis of axial length measurements

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<th>CV</th>
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<tr>
<td>Pre2</td>
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Notes. CV = coefficient of variation; ICC = intraclass correlation coefficient.
Table 3. Mean Vertical Phoria from Experiment 1

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<td>-1.00</td>
</tr>
<tr>
<td>4</td>
<td>-0.33</td>
<td>-0.67</td>
<td>0.83</td>
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<td>0.00</td>
</tr>
<tr>
<td>6</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>7</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>8</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>9</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>10</td>
<td>-2.33</td>
<td>-2.33</td>
<td>-2.00</td>
</tr>
</tbody>
</table>
Table 4. Mean Vertical Phoria from Experiment 2

<table>
<thead>
<tr>
<th>Subject ID</th>
<th>Base line (D)</th>
<th>Outcome Measure 1 (D)</th>
<th>Outcome Measure 2 (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>12</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>13</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>14</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>15</td>
<td>-0.33</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>16</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>17</td>
<td>0.00</td>
<td>-1.00</td>
<td>-0.67</td>
</tr>
<tr>
<td>18</td>
<td>0.33</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>19</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>20</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Table 5. Accuracy of Axial Length Data for Each Subject

<table>
<thead>
<tr>
<th>Subject ID</th>
<th>Ave Range for Eye1</th>
<th>Ave Range for Eye2</th>
<th>Ave SD for Eye1</th>
<th>Ave SD for Eye2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.057</td>
<td>0.147</td>
<td>0.021</td>
<td>0.053</td>
</tr>
<tr>
<td>2</td>
<td>0.140</td>
<td>0.073</td>
<td>0.051</td>
<td>0.029</td>
</tr>
<tr>
<td>3</td>
<td>0.093</td>
<td>0.090</td>
<td>0.038</td>
<td>0.032</td>
</tr>
<tr>
<td>4</td>
<td>0.060</td>
<td>0.153</td>
<td>0.025</td>
<td>0.056</td>
</tr>
<tr>
<td>5</td>
<td>0.130</td>
<td>0.190</td>
<td>0.049</td>
<td>0.076</td>
</tr>
<tr>
<td>6</td>
<td>0.083</td>
<td>0.053</td>
<td>0.032</td>
<td>0.021</td>
</tr>
<tr>
<td>7</td>
<td>0.047</td>
<td>0.047</td>
<td>0.017</td>
<td>0.018</td>
</tr>
<tr>
<td>8</td>
<td>0.057</td>
<td>0.033</td>
<td>0.020</td>
<td>0.013</td>
</tr>
<tr>
<td>9</td>
<td>0.053</td>
<td>0.063</td>
<td>0.021</td>
<td>0.024</td>
</tr>
<tr>
<td>10</td>
<td>0.053</td>
<td>0.060</td>
<td>0.020</td>
<td>0.022</td>
</tr>
<tr>
<td>11</td>
<td>0.073</td>
<td>0.050</td>
<td>0.028</td>
<td>0.018</td>
</tr>
<tr>
<td>12</td>
<td>0.147</td>
<td>0.127</td>
<td>0.055</td>
<td>0.048</td>
</tr>
<tr>
<td>13</td>
<td>0.110</td>
<td>0.047</td>
<td>0.040</td>
<td>0.018</td>
</tr>
<tr>
<td>14</td>
<td>0.127</td>
<td>0.040</td>
<td>0.049</td>
<td>0.016</td>
</tr>
<tr>
<td>15</td>
<td>0.210</td>
<td>0.063</td>
<td>0.088</td>
<td>0.024</td>
</tr>
<tr>
<td>16</td>
<td>0.243</td>
<td>0.093</td>
<td>0.086</td>
<td>0.037</td>
</tr>
<tr>
<td>17</td>
<td>0.100</td>
<td>0.060</td>
<td>0.037</td>
<td>0.022</td>
</tr>
<tr>
<td>18</td>
<td>0.057</td>
<td>0.040</td>
<td>0.022</td>
<td>0.015</td>
</tr>
<tr>
<td>19</td>
<td>0.160</td>
<td>0.183</td>
<td>0.059</td>
<td>0.078</td>
</tr>
<tr>
<td>20</td>
<td>0.063</td>
<td>0.060</td>
<td>0.023</td>
<td>0.021</td>
</tr>
</tbody>
</table>

Mean 0.103 0.084 0.039 0.032
SD 0.055 0.049 0.021 0.020
Max 0.243 0.190 0.088 0.078
Min 0.047 0.033 0.017 0.013
Max/Min 5.2 5.7 5.3 6.2

Notes. Ave = average; SD = standard deviation; Eye1 = the eye that had intervention first; Eye2 = the eye that had intervention second; Max = maximum; Min = minimum;
<table>
<thead>
<tr>
<th>Treatment Effect</th>
<th>Eye1</th>
<th>Eye1</th>
<th>Eye1</th>
<th>Eye2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>5</td>
<td>7</td>
<td>7</td>
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<tr>
<td>Negative</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Yes</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>No</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Total number of subjects: 10, 10, 10, 10

Notes. Eye1 = the eye that had intervention first; Eye2 = the eye that had intervention second; ttt = treatment. \(^{\text{§}}\)Subject 3.
Table 7. Number of Subjects and Effect of Intervention (Experiment 2)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Eye1</th>
<th>Eye1</th>
<th>Eye1</th>
<th>Eye2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre vs.</td>
<td>Post ttt effect</td>
<td>Pre vs. 10 min post ttt</td>
<td>Pooled pre vs. post ttt</td>
</tr>
<tr>
<td>Effect</td>
<td>Immediate post</td>
<td>over 10 min</td>
<td>post ttt</td>
<td></td>
</tr>
<tr>
<td>Clinically important?</td>
<td>ttt</td>
<td>(i.e. Effect ≥ 0.093 mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>Yes</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Negative</td>
<td>Yes</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>6</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Total number of subjects</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

Notes. Eye1 = the eye that had intervention first; Eye2 = the eye that had intervention second; ttt = treatment. \*Subject 16.
Table 8. Binocular Vision Test Results

<table>
<thead>
<tr>
<th>Subject ID</th>
<th>Stereo acuity (seconds of arc)</th>
<th>NPC (cm)</th>
<th>NPC - recovery (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>5</td>
<td>40</td>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>7.5</td>
<td>9.5</td>
</tr>
<tr>
<td>7</td>
<td>40</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>40</td>
<td>7</td>
<td>6.5</td>
</tr>
<tr>
<td>9</td>
<td>40</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>5.5</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>40</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>40</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
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<tr>
<td>13</td>
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<td>6</td>
<td>6</td>
</tr>
<tr>
<td>14</td>
<td>100</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>40</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>16</td>
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<td>6</td>
</tr>
<tr>
<td>17</td>
<td>40</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>18</td>
<td>40</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>19</td>
<td>40</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
</tr>
</tbody>
</table>

*Note.* NPC = near point of convergence.
8. APPENDIX

Ethics statement

The research presented in this manuscript has been approved by the Unitec Research Ethics Committee. All subjects in this research gave informed consent to their participation.

Acknowledgement

I would like to thank Robert Moran for reviewing this manuscript, Dr John Phillips for his technical support, and the University of Auckland for facilitating the data collection.
Section III - Appendices
Appendix A: Participant Information Sheet

Information for Participants

Effect of Osteopathic Techniques on the Extra-Ocular Muscles and Axial Length of the eye

What I am doing...
My name is Janice Huang and I am doing a master’s degree in osteopathy at Unitec New Zealand. Part of our degree programme involves a research project of my choice. My research interest is to investigate the potential of osteopathy in the intervention of myopia (“short-sightedness”), a common condition in which distance vision becomes blurry.

I am conducting an experiment to determine if short-sightedness improves after precise exercises of the eye muscles. I am looking for volunteers to participate in my experiment.

What does the experiment involve?
The experiment will be carried out at the Department of Optometry and Vision Science located at The University of Auckland (Medical School buildings) on Park Road, Grafton. The experiment will take approximately 45 minutes to complete.

During the experiment you will be asked to move your eyes to the left or to the right several times with the eyelids closed. I will place one finger on your closed eyelids to apply a gentle resistance to your eye movement. This resistance is gentle and safe. The position and the size of your eyes will be measured by a registered optometrist. The measurements will not involve any physical contact of your eyes.

Even though no direct contact to the eyes will be made in this study, a small risk of eye infection may be possible through my finger contacting your closed eyelids. This risk is minimal, and I will wash and dry my hands thoroughly before commencing. In the unlikely event that an eye infection does result, a registered optometrist will be available for consultation.

If at any stage you do not feel comfortable about any procedures, you are free to terminate your participation. You can also discuss your concerns with the optometrist.

If you agree to participate, you will be asked to sign a consent form. This does not stop you from changing your mind if you wish to withdraw from the project. However, because of our schedule, any withdrawals must be done within one week after the experiment.

Please contact me if you need more information about the project. My contact details are

Janice Huang
Phone 815 2205 or 021 235 8300
Email: magnollia@woosh.co.nz

At anytime if you have any concerns about the research project you can contact my supervisor:

Rob Moran
Phone 815 4321 extension 8642
Email rmoran@unitec.ac.nz

UREC registration number: 2008.916
This study has been approved by the Unitec Research Ethics Committee from 26 February 2009 to 26 February 2010. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the Chairperson (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix B: Participant Consent Form

CONSENT FORM

Effect of Osteopathic Techniques on the Extra-ocular Muscles and Axial Length of the eye

This research project investigates the effects of osteopathic techniques on short-sightedness. The research is being undertaken by Janice Huang from Unitec New Zealand, and will be supervised by Robert Moran and Dr Craig Hilton.

I, (name of participant): .................................................... have seen the “Information for Participants” sheet dated 05 February 2009 for people taking part in the project named above. I have had the opportunity to read the contents of the information sheet and to discuss the project with the researcher and I am satisfied with the explanations I have been given. I understand that taking part in this project is voluntary (my choice) and that I may withdraw from the project any time up until the point of data analysis (1 week after my participation in the experiment) and this will in no way affect my access to the services provided by Unitec New Zealand or any other support service.

I understand that I can withdraw from the research if, for any reason, I want this.

I understand that my participation in this project is confidential and that no material that could identify me will be used in any reports on this project. I accept that anonymised and summarised data will be presented in a thesis. These data may also be presented within a manuscript for consideration to publish in a peer reviewed journal, research conference, or other educational purpose.

I have had enough time to consider whether I want to take part.

I know whom to contact if I have any questions or concerns about the project.

The principal researcher is Janice Huang [ph: 815 2205 or 021 235 8300, e-mail: janice.huang@ihug.co.nz]

Signature..............................................................participant ..........(date)

Project explained by..................................................

Signature.............................................................. ..........(date)

B

UREC registration number: 2008.916
This study has been approved by the Unitec Research Ethics Committee from 26 February 2009 to 26 February 2010. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the Chairperson (ph: 09 815-4321 ext 6162). Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.
Appendix C: Instructions for Authors from International Journal of Osteopathic Medicine

Former title: Journal of Osteopathic Medicine

Guide for Authors
The journal Editors welcome contributions for publication from the following categories: Letters to the Editor, Reviews and Original Articles, Commentaries and Clinical Practice case studies with educational value.

Online Submission
Submission to this journal proceeds totally online. You will be guided stepwise through the creation and uploading of the various files. The system automatically converts source files to a single Adobe Acrobat PDF version of the article, which is used in the peer-review process. Please note that even though manuscript source files are converted to PDF at submission for the review process, these source files are needed for further processing after acceptance. All correspondence, including notification of the Editor's decision and requests for revision, takes place by e-mail and via the Author's homepage, removing the need for a hard-copy paper trail.

The above represents a very brief outline of this form of submission. It can be advantageous to print this “Guide for Authors” section from the site for reference in the subsequent stages of article preparation.

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, without the written consent of the Publisher.

Types of contributions
Letters to the Editor As is common in biomedical journals the editorial board welcomes critical response to any aspect of the journal. In particular, letters that point out deficiencies and that add to, or further clarify points made in a recently published work, are welcomed. The Editorial Board reserves the right to offer authors of papers the right of rebuttal, which may be published alongside the letter.

Reviews and Original Articles These should be either i) reports of new findings related to osteopathic medicine that are supported by research evidence. These should be original, previously unpublished works. The report will normally be divided into the following sections: abstract, introduction, materials and methods, results, discussion, conclusion, references. Or ii) critical or systematic review that seeks to summarise or draw conclusions from the established literature on a topic relevant to osteopathic medicine.

Short review The drawing together of present knowledge in a subject area, in order to provide a background for the reader not currently versed in the literature of a particular topic. Shorter in length than and not intended to be as comprehensive as that of the literature review paper. With more emphasis on outlining areas of deficit in the current literature that warrant further investigation.

Research Note Findings of interest arising from a larger study but not the primary aim of the research endeavour, for example short experiments aimed at establishing the reliability of new equipment used in the primary experiment or other incidental findings of interest, arising from, but not the topic of the primary research. Including further clarification of an experimental protocol after addition of further controls, or statistical reassessment of raw data.

Preliminary Findings Presentation of results from pilot studies which may establish a solid basis for further investigations. Format similar to original research report but with more emphasis in discussion of future studies and hypotheses arising from pilot study.

Commentaries Include articles that do not fit into the above criteria as original research. Includes commentary and essays especially in regards to history, philosophy, professional, educational, clinical, ethical, political and legal aspects of osteopathic medicine.
Clinical Practice Authors are encouraged to submit papers in one of the following formats: Case Report, Case Problem, and Evidence in Practice.

Case Reports usually document the management of one patient, with an emphasis on presentations that are unusual, rare or where there was an unexpected response to treatment eg. an unexpected side effect or adverse reaction. Authors may also wish to present a case series where multiple occurrences of a similar phenomenon are documented. Preference will be given to reports that are prospective in their planning and utilise Single System Designs, including objective measures.

The aim of the Case Problem is to provide a more thorough discussion of the differential diagnosis of a clinical problem. The emphasis is on the clinical reasoning and logic employed in the diagnostic process.

The purpose of the Evidence in Practice report is to provide an account of the application of the recognised Evidence Based Medicine process to a real clinical problem. The paper should be written with reference to each of the following five steps: 1. Developing an answerable clinical question. 2. The processes employed in searching the literature for evidence. 3. The appraisal of evidence for usefulness and applicability. 4. Integrating the critical appraisal with existing clinical expertise and with the patient's unique biology, values, and circumstances. 5. Reflect on the process (steps 1-4), evaluating effectiveness, and identifying deficiencies.

Presentation of Typescripts
Your article should be typed on A4 paper, double-spaced with margins of at least 3cm. Number all pages consecutively beginning with the title page.

To facilitate anonymity, the author's names and any reference to their addresses should only appear on the title page. Please check your typescript carefully before you send it off, both for correct content and typographic errors. It is not possible to change the content of accepted typescripts during production.

Papers should be set out as follows, with each section beginning on a separate page:

Title page
To facilitate the peer-review process, two title pages are required. The first should carry just the title of the paper and no information that might identify the author or institution. The second should contain the following information: title of paper; full name(s) and address(es) of author(s) clearly indicating who is the corresponding author; you should give a maximum of four degrees/qualifications for each author and the current relevant appointment only; institutional affiliation; name, address, telephone, fax and e-mail of the corresponding author; source(s) of support in the form of funding and/or equipment.

Keywords
Include three to ten keywords. These should be indexing terms that may be published with the abstract with the aim of increasing the likely accessibility of your paper to potential readers searching the literature. Therefore, ensure keywords are descriptive of the study. Refer to http://www.nlm.nih.gov/mesh/meshhome.html for the MeSH thesaurus.

Abstract
Both qualitative and quantitative research approaches should be accompanied by a structured abstract. Commentaries and Essays may continue to use text based abstracts of no more than 150 words. All original articles should include the following headings in the abstract as appropriate: Background, Objective, Design, Setting, Methods, Subjects, Results, and Conclusions. As an absolute minimum: Objectives, Methods, Results, and Conclusions must be provided for all original articles. Abstracts for reviews of the literature (in particular systematic reviews and meta-analysis) should include the following headings as appropriate: Objectives, Data Sources, Study Selection, Data Extraction, Data Synthesis, Conclusions. Abstracts for Case Studies should include the following headings as appropriate: Background, Objectives, Clinical Features, Intervention and Outcomes, Conclusions.

Text
The text of observational and experimental articles is usually, but not necessarily, divided into sections with the headings; introduction, methods, results, results and discussion. In longer articles, headings should be used only to enhance the readability. Three categories of headings should be used:

•major ones should be typed in capital letter in the centre of the page and underlined
•secondary ones should be typed in lower case (with an initial capital letter) in the left hand margin and underlined
•minor ones typed in lower case and italicised
Do not use 'he', 'his' etc. here the sex of the person is unknown; say 'the patient' etc. Avoid inelegant alternatives such as 'he/she'. Avoid sexist language.

References
Responsibility for the accuracy of bibliographic citations lies entirely with the Authors.

Citations in the text: Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Avoid using references in the abstract. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either "Unpublished results" or "Personal communication" Citation of a reference as "in press" implies that the item has been accepted for publication.

Text: Indicate references by superscript numbers in the text. The actual Authors can be referred to, but the reference number(s) must always be given.

List: Number the references in the list in the order in which they appear in the text.

Examples:
Reference to a journal publication:

Reference to a book:

Reference to a chapter in an edited book:

Note shortened form for last page number. e.g., 51-9, and that for more than 6 Authors the first 6 should be listed followed by "et al." For further details you are referred to "Uniform Requirements for Manuscripts submitted to Biomedical Journals" (J Am Med Assoc 1997;277:927-934) (see also http://www.nejm.org/general/text/requirements/1.htm)

Citing and listing of Web references: As a minimum, the full URL should be given. Any further information, if known (Author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

Tables, Illustrations and Figures
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**Acknowledgments**
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AB conceived the idea for the study. AB and CD contributed to the design and planning of the research. All authors were involved in data collection. AB and EF analysed the data. AB and CD wrote the first draft of the manuscript. EF coordinated funding for the project. All authors edited and approved the final version of the manuscript.

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Appendix D: Consort Flow Chart

Experiment Protocol

Optm: Baseline measure AL x 6 each eye, Phoria x 3

Rchr: decide to work on L or R eye firstly by random assignment

More resistance in Lat. mvt

MET LR
MET MR

MET MR
MET LR

Rchr: Palpate Med. & Lat. Mvmt of that eye

More resistance in Med. mvt

MET Inf. Rec.
MET Sup. Rec.

MET Sup. Rec.
MET Inf. Rec.

More resistance in Inf-Lat. mvt

MET Inf. Obl.
MET Sup. Obl.

MET Sup. Obl.
MET Inf. Obl.

Rchr: Palpate Inf-Lat. & Sup-Lat. Mvmt of that eye

More resistance in Sup-Lat. mvt

MET Inf. Obl.
MET Sup. Obl.

MET Sup. Obl.
MET Inf. Obl.

More resistance in Inf-Med. mvt

Rchr: Palpate Inf-Med. & Sup-Med. Mvmt of that eye

More resistance in Sup-Med. mvt

Optm: Alt x 6 each eye, Phoria x 3

Both eyes done?

Yes
No

Rchr: Work on the other eye

Test for NPC & Stereo acuity

Experiment complete

Legend

Optm: Optometrist
Rchr: Researcher
S: Subject
AL: Axial Length
NPC: Near Point Convergence
LR: Lateral Rectus
MR: Medial Rectus
Mvmt: Movement