ORIGINAL ARTICLES

Understanding the Extraocular Muscles and Oculomotor, Trochlear, and Abducens Nerves Through a Simulation in Physical Examination Training

An Innovative Approach*

Niu Zhang, MD, MS, and **Xiaohua He**, MD, MS, Palmer College of Chiropractic Florida

Purpose: The purpose of this study was to investigate the effect of an innovative exhibitory eye model simulation in a physical examination laboratory format on explaining Listing's Law concerning the individual extraocular muscle action and the rationale for cranial nerve testing. **Methods:** Participants were 71 volunteers in the third quarter of a chiropractic training program. The study involved a specially designed eyeball model used to explain the movements of individual extraocular muscles based on Listing's law and their cranial innervations in conjunction with the physical examination. Pre- and post-written tests were used to assess participants' understanding of the subjects taught. The test results were compared with those of nonparticipants who also took the same pre- and posttests. **Results:** An independent samples *t*-test of the posttest showed a significant difference between the groups. The study group students achieved higher scores than their counterparts in the control group. **Conclusion:** Using an innovative approach to explain Listing's law and rationale for cranial nerve tests can improve physical examination skill and help produce more effective written test results. (J Chiropr Educ 2010;24(2):153–158)

Key Indexing Terms: Chiropractic; Cranial Nerves; Education; Oculomotor Muscles; Physical Examination

INTRODUCTION

The study of cranial nerves has long been seen as one of the most relevant parts of preclinical training.[1,2] However, when learning the physical examination of the oculomotor, trochlear, and abducens nerves, students often have difficulty understanding the direction of the eye movement in conjunction with the examination of these cranial nerves. Instructors are thus challenged to find more feasible ways of teaching extraocular muscle movements in conjunction with oculomotor, trochlear, and abducens nerve tests to ensure that students can efficiently comprehend the actions of extraocular muscles when performing cranial nerve tests in their preclinical training. Traditionally, in teaching clinical reasoning, as in some of the medical schools,[3] the chiropractic schools have provided a passive educational experience, focusing mainly on didactics rather than hands-on functional training. Consequently, the physical examination of the oculomotor, trochlear, and abducens nerves and their influences on individual extraocular muscles are counterintuitive.

One of the difficulties in training students about the oculomotor, trochlear, and abducens nerve tests in relation to extraocular muscle movements is ignorance of Listing's law.[4] Listing's law describes the three-dimensional orientation of an eyeball and its

*This paper was selected as a 2010 Association of Chiropractic Colleges Research Agenda Conference Prize Winning Paper. The award is funded by the National Board of Chiropractic Examiners.

The Journal of Chiropractic Education

Vol. 24, No. 2. Printed in U.S.A.
1042-5055/$22.00

axes of rotation.[5] This law states that visual directions of sight are related to rotations of the eye so that all the rotation axes lie in a plane.[6] According to Listing's law, the vertical axis is within the plane of the globe's equator (a coronal plane), while the anteroposterior (AP) axis is within the plane of the horizontal meridian (a transverse plane). When the eye moves from any position of gaze to an object, it revolves about an axis perpendicular to a plane (visual line).

Unfortunately, Listing's law is often overlooked by both instructors and students in the subject of extraocular muscle and cranial nerve teaching, primarily because none of the available anatomy textbooks include Listing's law. In addition, Listing's law is conceptually difficult to deliver in classroom sessions without an actual demonstration, and there is no current model of the eyeball with extraocular muscles that can be used to demonstrate this law during anatomy laboratory sessions.

In the mid-1800s, an ophthalmotrope was invented by Ruete based on the concept of Listing's law.[7] This model was structurally complex and is not commercially available now. Many instructors have tried to recreate the ophthalmotrope using current technology, such as a virtual model of the ophthalmotrope[8] and a biomedical engineering program.[9] However, these inventions were limited to their institutes and not available to other schools. One of the important questions never answered is the effectiveness of ophthalmotrope in teaching and learning.

In this study, the authors created a simpler exhibitory eyeball model, similar to the ophthalmotrope but easier to make so that it can be used in all schools. The authors further hypothesized that this model could benefit students in understanding Listing's law if this law was delivered in the physical examination (PE) laboratory in conjunction with the training of cranial nerve tests. For that reason, the authors utilized this exhibitory eyeball model to demonstrate the individual extraocular muscle actions in the hope that students might understand the rationale for cranial nerve testing through this simulation in the PE laboratory sessions. Medical education simulation programs have been increasingly popular because they offer an attractive advantage for allowing the novice to acquire basic knowledge and skills often seen as a prelude to clinical practice.[3,10] It was the authors' belief that the PE laboratory could be a useful supplement to the commonly used teaching methods, such as lectures and anatomy laboratories, to carry out the simulation program; therefore, students could gain knowledge of human anatomy and develop clinical reasoning skills. This article considers the place of simulation in offering alternatives to the traditional approaches for students to learn extraocular muscle movements in conjunction with cranial nerve examinations. Thus, in this study, the authors designed a simulation-based training experience of extraocular muscle movement and cranial nerve examination for chiropractic students and evaluated whether such an innovative approach could improve students' performance in their written tests.

METHODS

Setting

The study was carried out in a PE laboratory session where the students received training on how the extraocular muscles act on the globe and what cranial nerve examination procedures should be used to test the functions of the extraocular muscles.

Study and Control Groups

This study was approved by the Palmer College of Chiropractic Institutional Review Board. The participants were 71 volunteers recruited from the third-quarter class. These students were randomly assigned into two groups: a study group ($n = 37$) and a control group ($n = 34$). There was no significant difference of learning ability between these two groups in terms of educational background (all participants had received their bachelor degree before enrolling in the school) and their past academic performances in other courses. All participants were exposed to exactly the same teaching materials in the lectures and anatomy labs, which were delivered by the anatomy instructors. All of the students also received identical physical examination training and had equal opportunities to practice cranial nerve tests on each other. Before the laboratory physical examination training, both groups of students received anatomy teachings of extraocular muscles and cranial nerves. The study group participants, however, had an opportunity to use the eyeball model to simulate the actions of the extraocular muscles described by Listing's law in conjunction with the physical examinations of the oculomotor, trochlear, and abducens nerves.

Exhibitory Eyeball Model

This eyeball model was designed by the authors based on the principle of Listing's law and delivered to the students who were in the study group. Briefly, three floral foam balls were used to represent eyeballs and inserted with three 10-inch-long wooden skewers as the vertical, horizontal, and AP axes of the globe. All axes were within the planes of the equator and/or horizontal meridian. Rubber bands were carefully attached to the eyeball presenting the extraocular muscles, such as the vertical (superior and inferior recti), horizontal (lateral and medial recti), and oblique (superior and inferior obliqui) muscles. The horizontal recti were attached to the "globe" anterior to its equator on the lateral or medial sides, the vertical recti were attached to the globe anterior to its equator on the superior or inferior sides, the superior oblique was attached posterior to the equator plane and its intermediate tendon was passed through a trochlear, and a similar method was used to attach the inferior oblique. The oculomotor, trochlear, and abducens nerves were labeled on the corresponding muscles. Figure 1 shows the exhibitory eyeball model used in the study.

In explaining the mechanism of extraocular muscle actions (Listing's law), the students were told that individual muscle action was closely related to its attachments and moving along the axis or axes of the globe under specific cranial nerve control. The normal actions of the extraocular muscles were shown to and practiced by students using the eye model. In order to mimic the actions of the muscles, students pulled different rubber bands in different directions based on the muscle movements. During the practice, students were shown that the horizontal recti were parallel to the AP axis of the globe; pulling these two muscles would cause abduction (Fig. 2A) and adduction (Fig. 2B) only. The students were then shown that the vertical recti were not parallel to the AP axis, nor to any other axes of the globe, but rather to the central axis of the bony orbit. Pulling these two muscles would produce elevation (Fig. 3A) and depression, adduction (due to crossing the end of the vertical axis unevenly, Fig. 3B), and intorsion (Fig. 3C) and extorsion (due to crossing the AP axis). Finally, the students were shown that pulling the inferior and superior obliqi would cause elevation (Fig. 4A) and depression (due to crossing the horizontal axis), abduction (due crossing the end of vertical axis unevenly, Fig. 4B), and intorsion and extorsion (due to crossing AP axis from different direction, Fig. 4C).

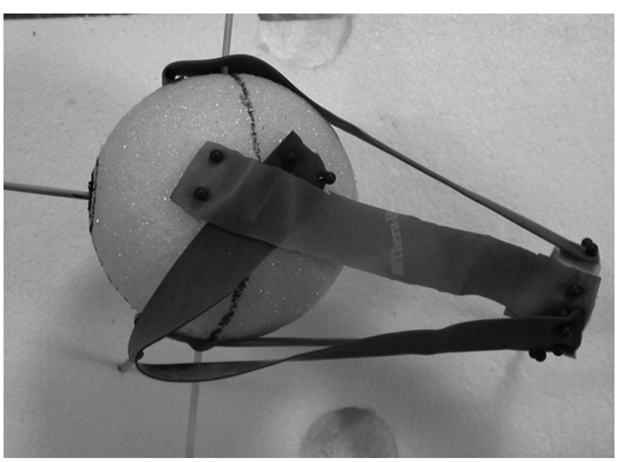

Figure 1. The exhibitory eyeball model showing the axes, plane, and extraocular muscle attachments.

Furthermore, students could switch and reattach the "muscle insertions" along three axes (abnormal insertions) to learn altered actions of muscles (e.g., by switching the insertion of obliqi not crossing AP axis, the intorsion and extorsion could be reversed). This way, students might have a better idea of how the relationship between muscle insertions and axes would affect muscle movement.

Data Analysis

Before the start of the study, the students in both groups were asked to complete a written test to assess their knowledge about the extraocular muscles and the oculomotor, trochlear, and abducens nerves. A written test at a difficulty level similar to the pretest was then conducted among the same students after they completed their PE lab training. The test questions were validated by the upper-quarter students who had completed both anatomy lectures and lab on extraocular muscles and cranial nerves, as well as physical examination, who were not involved in the study. Since these students had graduated from the school, the possibility of test question leakage was almost zero. The test questions were also validated by some anatomy faculty members. Appropriate modifications were made to these questions on the recommendation of the faculty members and students based on the test results.

Once the test scores were collected, independent samples *t*-tests were used to compare the test scores of both pre- and posttests between the study and

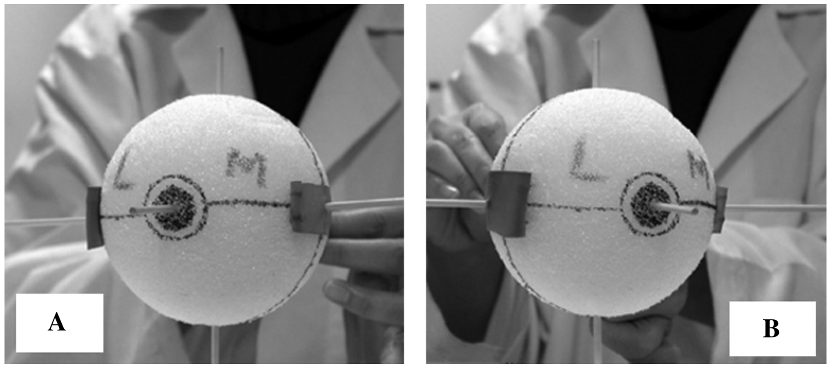

Figure 2. *By pulling the horizontal (lateral and medial) recti while holding longitudinal axis, students were shown the mechanism of eye abduction (A) and adduction (B), which is usually easy for students to understand.*

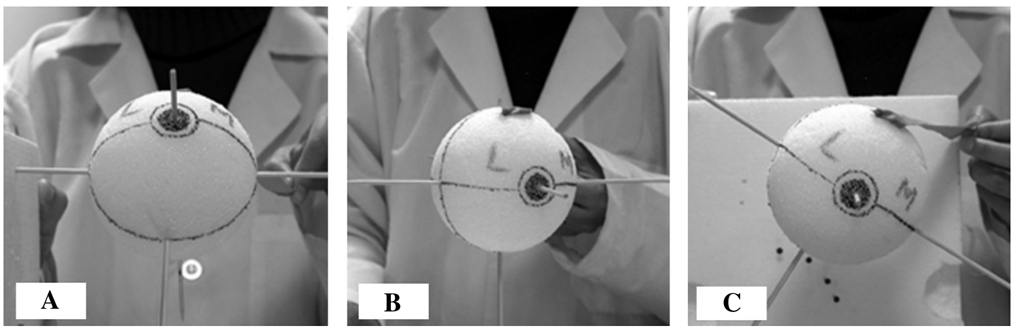

Figure 3. *By pulling the vertical (superior and inferior) recti while holding different axes, students were shown the mechanism of eye elevation (A), adduction (B), and intorsion (C).*

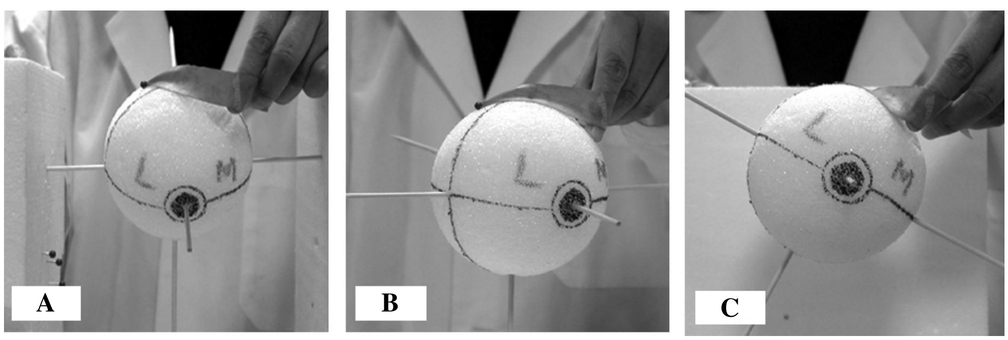

Figure 4. *Similar to the vertical recti, the obliqui (superior and interior) produced different movements along different axes, such as depression (A), abduction (B), and extorsion (C).*

control groups. Furthermore, the paired samples *t*-test was used to compare the test scores within both groups. All statistical comparisons were conducted using SPSS for Windows (Version 15, SPSS Inc., Chicago, Illinois). The significance was set when the *p*-value was less than .05.

RESULTS

Results of the independent samples *t*-test indicated no significant difference between the students of both groups on the conceptual understanding of cranial nerve tests and extraocular muscle movements in the grades of their pretest before implementing the innovative teaching model ($p > .05$, Fig. 5). An independent samples *t*-test of the posttest showed a significant difference between the groups ($p < .05$, Fig. 5). The study group students achieved higher scores than their counterparts in the control group. The paired samples *t*-test further revealed that there was no significant difference between pre- and posttests in control group students ($p > .05$, Fig. 6), whereas a significant difference in pre- and

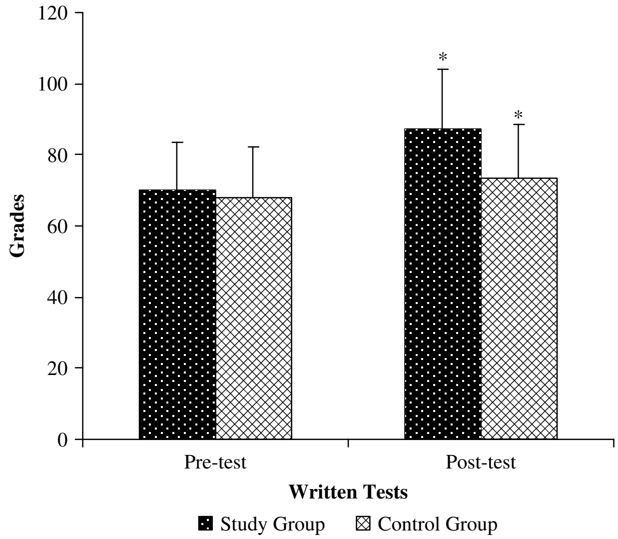

Figure 5. *Independent samples t-test of comparisons between control and study groups.*

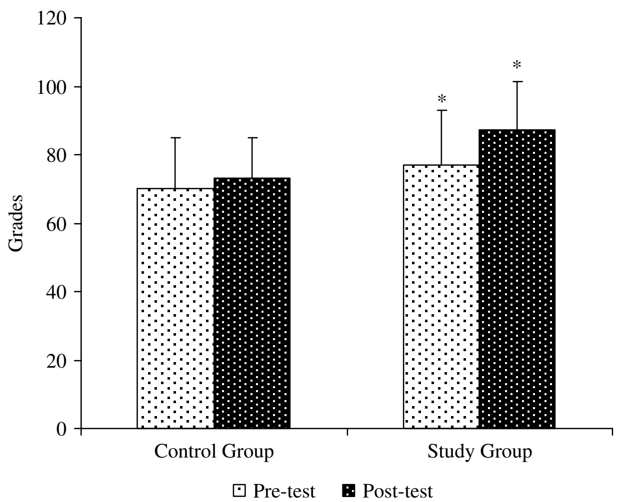

Figure 6. *Paired samples t-test of comparison between the control and study groups.*

posttests existed in the study group students ($p < .05$, Fig. 6). In the study group, the students achieved higher scores in the posttest after they completed the practice with the eyeball model.

DISCUSSION

These findings indicate that the introduction of the simulation experience in the PE lab sessions could yield a statistically significant improvement in students' physical examination skills and written test performance. Clinically, patients with oculomotor, trochlear, and abducens nerve disorders are evaluated through testing the eyes individually and together with the degree of movement using a variety of approaches.[8] During the PE lab, the authors find that some diagnostic tests for cranial nerve lesions are intuitively obvious to students when students practice the cranial nerve examination. For example, students usually perform well on the testing of abducens nerve and lateral rectus muscle. Similarly, the involvement of oculomotor nerve and medial rectus muscle in eye abduction is also less problematic for students when performing physical examination. However, other diagnostic tests seem more difficult for students to comprehend due to a lack of knowledge of Listing's law. For example, students often have questions about why it is sometimes necessary to take a sequence of two movements to test the integrity of a particular muscle (such as superior or inferior obliqi). The conventional anatomical way of explaining these physical examinations is often ineffective. Students often take extra time to find additional sources of supplemental information. Even so, mistakes still could occur during training in the physical examination. This reflects the fact that students often have difficulties understanding the actions of the extraocular muscles in a traditional educational setting because it is not always obvious what movements of the eye are elicited by concentric contraction of an individual muscle, and the tests for the functional integrity of the oculomotor, trochlear, and abducens nerves that innervate some of the extraocular muscles are counterintuitive.

The exhibitory eye model designed by the authors shows the muscle attachments at different locations of the eyeball and explains the structural and functional relationships between the extraocular muscles and different axes or planes of the eyeball. This model allows students to visualize the movements of the extraocular muscles by pulling the "muscles" while holding different axes through the simulation. This activity ultimately helps students to understand the mechanisms of muscle movements with regard to innervation and the rationale for cranial nerve tests.

Simulation in medical education has been established as a safe and efficient adjunct to learning clinical skills and has been applied in the training of medical students[3,10] and medical interns.[11] The great advantage of medical educational simulation activities is that they offer learner-centered education that enables the attainment of practical skills.[12] This study supports the idea that educational programs incorporating role playing and simulation are valuable training tools and demonstrates that a simulation may improve students' clinical skills through practicing and mastering specific knowledge of extraocular muscles and their innervation.

The other advantages of this eye model are that it is low cost, easy to construct, and easy to practice in PE lab sessions. Cutting-edge technologies are filling the classroom and have been quickly adopted by instructors and students. However, high tech equals high cost. Low-cost models help institutions reduce the costs of education, such as the materials used in this study. This model allows students to detach and reattach the muscle insertions, which may further strengthen students' understanding of Listing's law. The results of the study show that the use of low-cost simulations and easy-to-use models could also make the process of teaching and learning more varied, interesting, and effective.

This study has some limitations. First, the study was carried out on a relatively small number of participants at a single institution, limiting the generalization of the results to larger groups. Second, this study was carried out independent of the anatomy lectures and laboratories, which may have resulted in some confusion caused by any inconsistent information that students learned between the anatomy and PE laboratories. Third, although the authors observed qualitatively that study group students were more accurate and faster in performing physical examination, this was not part of the original design and was not statistically evaluated. Further statistical evaluation in future research may be necessary to support this assertion. Despite these limitations, however, the present findings still indicate that this teaching method is of considerable benefit for students.

CONCLUSION

This innovative teaching approach allows the instructors to deliver extraocular muscle actions and innervations in an efficient way during PE laboratory sessions. When used appropriately, such an approach will help students to improve their PE skills as well as their written test scores.

CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

ACKNOWLEDGMENT

The authors thank James La Rose for reviewing the manuscript and offering his recommendations.

About the Authors

Niu Zhang and Xiaohua He are with Palmer College of Chiropractic Florida. Address correspondence to Niu Zhang, Palmer College of Chiropractic Florida, 4777 City Center Parkway, Port Orange, FL 32129 (e-mail: niu.zhang@palmer.edu). This article was received April 2, 2010, revised May 9, 2010, and accepted June 17, 2010.

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