

**The Use of a Tuning Fork and Stethoscope Versus Clinical Fracture
Testing in Assessing Possible Fractures**

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ABSTRACT

Traditional fracture testing in the field of athletic training relies heavily on subjective responses of the athlete. Percussion and compression type tests rely on the athlete stating an increase in pain which represents a positive symptom of a possible fracture. The tuning fork and stethoscope method relied purely on a subjective assessment from the examiner. The purpose of the study was to determine if the use of a 128Hz tuning fork and stethoscope were effective evaluation tools in the assessment of possible fractures as compared to the traditional fracture tests that are used in the athletic training field. A vibrating 128 Hz tuning fork was placed on the bone/area where swelling was minor to facilitate good cortical bone contact. Then the conical bell of a stethoscope was placed on the opposite end on the bone or bones. A diminished sound arising from the injured bone as compared to the uninjured represented a positive sign for a possible fracture. Traditional fracture testing was performed and noted. An x-ray, diagnosed by an orthopedic physician, supported the validity of the tuning fork and traditional fracture testing methods. The attempt was to see what testing method, the tuning fork and stethoscope or traditional fracture testing, was a more valid evaluation tool when it comes to fractures. This study was performed at a university's athletic training room and a local orthopedic center. The study consisted of any subject between the ages of 18-85 that presented with a suspected fracture at either testing facilities. The current study examined 37 male and female subjects whose age ranged from 18-85 years old. The long bones that were tested in this research were as follows: the phalanges of the hand and foot, metacarpals, metatarsals, humerus, radius, ulna, fibula (including the lateral malleolus), and tibia (including the medial malleolus). The tuning fork and stethoscope was shown to be an effective and valid tool for evaluating possible fractures by yielding a success rate of 89.2% when compared to an x-ray. The percussion and compression fracture testing methods yielded only a success rate of 67.6% and 64.9% respectively.

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CHAPTER 1

INTRODUCTION

Athletics represent an important segment of our world, and people of all ages are engaged in some type of sport or athletic activity. When physical activity occurs there is a chance of bodily injury. Athletic trainers at all levels have to evaluate injuries, which may occur during practice or competition. Various injuries, including fractures, could end the season for some athletes.

According to the National Collegiate Athletic Association (NCAA) Injury Surveillance System (1996), 7.82% (n=171) of all injuries were fractures. This particular NCAA Surveillance System study consisted of women's soccer, men's basketball, men's and women's gymnastics, men's lacrosse, and women's softball. This study did not include other sports with high fracture rates such as football, rodeo, ice hockey, rugby, men's soccer, and wrestling. There were a total of 2,855 injuries reported in the study and 1,587 (56%) were evaluated only by the athletic trainer. The other 1,268 (44%) were referred to a physician who diagnosed the injuries. Of those that were referred to a physician 418 (33%) received x-rays to confirm or rule out a fractured bone.

Another NCAA Injury Surveillance System (2002) study consisted of women's field hockey, men's soccer, women's volleyball, men's basketball, and baseball showed that 5.9% (n=172) of all injuries reported were fractures during the 2001-2002 year. This study also did not include sports of high fracture rates such as football, rodeo, ice hockey, rugby, gymnastics, women's basketball, women's soccer and wrestling. There were a total of 2,903 injuries reported in this study of which 1,580 (54.4%) were evaluated solely by certified athletic trainers. That means that over half of the injuries

reported in this study were evaluated by a certified athletic trainer the day of the injury on the side line or in the athletic training room or the day after in the athletic training room. The other 1,323 (45.6%) injuries that were reported in the 2001-2002 NCAA surveillance study were referred to a physician to diagnose the injury. Of those that were referred to a physician 410 (31%) received x-rays to confirm or rule out a fractured bone.

Statement of the Problem

A proper evaluation of possible fractures by an athletic trainer is critical for athletes. The clinical tests athletic trainers perform for fractures are universal in the medical field and are taught to athletic trainers in their didactic courses. These tests are taught during an athletic trainer's education. Fracture tests that are commonly used are percussion and compression type tests. These tests are performed to elicit pain that is indicative of a possible fracture. Sometimes these tests are not reliable due to subjective responses of the athlete. Some athletes could have a higher or lower pain tolerance than others, which could lead to signs of false negatives or false positives. The tuning fork and stethoscope method is a painless evaluation technique for possible fractures. This test has seen limited review in the literature and is subjective to the athletic trainer and has shown promising results when compared to an x-rays when evaluating possible fractures. If athletic trainers had fracture tests that were more valid, it would be easier to decide whether to refer these athletes for an x-ray. Is the tuning fork and stethoscope more effective than percussion and compression tests in evaluating fractures? The tuning fork and stethoscope fracture evaluation test could save an athlete the time and the expense of a trip to a medical facility.

Null Hypotheses

1. There will be no significant difference between correct and incorrect fracture assessments via the percussion clinical fracture test when compared with an x-ray diagnosis.
2. There will be no significant difference between correct and incorrect fracture assessments via the compression clinical fracture test when compared with an x-ray diagnosis.
3. There will be no significant difference between correct and incorrect fracture assessments via the tuning fork and stethoscope fracture testing method when compared with an x-ray diagnosis.

Limitations

Limitations in this study included:

1. The amount of edema at the possible fracture site. This may make the test less effective because the tester may not have been able to perceive a normal sound.
2. The limited number of subjects with possible fractures.
3. Avulsion, impacted and comminuted type fractures are injuries that the tuning fork and stethoscope may not detect because of enough cortical bone contact within the bone being tested.
4. The ability of the examiner to hear a diminished or absence of sound. This is the subjectivity that was taken away from the athlete and given to the athletic trainer when using the tuning fork method.

Significance of the Study

A study of this nature will attempt to validate a different evaluation technique, which may improve the athletic trainer's ability to assess possible fractures. Athletic trainers' evaluation techniques have been limited to the conventional tests that exist in the athletic training field. A simple and valid test would help athletic trainers in their evaluation of potential fractures. If proven to be valid, the tuning fork and stethoscope evaluation technique could save expensive and time consuming trips to a physician's office or an emergency room (Bach & Cross, 1984; Kazemi, 1999). The purpose of the proposed study is to determine if the use of a tuning fork and stethoscope on suspected fractures is a more valid evaluation tool than traditional fracture testing used in the field of athletic training.

CHAPTER 2

REVIEW OF LITERATURE

There has been limited research in using a tuning fork and stethoscope in detecting extremity fractures that occur in athletics. In particular, the researcher could not find any research that proposed examining extremity fractures by means of the tuning fork and stethoscope technique verses clinical fracture testing then comparing the results to an x-ray diagnosis to see which test was more valid in the field of athletic training. The following review of literature will provide a historical background of the tuning fork and its use in the medical field, an exhausted background review of the use of a tuning fork and or percussion and a stethoscope in detecting fractures. It will also discuss the role of osteoporosis and how it may determine an age range of possible subjects within the study.

Tuning Fork and Stethoscope Evaluation Technique

In 1711, John Shore invented the tuning fork for musical purposes (Bickerton & Barr, 1987). It was not until 1825 that Ernest Weber announced his initial description of the tuning fork test for medical purposes (Bickerton & Barr). This was the first case of using a tuning fork in the medical field. Weber believed the purpose of the tuning fork test was to differentiate between conductive and sensorineural hearing loss. Later in history, Heinrich Adolf Rinne used the tuning fork in assessing hearing loss. Rinne used the tuning fork test to compare bone conduction with air conduction on the same side of the skull (Bickerton & Barr). Rinne & Weber's tests are still used today to assess hearing loss in patients.

It was not until the late 20th century that research on the use of a tuning fork and stethoscope in assessing possible fractures was documented. However, the use of a tuning fork for assessing possible fractures has seen limited review in medical journals.

The first study to address the tuning fork and stethoscope technique was published in 1984 by Bache and Cross. Bache and Cross (1984) studied femoral neck fractures at the East Birmingham Hospital using the Barford Tuning Fork test. The Barford Tuning Fork Test consisted of the following steps: a) a vibrating 128 Hz tuning fork was placed over each medial femoral condyle or each patella if more convenient so that sound conduction could be compared on both sides, b) the stethoscope's conical bell was placed over the pubic symphysis, c) the examiner listened for a diminished sound auscultating from the injured bone, and d) the sound was compared to the uninjured bone (Bache & Cross, 1984).

The Bache and Cross (1984) study consisted of 100 subjects with possible femoral neck fractures. There were 56 subjects with femoral neck fractures and 44 subjects without femoral neck fractures. According to the study 91.1% (n= 51), of the 56 subjects with femoral neck fractures had a diminished or absence of sound when the Barford test was administered. The absence of sound represented a positive sign for a fracture and was followed up by a positive radiological exam that indicated a fracture. A clinical diagnosis was presumed to consist of percussion, compression, or palpation of the suspected fracture site. Csongradi and Maloney (1989) have documented that palpation and pain with stress tests are all positive signs of a fracture. Clinical diagnosis was correct in 85.7% of the patients.

False negatives also occurred with the Bache and Cross (1984) study. Bache and Cross found three subjects where a fracture was judged unlikely clinically and by the Barford Test. Both diagnoses were incorrect because a fracture of the femoral neck was subsequently detected by an X-ray.

The authors concluded that the Barford tuning fork test was correct in 87% of all subjects tested. According to Bache and Cross (1984), practitioners should combine the clinical and Barford tests when evaluating fractures of the femoral neck. The authors suggested,

that the judicious application of the Barford test, together with a careful clinical examination, would help to more accurately diagnose femoral neck fractures and therefore, in some cases, may prevent unnecessary and expensive journeys to hospitals for radiological examination (p.308).

Another study Misurya, Khare, Mallek, Sural, & Vishwakarma, (1987) studied the use of a tuning fork in diagnostic auscultation of suspected fractures. The Barford Test that was used in the Bache and Cross study was the cornerstone of the Misurya et al. (1987) study. The study revealed that the use of a tuning fork in diagnosing fractures was correct in 94 percent of patients as confirmed by radiological examination (Misurya et al.). The study consisted of 50 subjects who were examined for possible fractures of the femoral neck and shaft and tibia at the Fracture Clinic of the Central Institute of Orthopedics, Safdarjung Hospital, New Delhi, India. A tuning fork of 128 Hz and a child's stethoscope were the instruments used during the testing. A 128 Hz tuning fork was used because waves of this frequency were not as easily transmitted through the fractured part as were waves of higher frequencies (Misurya et al.). Other tuning forks

had a higher frequency, transmitted more kinetic energy to the bone, and were more likely to overcome any obstruction to the propagation of sound waves (Misurya et al.).

In Misurya's et al. (1987) study, a possible fractured body part was compared to the uninjured limb. The vibrating tuning fork was placed distal to the injury site on the bone and the stethoscope was placed proximal to the injury site of the same bone. For example, if there was a possible fracture of the shaft of the fibula, the tuning fork would be placed on the lateral malleolus and the stethoscope on the head of the fibula. The presence of a fracture would abolish or reduce the conduction of sound by the bone as compared to the uninjured limb (Misurya et al.). The diminished sound was perceived by the examiner via the child's stethoscope.

The results of the tuning fork test were correct in 94 percent of patients and were confirmed by radiological examination, whereas clinical diagnoses were correct in only 88 percent of cases. The researcher of the current study assumed that the clinical diagnosis consisted of palpation, tap, squeeze, and bump type tests to elicit pain as a positive sign for a fracture. Csongradi and Maloney (1989) state that “tenderness to palpation and pain with stress testing” are positive signs of a fracture. The tuning fork test gave a false negative in three out of 50 cases. This meant that the examiner could not hear a diminished sound with the stethoscope, but the radiological exams were positive for an x-ray. The three false-negative cases had impacted fractures. According to Misurya et al. (1987), the reason for the false negatives was because there was enough cortical bone contact at an impacted fracture so the sound waves were transmitted through the fracture and gave a false negative reading.

A more recent study by Moore in 1997 examined the use of a tuning fork and

stethoscope in assessing possible fractures of long bones. This was the first study of its kind to examine long bones that were typically injured and possibly fractured during athletic competition. Previous studies by Bache and Cross (1984) and Misurya et al. (1987) mainly examined possible fractures of the femoral neck and femoral shaft. The Moore study examined the following bones: phalanges of the hand and foot, fibula, tibia, metacarpals, metatarsals, ulna, radius, humerus and clavicle. The study followed the methodology that the Misurya et al. study utilized in 1987.

The outcome results of the Moore (1997) study indicated that there were 10 fractures assessed using both the tuning fork and X-rays. There were also 20 non-fractures that were accurately evaluated by the tuning fork and confirmed by an x-ray. There were also 5 false positives and 2 false negatives. The tuning fork testing method was correct in 81% of the subjects (30 out of 37). Based on the Chi-Square results, there was a significant difference found between correct and incorrect classifications ($X^2_{(1)} n=37, 14.29, p < .005$) (Moore, 1997).

Three of the false positives had a substantial amount of swelling around the possible fractured bone which was the lateral malleolus. Moore hypothesized that the swelling “lead to poor bone contact” with the tuning fork (1997). He further stated “this may have prevented the examiner from hearing any sound arising” from the injured bone (Moore, 1997). A diminished sound arising from the injured bone represents a positive sign for a possible fracture in all previous literature of the tuning fork and stethoscope (Bache and Cross, 1984; Misurya et al., 1987; Moore, 1997). One of the two false negatives was a buckle type fracture of the styloid process of the 5th metatarsal. Moore (1997) stated, the orthopedic physician indicated that the fracture line in this type of

fracture was curved and did not go through the entire bone. The fracture was not transverse so there was enough cortical bone contact. Bache and Cross (1984) explained that the sound waves from the tuning fork were transmitted easily with non-transverse fractures because there was enough bone contact that produced a false negative reading.

Percussion Testing Method

The studies discussed so far demonstrated that the tuning fork could be a valid tool for athletic trainers to use when assessing fractures. When performed correctly, the tuning fork test has presented very promising results for evaluating possible fractures. Other researchers have used different methods, such as percussion, to evaluate possible fractures.

Limited research has been found on fracture testing in the athletic training literature. Percussion and auscultation are some methods that have seen some review. Auscultation is the act of listening to sounds arising within organs as an aid to diagnosis (Woolf, 1997). Using auscultation, percussion, and a stethoscope in particular, during an evaluation to assess a possible fracture are several testing procedures that have been documented.

Percussion tests were first used by Leopold Auenbrugger in 1761 (Bloch, 1993). Percussion techniques were originally a method of producing sounds by striking on the walls of the thorax (Bloch). Auenbrugger derived this technique from watching his father tap with his finger tips on the side of wine barrels to produce sounds that indicated the level of its contents. Bloch stated that Auenbrugger's approach was to predict organ abnormalities of chest diseases then either confirm or refute his diagnosis by autopsy findings (Bloch, 1993). Percussion and auscultation are some methods that have seen

some review in the literature. Auscultation plays a major part in the tuning fork and stethoscope method.

In 1846 Bowditch published evidence of using percussion and a stethoscope in detecting fractures (Peltier, 1977). One hundred and six years later in 1952, Dr. Albert Sullivan, from the Department of Surgery at the University of Minnesota, showed Dr. Leonard F. Peltier how to use percussion and a stethoscope with possible fractures (Peltier, 1977). Other researchers have used this particular technique in diagnosing fractured bones (Carter, 1981; Colwell & Berg, 1958; Peltier, 1977).

A study by Colwell and Berg (1958) used percussion and a stethoscope to better hear the sound transmission to diagnose fractures. In Colwell & Berg's study, 100 subjects were tested, 50 with fractures and 50 without fractures. Colwell and Berg placed the stethoscope proximal to the fracture site and percussion was performed distally with the examiners' fingers tips. This percussion technique was similar to that of tapping the chest of a patient during a normal percussion exam. The examiner was to listen for a diminished sound arising from the injured bone as compared to an uninjured bone. For example, when a fracture of the ulna was suspected, the stethoscope would be placed over the olecranon (the tip of the elbow) and a tapping force would be applied to the styloid process of the ulna. A diminished or reduced sound heard through the stethoscope was a positive sign of a fracture. According to Colwell and Berg, a complete fracture interrupted the conduction of sound by separation of the cortical bony surfaces. However, sound made by percussion can be transmitted across joint surfaces (Colwell & Berg, 1958).

There was an 88% correct reading (44 out of 50) with the percussion and stethoscope when compared to x-ray (Colwell & Berg, 1958). The authors stated in every case of fractures of the long bones, other than the impacted fractures of the head of the femur in which x-ray examination demonstrated solid cortical contact, the test was positive (Colwell & Berg, 1958). The authors found that the percussion and stethoscope was incorrect (false negative) in all three injuries to the medial malleolus. Colwell and Berg examined a variety of body parts in their study. Their study consisted of fractures of the clavicle, humerus, radius, ulna, femoral shaft, tibia, and fibula. However, Colwell and Berg used different subjects without fractures as their control group. They did not compare the sounds arising from the uninjured limb to the sound of the injured limb as did Bache and Cross (1984), Misurya et al. (1987), and Moore (1997).

Other authors also believed in using percussion and a stethoscope in diagnosing fractures. Peltier (1977) stated that when a solid medium (meaning bone) was interrupted by a fracture, sound transmission was diminished. Peltier used percussion and a stethoscope in diagnosing fractures for 20 years. He believed that percussing a site distal to a possible fracture and listening with a stethoscope proximal to it was an accurate and simple means of determining whether or not there was a fracture.

Maurice Carter (1981) in a letter to the *New England Journal of Medicine*, also used a stethoscope and percussion to assess fractures. Carter stated,

to elicit the sign the examiner places a stethoscope at the symphysis pubis and percusses each patella in turn. The sound reaching the examiner's ear on the side of the fracture will be lower in pitch and volume than the sound from the intact side. This test will be positive

in fractures of the femur and also in fractures of the pubic rami.

It should alert the observer to the urgent need for x-ray films of the pelvis and hip (p. 1220).

Carter continued to explain that this testing method was extremely reliable and accurate and could be administered when x-ray equipment was not available.

Several, studies have demonstrated that using a tuning fork and stethoscope has shown favorable results in detecting possible fractures. Bache and Cross (1984), Misurya et al. (1987) Moore (1997) were the most significant studies that showed promising results. There was no literature found that related directly to the use of the tuning fork and stethoscope in the athletic training journals or in the modern realm of sports medicine. Research conducted in this area could be very beneficial for athletic trainers.

Osteoporosis

When using the tuning fork and stethoscope method, the examiner is listening for sound arising from the injured bone and comparing it to the uninjured bone. This brings up the questions about bone density which may have an affect on the results of the study. Both women and men suffer from osteoporosis however, each may suffer from this disease at different times in their lives.

Osteoporosis is a disease that affects millions of individuals every year. Osteoporosis, or porous bone, is a disease described by low bone mass and structural deterioration on bone tissue, leading to bone fragility and an increased vulnerability to fractures (National Institutes of Health [NIH], 2003). The latest statistics from the National Institutes of Health show that 44 millions Americans are at risk of osteoporosis and 10 million currently have the disease (2003). Of those 10 million Americans that

have osteoporosis, 8 million are women and 2 million are men, or 80% and 20 % respectively (NIH, 2003 and National Osteoporosis Foundation, 2003). The occurrences of this disease place many individuals, male and female alike, at an increased risk of possible fractures because of the deterioration of bone tissue making bones weaker or more fragile.

Several factors increase the risk of an individual's likelihood of developing osteoporosis. Some are as follows: being female, thin and/or small frame, advanced age, postmenopause, inactive lifestyle, and cigarette smoking (NIH, 2003, National Osteoporosis Foundation, 2003, and National Institutes of Health [NIH], Pamphlet, 2000). Some of the above can be prevented while others can not.

It appears that osteoporosis increases the chances of a fractured bone in both women and men. Women who have gone through menopause are at an increased risk of developing osteoporosis. Menopause can not be prevented it is just a natural part of life. The average women starts menopause at the age of 51; with most completing menopause by the age of 58 (Gulli, 2001; Tuteur, 1999). A women's body begins to produce less estrogen after menopause and estrogen is the hormone that aids in keeping bones strong (Belt-Marachesi, 2001). As for men, they do not start rapid bone loss at the levels of postmenopausal women until they reach the age of 65-70 (National Institutes of Health [NIH], Pamphlet, 2001).

Does osteoporosis have an effect on the sound transmission produced by the tuning fork in the injured and uninjured bone? If the answer is no, then the tuning fork and stethoscope could be administered on older populations who may suffer from osteoporosis. Sometimes these older populations are on a limited or fixed income and the

expense of an x-ray is probably not budgeted in. So, the tuning fork method could possibly be administered on a larger and older population who are injured.

CHAPTER 3

METHOD

The method chapter was composed of the following sections: Subject Pool, Instruments, Procedure, Long Bones tested, Swelling Measurement sites, Related Questions, and Statistical Analysis.

Subject Pool

All subjects were informed of the testing procedure before they signed a Virginia Polytechnic Institute & State University Individual Review Board Consent Form. The subjects for the study included collegiate athletes and adults who were tested for extremity fractures when circumstances arose during the data collection period. The age range for men and women was 18-85. The subject's age and gender varied due to the random occurrence of possible fractures that were presented at a particular testing site. Because of the nature of the study, the investigator tested subjects as they were presented at the respective medical facility. For the chi-square statistic to be significant at the .05 level and to have a power of at least .80 and an effect size of .5, the researcher gathered a minimum of 35 subjects (Cohen, 1977).

Instruments

Three instruments were used in the study. A 128 Hz tuning fork (model #3616 C128) along with the conical bell of a standard stethoscope (Figure 1), and a standard x-ray machine which was located at the physician's office. The x-ray machine was calibrated throughout the study. The radiological exams were administered at a local orthopedic center.

Procedures

The tuning fork test was administered by the author on all suspected fractures. Each test was performed at the Radford Orthopedic Center or the Athletic Training Rooms on the campus of Radford University. The author followed the procedures in Misurya's et al. (1987) and Moore (1997) studies with only minor changes. The tuning fork was placed on the bone where swelling was minor in which good cortical bone contact could be made. Then the conical bell of a stethoscope was placed on the opposite end on the same bone or bones. This change from the original Misurya et al. and Moore studies was to take into account for possible swelling that may impede direct bone contact of the vibrating tuning fork. If direct bone contact was not available because of swelling it might lead to a false positive because of the diminished sound arising from the injured body part. The examiner struck the tuning fork against a rubber pad, and then placed the vibrating tuning fork on the bone where swelling was minor. The examiner listened to the sound arising from the bone with the stethoscope for approximately six to eight seconds. The examiner listened for a clear tone created by the tuning fork. For example, if the fibula were the injured bone, the vibrating tuning fork was placed on the head of the fibula and the conical bell of a stethoscope was placed on the lateral malleolus, as illustrated in Figure 2. The uninjured limb was tested first followed by the injured limb. The sound or lack of sound conducted from the injured limb was compared to that of the uninjured limb. When a fracture was present a diminished or absence of sound was detected arising from the injured limb as compared to the uninjured limb. Following the test administration, an x-ray was taken and read by the attending orthopedic physician to confirm or deny the presence of a fracture.

If a fracture was suspected in the phalanges of the hand the tuning fork was placed on the metacarpal-interphalangeal joint and the conical bell of the stethoscope was placed at the tip of the phalange. The entire phalange was tested, which includes the distal and proximal interphalangeal joints and each phalanx (See Figure 3). In addition, if a fracture was suspected in the phalanges of the foot or the metatarsals the tuning fork was placed on proximal portion of the suspected metatarsal and the conical bell of the stethoscope was placed at the tip of the suspected phalange (See Figure 4). The suspected entire phalange and metatarsal were tested, which includes the distal and proximal interphalangeal joints and each phalanx. The examiner asked which area hurt the worst, the phalange or the metatarsal, and that was the area recorded for the study.

The literature available on the use of a tuning fork or percussion in assessing fractures only described testing femoral neck and shaft, pubis ramus, and tibial fractures (Bache and Cross 1984; Carter, 1981; Colwell & Berg 1958; Misurya et al. 1987; Peltier 1977). The author expanded the current study to incorporate other body parts like the 1997 study by Moore did. Extremity fractures of humerus, ulna, radius, tibia, fibula, metacarpals, metatarsals, and phalanges were also examined. However, this study expanded to examine clinical fracture testing and tuning fork versus an x-ray and took girth measurements to assess swelling. The author also asked other questions about osteoporosis and previous fractured body parts to see if this anecdotal data had an effect on the results. The author administered the tuning fork test and clinical fracture tests on all possible fractures that were referred for an x-rays.

Interrater Reliability

Interrater reliability was tested by having a post graduate student athletic trainer perform the tuning fork, percussion, and compression tests on approximately a one-third convenience sample of all subjects in the study exactly how the method stated. The examiner educated the student athletic trainer on the use of the tuning fork and stethoscope in assessing possible fractures before the study began. The examiner did not know the results of the student's tests until after an x-ray was performed and a diagnosis given to the subject. This strengthened the results of the study if the student obtained the same results as the examiner.

The examiner and athletic training student also compared traditional fracture testing versus an x-ray. The examiner could not find any literature on the effectiveness of traditional fracture testing of long bones when compared to x-ray. Clinical fracture tests that are used within the field of athletic training are bump/tap, squeeze, compression, and distraction type tests (Anderson, 2001; Arnheim & Prentice 1997; Starkey & Ryan, 2002). Traditional fracture testing in the field of athletic training relies heavily on subjective responses of the athlete. These clinical fracture tests all rely on the athlete stating an increase/decrease in pain. This increase/decrease in pain represents a positive sign/symptom of a possible fracture (Anderson, 2001; Arnheim & Prentice 1997; Starkey & Ryan, 2002). Csongradi and Maloney (1989) stated that "tenderness to palpation and pain with stress testing" are positive signs of a fracture. Kazemi (1999) also stated clinical tests that are used to diagnose fractures are percussion, compression, and localized tenderness. Distraction tests were not performed because they could not be administered on all the bones tested in the study. So, percussion and compression type

test were the clinical fracture tests used in the study. The clinical fracture testing results were recorded and compared to an x-ray and diagnosis. The tuning fork and stethoscope method rely purely on a subjective assessment from the tester or athletic trainer. The tuning fork method took the subjectivity of the traditional clinical fracture testing away from the athlete and gave it to the athletic trainer.

Permission to administer the test was granted by the individual testing facilities. These facilities were the Radford Orthopedic Center and the athletic training rooms on the campus of Radford University. Written consent was given to the researcher before all subjects were tested (Appendix A). A written explanation of the study was given to all subjects by the researcher before testing began (Appendix B). Once consent was granted, the author administered the tuning fork and clinical fracture testing techniques and recorded the findings. The subjects were informed that the results of the tests did not represent a diagnosis. The radiological exam and the physician made the actual diagnosis. The results of the tuning fork test and clinical fracture testing were compared to the radiological results and diagnosis by the physician. The type and location of the fractures were recorded for the study.

The author decided to administer the tuning fork and clinical fracture tests on possible fractures that were eight days or less old. If fractures were older than eight days, they may begin to heal (i.e., the bony surface begins to heal and close) and an invalid test could occur. Browner and Jupiter (2003) explained that fractures start healing at different stages depending on sufficient blood flow. They continued to say fractures begin to healing within several days after injury (Browner & Jupiter, 2003). Growth factors from

platelets and cells begin to form new blood vessels in the injured area within seven to twenty-one days (Mourad, 1994).

The researcher utilized a Modified Latin Square to assure each test would not follow a particular test more than 33% of the time. This decreased the chance of testing bias by not having a particular test always follow the previous test. Table 1 (See Appendix F for all Table information) described the Modified Latin Square set up. The examiners always performed the tuning fork test and clinical fracture testing before an x-ray was completed.

Long Bones Being Tested and Swelling Measurements

The long bones that were tested in this research were as follows: the phalanges of the hand and foot, metacarpals, metatarsals, humerus, radius, ulna, fibula (including the lateral malleolus), and tibia (including the medial malleolus).

The injured bone swelling measurement was the difference from the uninjured and injured side. This difference was recorded for the study. The landmark circumference swelling measurements in centimeters of the individual bones were:

- Phalanges of the hand - around the PIP joint (Figure 5)
- Phalanges of the foot – around the PIP joint (Figure 6)
- Metacarpals of the hand – midway between the MP joint and CM joint of the bone in question; mid hand (Figure 7)
- Metatarsal of foot – midway between the MP joint and the TM joint of the bone in question; mid foot (Figure 8)
- Distal Radius/Ulna – directly around the radial/ulna styloid process (Figure 9)
- Proximal Radius/Ulna – around head of the radius (Figure 10)
- Fibula/Tibia - Follow the standard Figure-8 measurement as cited Starkey and Ryan, 2002 (Figure 11)
- Humerus – directly around the lateral/medial epicondyle of humerus (Figure 12)

Questions Asked

Each question was asked and the answers were recorded for the study. The questions were designed to see if osteoporosis and previous fractures would affect the sound arising from the two bones/bony areas being tested and to also, hopefully; strength the results of the study.

Osteoporosis Question:

Have you ever been diagnosed with or currently under treatment for osteoporosis?

Previous Fracture Question:

Have you previously fractured the body part or bone you are being treated for today?

Statistical Analysis

Chi-Squares were used to determine if significant differences occurred among the four possible outcomes of the tuning fork versus x-ray and clinical fracture testing versus x-ray. The investigator analyzed the results by placing the data into three separate 2 x 2 contingency tables (Daniel, 1995). The four possible outcomes of the tuning fork method were listed in Table 2. Separate 2 x 2 contingency tables were used for the two special tests (percussion and compression) to determine if there was a significant difference in traditional fracture testing and x-ray. See Table 3 and 4 for the difference outcomes of traditional fracture testing versus x-ray. The Chi-Square statistical formula calculates what is observed versus expected. The formula analyzed outcomes one and four (correct tuning fork readings or clinical fracture testing techniques) and outcomes two and three (incorrect tuning fork readings or clinical fracture testing techniques). After data was collected, the results were analyzed with SPSS 11.5 version. The standard Chi-Square formula was represented in Table 5 which was used as part of the analysis (Daniel, 1995).

CHAPTER 4

RESULTS

Institutional Review Board (IRB) approval was obtained from Virginia Polytechnic Institute & State University (IRB# 04-366) Appendix C and Radford University (IRB# FY04-061) Appendix D before data was collected at either site. Also, permission was granted from Radford Orthopedic Center prior to the start of data collecting (Appendix E). Data collection began in the fall of 2004 at the two specified sites; the athletic training rooms on the campus of Radford University and Radford Orthopedic Center. When subjects who fit the testing criteria as defined in the method section presented themselves at either site, the tuning fork evaluation technique and clinical fracture testing were administered.

Each subject who agreed to participate in the study signed the informed consent document and had the tuning fork and stethoscope and clinical fracture testing techniques administered on them for the study. The percussion and compression clinical fracture testing techniques were the ones chosen for the study. The tuning fork and stethoscope evaluation technique was simply referred to as the “tuning fork” method, the percussion and compression will be called simply as “percussion” and “compression”. A total of 37 subjects, 20 male and 17 female, fit the methodology criteria for the study. Each test was administered on all the subjects.

Table 6 categorized the different types of bones/bony landmarks and frequency of each tested. There were a total of 37 subjects tested. The lateral malleolus, phalanges of the hand, radius, and ulna were the most frequently tested bones/bony landmark. Table 7 identified the total number and type of fractures that occurred during the data gathering

period. Transverse fractures occurred most often, but avulsion, comminuted, and impacted fractures also occurred.

Interrater Reliability

Interrater reliability was depicted in Table 8. As called for in the methodology, a 32% convenience sample of the total subjects was tested by the student athletic trainer. This convenience sample represented a reasonable representation of the subject pool. The student had a 100% correct reading with the tuning fork evaluation method. The researcher had a 92% (11 out of 12) accurate evaluation with the tuning fork and stethoscope technique when compared to an x-ray. The only incorrect reading was a false positive of the phalange of the hand.

Null Hypotheses 1

The Chi-Square statistic was used to analyze the three different testing techniques used within the study. The percussion clinical fracture testing method found no significant difference between correct and incorrect classifications ($X^2_{(1)} n=37, 3.17 p > .05$). Based on these findings, the null hypothesis was not rejected at the .05 level of confidence. This meant there was no relationship between the percussion fracture testing method and an x-ray. Of the fourteen positive percussion tests, 7 had positive x-ray and 7 did not have a positive x-ray. As far as negative percussion tests, 5 were false negatives, which meant 5 fractures, were wrongly classified with the percussion tests.

There were four possible outcomes within percussion technique within the current study. These outcomes were:

- a) positive (+) percussion, positive (+) x-ray
- b) negative (-) percussion, positive (+) x-ray
- c) positive (+) percussion, negative (-) x-ray
- d) negative (-) percussion, negative (-) x-ray

- (+) percussion test = increased pain in affected body part
- (-) percussion test = no increased pain in affected body part
- (+) x-ray = a fracture was visible in x-ray
- (-) x-ray = no fracture was visible in x-ray

The outcome results of the percussion method versus x-ray illustrated there were 7 fractures assessed using the percussion and x-ray. Also, there were 18 non-fractures accurately evaluated when compared to x-ray. Table 9 represented the findings of the percussion testing technique when compared to an x-ray.

Null Hypothesis 2

Next, there were four possible outcomes for the compression fracture testing method within the current study. These outcomes were:

- a) positive (+) compression, positive (+) x-ray
- b) negative (-) compression, positive (+) x-ray
- c) positive (+) compression, negative (-) x-ray
- d) negative (-) compression, negative (-) x-ray

- (+) compression test = increased pain in affected body part
- (-) compression test = no increased pain in affected body part
- (+) x-ray = a fracture was visible in x-ray
- (-) x-ray = no fracture was visible in x-ray

The outcome results of the compression method versus x-ray illustrated there were 8 fractures assessed using the compression and x-ray. Also, there were 16 non-fractures accurately evaluated when compared to x-ray. Table 10 represents the findings of the compression testing technique when compared to an x-ray. The compression clinical fracture testing method showed no significant difference between correct and incorrect classifications ($X^2_{(1)} n=37, 3.07 p > .05$). Based on these findings, the null hypothesis was not rejected at the .05 level of confidence. This meant there was no relationship between the compression fracture testing method and an x-ray. Of the

seventeen positive compression tests, eight had a positive x-ray and nine did not have a positive x-ray. As far as negative compression tests, four were false negatives, which meant four fractures, were wrongly classified with the compression test.

Within the percussion and compression fracture testing results there were numerous false positives and false negatives. Table 11 represents the number of false positives and false negatives with the clinical fracture testing and bones/bony landmarks examined.

Null Hypothesis 3

Finally, there were four possible outcomes with the tuning fork method within the current study. These outcomes were:

- a) positive (+) tuning fork, positive (+) x-ray
- b) negative (-) tuning fork, positive (+) x-ray
- c) positive (+) tuning fork, negative (-) x-ray
- d) negative (-) tuning fork, negative (-) x-ray

(+) tuning fork test = a diminished sound detected

(-) tuning fork test = no diminished sound

(+) x-ray = a fracture was visible in x-ray

(-) x-ray = no fracture was visible in x-ray

The outcome results of the tuning fork method versus x-ray indicated there were 11 fractures assessed using both the tuning fork and x-rays. There were also 22 non-fractures that were accurately evaluated by the tuning fork and confirmed by an x-ray. The tuning fork and stethoscope evaluation technique for possible fractures showed a significant difference between correct and incorrect classifications ($\chi^2_{(1)} n=37, 25.28 p < .05$).

Based on these findings, the null hypothesis was rejected at the .05 level of confidence.

This meant there was a relationship between the tuning fork fracture testing method and an x-ray. The results were shown in Table 12.

Is the tuning fork method more effective than the traditional clinical fracture evaluation methods? In terms of percent correct, the percussion and compression clinical fracture testing evaluation methods had a success rate of 67.6% and 64.9% respectively. As for the tuning fork, 11 of the 14 positive tuning fork tests also had a positive x-ray or fracture. The tuning fork evaluation technique in terms of percent correct had an 89.2% success rate. The frequencies of correct and incorrect and percent of correct tuning fork tests in assessing different bones/bony landmarks were identified in Table 13.

CHAPTER 5

DISCUSSION

A proper evaluation of possible fractures by athletic trainers is critical for athletes. The clinical tests athletic trainers perform for fractures are universal in the athletic training field. Fracture tests that are commonly used are percussion and compression type tests. These tests are performed to elicit pain that is indicative of a possible fracture. Sometimes these tests are not reliable due to subjective responses by the athlete. Some athletes could have a higher or lower pain tolerance than others, which could lead to signs of false negatives or false positives. If athletic trainers had fracture tests that were more objective, it would be easier to decide whether to refer these athletes for an x-ray. An objective fracture evaluation test could save an athlete time and the expense of a trip to a medical facility.

There has been some research on the use of a tuning fork and stethoscope in detecting possible fracture (Bache & Cross; 1984, Misurya et al. 1987; Moore, 1997). However, the researcher could not find any research on comparing the tuning fork and stethoscope method with traditional fracture testing used in the field of athletic training. Only the Moore study in 1997 used the tuning fork technique on long bones that are commonly injured in the field of athletics, recreation, or fitness. The Bache and Cross study only used possible fractures of the femoral neck and femur. The Misurya et al. study examined femoral neck and shaft and some tibial fractures but did not examine other long that could be injured in athletics.

The current studies' results mirrors the Misurya et al. (1987), Bache and Cross (1984), and Moore (1997) studies. The Misurya et al., Bache and Cross, and Moore

studies had a percent correct of 94%, 87%, and 81% respectively when compared to an x-ray. The current study had a success rate of 89%, 33 of 37 subjects were correctly evaluated with the tuning fork and stethoscope when compared to an x-ray.

However, the current study was the first of the author's knowledge to compare traditional fracture testing in the field of athletic training with the tuning fork technique compared to an x-ray, the gold standard diagnostic technique for fractures. The two traditional fracture techniques that were studied were the percussion and compression evaluation techniques. These tests are what athletic trainers are taught during their training and use when evaluating possible fractures. Both tests are based on pain tolerance, which is a subjective response from the athlete. As mentioned above, the current study showed the tuning fork and stethoscope had a success rate of 89% when compared to an x-ray. The percussion fracture testing method yielded only a success rate of 67.6% in the subjects tested. The compression fracture testing was only correct 64.9% of the time when compared an x-ray.

The Chi-Square statistical method was used to show whether the percussion, compression, and tuning fork method were significantly different from an x-ray diagnosis for a fracture. Theoretically, if any of the special tests being studied could not detect fractures accurately; there would be a 50-50 chance that the test was correctly or incorrectly classified. The results showed that the tuning fork test correctly classified subjects 33 times. Only four subjects were wrongly classified. Based on the Chi-Square results, there was a significant difference found between correct and incorrect classifications ($\chi^2_{(1)} n=37, 21.4, p < .05$). This means that the tuning fork had a better chance of correctly evaluating a possible fracture. Conversely, the percussion and

compression fracture tests only correctly classified 25 and 24 times respectively. The Chi-Square results of the percussion test showed no significant difference between correct and incorrect classifications ($X^2_{(1)} n=37, 3.17, p > .05$). As for the Chi-Square results of the compression test, there was also no significant difference found between correct and incorrect classifications ($X^2_{(1)} n=37, 3.07, p > .05$). These results, within this particular study, illustrated that the tuning fork and stethoscope evaluation method for detecting possible fractures was a valid and effective technique. The reason the author came to this conclusion was because there were fewer errors with the tuning fork method and it was significantly different than pure chance when compared to an x-ray. The traditional fracture testing techniques used were shown not to be a valid fracture testing method because both tests were not significant when compared to an x-ray. Also, the percussion and compression methods produced 12 and 13 incorrect reading respectively.

There were four subjects in which the tuning fork technique incorrectly identified a subject. In particular, there were three false positives and one false negative. A false positive occurred when the researcher detected a diminished sound arising from the injured bone representing a positive sign for a fracture and the x-ray represented no fracture. A false negative occurred when the researcher detected no diminished sound arising from the injured bone representing a negative sign for a fracture and the x-ray represented a fracture. As stated in Table 13, the four bones that were incorrectly identified with the tuning fork were the phalange of the hand and foot, ulna, and tibia. The three false positives were in the ulna, tibia, and phalange of the hand. The only false negative evaluation with the tuning fork and stethoscope was of the great hallux (great toe).

If a closer look was taken at the percussion and compression, Tables 9 and 10 respectively, in terms of false negatives and false positives there were numerous more occurrences of both. The percussion test yielded five false negatives and seven false positives. The compression test yielded four false negatives and nine false positives. This meant that 16 subjects could have been saved the financial burden and time of seeing a physician. Also, nine subjects went undetected who had fractures. Since the percussion and compression evaluation methods rely purely on the production of pain within the injured body part and pain is a subjective response, each individual could have responded differently to these traditional fracture testing procedures. However, this study has possibly shown that the tuning fork evaluation technique for possible fractures may be a more valid method than the percussion and compression evaluation methods currently being used in the field of athletic training.

Table 11 shows the false positives and false negatives that occurred with the traditional fracture testing within each bone/bony landmark that was tested in the study. As the table illustrates, 8 separate bones/bony landmarks out of the 12 bones tested rendered false positives and/or false negatives when the percussion and compression clinical fracture tests were administered. 67% (8 out of 12) of the total bones/bony landmarks examined were incorrectly evaluated with traditional fracture testing. However, only 33% (4 out of 12) of the total number of bones evaluated with the tuning fork and stethoscope had false positives and false negatives (See Table 13). The author believes there were so many incorrect readings because of the subjectivity of the traditional fracture test. These tests rely purely on pain tolerance which can lead to inaccurate evaluations.

Interrater reliability (see Table 8) was examined in 32% (n=12) of the total subjects. The interrater was a post graduate athletic trainer student at Radford University. She was trained by the author and followed the methodology within chapter 3. As depicted in Table 8, the student was 100% correct in the tuning fork reading when compared to x-ray and the researcher was correct in 92% of the subjects. The researcher could not explain the difference in readings between the two different testers. Interrater reliability was also examined with the traditional fracture testing. The percussion and compression test were performed on the same 32% (n=12) of the subjects the tuning fork was performed on. Both of these test had a 100% interrater reliability. This meant that both the researcher and the athletic training student had the same responses from each of the subjects tested with the percussion and compression fracture testing methods.

Swelling measurements were taken with each subject to see if the amount of swelling would lead to an incorrect reading with the tuning fork technique. The technique for measuring the swelling with each injured body part was described on page 21. None of the related literature mentioned addressing the issue of swelling in a body part and how it would affect the outcome of the tuning fork method. Out of the four incorrect readings, the most significant swelling was two centimeters which occurred in the tibia. This was one of the false positives. All other incorrect readings had less swelling than the edema in the wrongly classified tibia. However, the researcher had other subjects with substantially more swelling present in their injured body part and the tuning fork and stethoscope rendered correct readings. The tuning fork delivered both positive and negative signs for a fracture when compared to a radiological exam when

swelling was substantial. Some of the positive and negative readings for fractures, bones/bony landmarks and swelling measurements were shown in Table 14.

The researcher changed the original technique from the Misurya et al study in 1987, to place the tuning fork away from the swelling on the injured bone. Swelling in the 1997 study by Moore, showed some false positives because the tuning fork was placed directly on the swelling that was present in a body part. Moore believed this diminished the sound because of the poor direct bone contact that occurred. The current study reduced the false positives to three as compared to five in the 1997 Moore study.

As Table 7 indicated, transverse, impacted, avulsion, and comminuted fractures were all correctly evaluated with the tuning fork. There was one transverse fracture of the hallux or great toe that was inaccurately evaluated which led to the only false negative of the study. This current research expanded the types of fractures that were correctly identified from the previous Moore study in 1997, by correctly identifying avulsion, comminuted and impacted fractures. The author could not explain why the false negative occurred in the one subject's hallux. Swelling was less than one centimeter and the x-ray clearly showed a transverse fracture completely across the bone.

Other anecdotal data that was gathered during the study was information about osteoporosis, previous fractures and the length of time since the subject's injury. The following question was asked to each subject, "Have you ever been diagnosed with or currently under treatment for osteoporosis?" Only three subjects responded yes to this question, two females and one male. The two females had injuries to their ulna and radius. The tuning fork test, clinical fracture testing and x-ray were all negative on the female subject with the ulna injury. The other female subject suffered a transverse

fracture of the radius and all of the fracture testing techniques studied had positive signs. The male subject who responded yes to the osteoporosis question had impacted fracture of the humerus. Once again all the fracture testing techniques studied had a positive sign for a fracture. As far as days the subjects were tested after the injury, this ranged from the day of the injury to eight days after the injury. The four subjects with incorrect readings with the tuning fork had a range of 1-5 days since their injury. The last question that was asked during the study was “Have you previously fractured the body part or bone you are being treated for today?” Only one male subject answered yes to this question and the injury was to his lateral malleolus. There was no fracture present and all fracture testing was also negative.

Finally, if a closer look was taken at each individual fracture testing technique, at least one of the examined methods did correctly evaluate the body part in question. Of the four wrongly classified subjects with the tuning fork, three were false positives and one was a false negative. All four of the wrongly classified subjects were correctly classified with one of the traditional fracture testing techniques when compared to an x-ray. So, the author suggested that the tuning fork and clinical fracture testing techniques be utilized when evaluating possible fractures until further research is conducted.

Recommendations

Further research with the tuning fork and stethoscope as a valid evaluation tool for possible fractures of long bones is needed because this study's sample size was relatively small. The only previous study that examined long bones that are typically injured in the field of athletic training was the Moore 1997. That particular study only had 37 subjects also. Therefore, there was only research on 74 subjects with possible

fractures of long bone. Both studies had such small subject pool, there needs to be continued research to further validate the tuning fork method as a valued evaluation tool for athletic trainers. The author also recommends that the tuning fork and traditional fracture testing be researched more to see which technique would produce valid results when compared to an x-ray.

Also, a different study could have a sound measuring device added to the stethoscope to measure the sound decimals arising from the uninjured and injured bone. These sound decimals could be recorded directly on a “PDA” or “hand held.” These sound waves could be analyzed on a computer program to see if an injured bone is truly producing a diminished sound. In addition, a researcher could see how low a decimal reading produced represented a positive sign for a fracture when compared to an x-ray. This technique would be completely objective and possibly decrease the number of false positives and false negatives. This in turn would speed up the process of referring an individual to receive x-rays or save them a trip all together.

Finally, more subjects need to be tested with different types of fractures, previous fractures, and the question of osteoporosis needs to be asked. Impacted, comminuted, avulsion, greenstick, and spiral fractures all need to be examined. These fractures occur at a low rate within athletics but need to be tested. Misurya et al (1987) and Colwell and Berg (1958) stated that impacted fractures yield a false negative because enough cortical bone contact were present in these types of fractures so that a diminished or absent sound could not be heard. However, the current study did have one avulsion, comminuted and impacted fractures that surrendered a positive tuning fork and stethoscope evaluation and a positive x-ray. The author understands that was only three

cases but believes that more research is needed to see if a variety of fractures could be accurately evaluated by means of the tuning fork and stethoscope. More subjects with osteoporosis or under treatment for osteoporosis should be studied to see if bone density affects the tuning fork and stethoscope technique. The current study only had 3 subjects who answered yes to the osteoporosis question that was listed in the methodology section. My conclusion

Conclusion

The results of the present study indicated that the tuning fork test was a more accurate testing method for possible fractures than the traditional fracture testing techniques currently used in the field of athletic training. These traditional methods rely heavily on the subjective response from the injured person. In the athletic training field, the fracture tests athletic trainers use in their evaluation process are sometimes misleading. Most of the tests athletic trainers utilize are subjective to the athlete, and this leaves room for error and misinterpretation. Athletic trainers cannot determine pain tolerances of individual athletes. One test that may be positive for pain in one athlete may not elicit pain in another athlete. This was the reason the present study was conducted. The researcher wanted to find out if a non-evasive testing technique, that did not rely on individual differences in pain would show promising results in the detection of fractures. In the current study, the percussion and compression test led to more false positives and false negatives and a lower percent correct.

The tuning fork and stethoscope test was easy, painless, and inexpensive to perform and could be administered quickly. However, more research is needed when comparing the tuning fork to percussion and compression clinical fracture testing as valid

evaluation methods in the field of athletic training. Past research had been performed on the femur and pubic ramus. The current study examined other body parts and showed promising results. If research were performed on additional subjects with favorable results, then this would hopefully increase the legitimacy of the tuning fork evaluation method.

When performing the tuning fork test, swelling within a tissue or a joint may hinder the results. That was why the researcher measured each body part for swelling to see if swelling would encumber the results of the tuning fork and stethoscope method. As discussed earlier, swelling was not a factor in having the tuning fork accurately evaluate a possible fracture within this study. Modifications were made to the methodology proposed in the Misurya et al (1987) and Moore (1997) to allow for sufficient cortical bone contact with the tuning fork. This allowed the tuning fork to radiate sound down the injured bone to the stethoscope when significant swelling was present.

This fracture testing method could assist athletic trainers practicing at all levels. Most tests athletic trainers utilize are subjective to the athlete. These evaluation techniques try to elicit pain as a positive sign of a fracture. The tuning fork test was painless for the subject. The author believes the decision to refer an athlete would be more advantageous if the athletic trainer incorporated this particular test in addition to the current fracture testing used in the field of athletic training. The author believes the tuning fork and stethoscope technique could be used at many levels where possible fractures could occur. Physicians, physician's assistances, nurses, physical therapist, athletic trainers, and all students within these fields could be trained and educated to use

the tuning fork technique as part of their evaluation of possible fractures of long bones of the extremities. If the tuning fork and stethoscope evaluation technique were researched more and future results mirror the current study, Misurya et al.(1987), Bache and Cross (1984), Moore (1997) studies; time and money could be saved, the quality and consistency of care for possible fractures of extremity long bones could improve also.

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Figure 1
Instruments



Figure 2
Method of the Fibula/Lateral Malleolus



Figure 3

Method of the Phalange of Hand



Figure 4

Method of the Phalange and Metatarsal of Foot



Figure 5

Phalanges of the Hand – Around the PIP joint



Figure 6

Phalanges of the Foot – Around the PIP Joint



Figure 7
Metacarpals of the Hand



Figure 8
Metacarpals of the Foot



Figure 9
Distal Radius/Ulna



Figure 10
Proximal Radius/Ulna



Figure 11
Fibula/Tibia



Figure 12
Humerus



Appendix A

Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project: “The Use of a Tuning Fork and Stethoscope Verses Traditional Clinical Fracture Testing in Assessing Possible Fractures”

Investigators: Dr. Richard Stratton, Michael Moore, MS, ATC, and Elizabeth Glass, BS

I. Purpose

The purpose of this study is to determine if using a tuning fork and stethoscope on suspected fractures is a more valid evaluation tool than traditional clinical fracture testing in evaluating possible fractures. The researchers will have approximately 35 male and/or female subjects ranging in age from 18-85 years of age for men and 18-85 years of age for women who have a possible fractured body part. All subjects will be referred to a physician who will order and read the x-ray.

II. Procedures

Each subject with a suspected fracture who agrees to participate in the study will have the tuning fork test administered on them. The uninjured and then the injured body will be tested. A vibrating 128 Hz tuning fork will be placed proximal (above) to the suspected fracture and the conical bell of a stethoscope will be placed distal (below) to the site on the same bone. The examiner will then listen to the sound produced by the vibrating tuning fork via the stethoscope on both the uninjured and injured body part for approximately 5-8 seconds. The two separate sounds will then be compared. A positive sign for a possible fracture will be a diminished or absent sound that is detected in the injured (possible fractured) body part as compared to the uninjured area as detected by the examiner.

Then, I will administer clinical fracture testing that is traditionally used within the field of Athletic Training and medicine. These tests are used to increase pain in the suspected body part which in turn is a positive sign for a possible fracture. The tests that I will administer are compression and vibration type test. (I will at this point demonstrate the test on myself so the subjects can see the tuning fork and traditional clinical fracture testing used in the field of medicine.)

I will also measure for swelling in both body parts with a tape measure and record this measurement ask you an osteoporosis question, record your gender, location of injury, days since your injury, previous fractures, and type of fracture if necessary.

Finally, an x-ray and physician consultation will follow with the true diagnosis.

III. Risks

The related literature on this subject states that the tuning fork test is a painless evaluation technique that can be administered quickly. Minimal increased pain is associated with traditional fracture testing in the fields of Athletic Training and medicine. To my knowledge there are no adverse side effects.

IV. Benefits

As a subject in this research, no promise of benefit have been made to encourage you to participate. If this research is valid, then athletic trainers will be able to use this tuning fork evaluation method along with the other test they presently use. I do not believe the individual subject will gain any benefit from the research.

V. Extent of Anonymity and Confidentiality

Each subject will be assigned a random number that is at the top of this consent form and on the copy they will receive. Only the number on the form, type and location of fracture (if one is present), previous fracture of same body part, gender, age, swelling measurement, and an osteoporosis question will be recorded. The subject and only subject themselves will agree to tell me the above information for research purposes only.

VI. Compensation

Subjects will not be compensated for their voluntary participation in this study.

VII. Freedom to Withdraw

I further understand that I am free to withdraw my consent and terminate my participation at any time.

VIII. Subjects Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities:

- 1) Allow the researchers to perform all the evaluation techniques described above.
- 2) Report the results of the x-ray/physicians diagnosis, type of fracture, age, and sports participation at the time of injury directly to the examiner.

IX. Subjects Permission

I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_____ Date _____
 Subject signature

_____ Date _____
 Witness (Optional except for certain classes of subjects)

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact:

Michael Moore	831-6218/mbmoore@radford.edu
Elizabeth Glass	831-5164/eglass@radford.edu
Investigator(s)	Telephone/e-mail

Dr. Richard Stratton	231-5617/rstratto@vt.edu
Faculty Advisor	Telephone/e-mail

Dr. Kerry Redican	231-5743/kredican@vt.edu
Departmental Reviewer/Department Head	Telephone/e-mail

David M. Moore
 Chair, Virginia Tech Institutional
 Review Board for the Protection of Human Subjects
 Office of Research Compliance – CVM Phase II (0442) Research Division
 Telephone/e-mail: 540-231-4991/moored@vt.edu

This Informed Consent is valid from 7/30/04 to 7/29/05.

Appendix B

Instructions For Subjects

- 1) Hello my name is Michael Moore and I'm a PhD student at Virginia Tech and a Certified-Licensed Athletic Trainer in the state of Virginia.
- 2) With your permission, I would like to use a tuning fork and stethoscope and try to assess the possibility of you having a fracture.
- 3) What I want to do is to place a vibrating 128 hz tuning fork at one end of your injured limb and a stethoscope at the other end and listen to the sound that is produced. All the studies I have read on using this technique in assessing possible fractures say that it is a painless process.
- 4) I will perform the test on your uninjured then your injured body part. A positive sign would be a diminished or absent sound detected in your injured limb via the stethoscope as compared to the uninjured limb.
- 5) Also with your permission, I would like to perform traditional clinical fracture testing methods that Certified Athletic Trainers use in the field of athletic training.
- 6) Traditional clinical fracture testing that I will use are compression and percussion type tests. Compression test are performed by pressing a body part together to produce pain at the site of a suspected fractures. Percussion type test are performed by tapping the suspected fractured bone above or below the possible fracture site in order to produce pain. With both test, a positive sign of a fracture is pain.
- 5) **THIS IS IN NO MEANS A DIAGNOSIS, ONLY THE X-RAY AND THE DOCTOR CAN GIVE YOU A TRUE DIAGNOSIS.**
- 6) With your permission I will record your diagnosis provided by your doctor and compare it to the tuning fork and clinical fracture testing method.
- 7) Your identity will be kept completely confidential. You will be assigned a number and no name will be assigned to your number. I will also measure for swelling in both body parts with a tape measure and record this measurement ask you an osteoporosis question, record your gender, location of injury, days since your injury, previous fractures, and type of fracture if necessary.
- 8) I hope to one day publish this study in a journal within the athletic training field.
- 9) Will you sign the appropriate consent form I have for you?
- 10) Do you have any questions?

Appendix C

Virginia Tech's IRB Approval



Institutional Review Board

Dr. David M. Moore
IRB (Human Subjects) Chair
Assistant Vice President for Research Compliance
CVM Phase II- Duckpond Dr., Blacksburg, VA 24061-0442
Office: 540/231-4991; FAX: 540/231-6033
email: moored@vt.edu

DATE: July 30, 2004

MEMORANDUM

TO: Richard K. Stratton Teaching and Learning 0313
Michael Bryan Moore T&L

FROM: David Moore 

SUBJECT: **IRB Expedited Approval:** "The use of a Tuning Fork and Stethoscope Verses
Clinical Fracture Testing in Assessing Possible Fractures" IRB # 04-366

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective July 30, 2004.

cc: File
Department Reviewer Jan Nespor T&L 0313

Appendix D

Radford University's IRB Approval

Honors Academy

March 23, 2004

Ms. Michael Moore
Department Exercise Sport and Health Education
Box 6957
Radford University

P.O. Box 6971
Radford, VA 24142

(540) 831-6125
(540) 831-5004 FAX

www.radford.edu

Mr Moore:

This is to confirm that the study you submitted for review to the Institutional Review Board, "The Use of a Tuning Fork and Stethoscope Versus Traditional Clinical Fracture Testing in Assessing Possible Fractures," has been granted expedited approval. The protocol you submitted are approved for use with human subjects through March 23, 2005; please be advised that you will need to have the protocol re-reviewed by the Institutional Review Board if you wish to continue using it to collect data after that date. Please contact me or Janet Hahn in the Office of Sponsored Programs & Grants Management if you make any substantive changes to the protocol that has been approved, as the committee would need to review and approve these changes.

As the principal investigator for this project, you are ultimately responsible for seeing that the study is conducted in an ethical manner and for filing all reports related to this project. Please make sure that you obtain/retain the information needed for these purposes, as outlined in the IRB manual. Feel free to contact me if you have any questions about this aspect of project management. Also, please remember that all work involving human subjects is subject to the standards for the protection of human subjects established by the IRB and Federal Regulations. Don't hesitate to contact me or Janet Hahn if you have any questions about application of these standards to your project.

Best of luck with your study.

Sincerely,

Joseph S. King, Ph.D.
Chair, Radford University Institutional Review Board
for the Review of Human Subjects Research

cc: Janet Hahn

Appendix E

Orthopedic Center's Permission

August 30, 2004

Michael Moore
Clinical Coordinator
Radford University

Drs. Gray and Donnelly have agreed to allow Michael Moore to perform his Tuning Fork Theory on patients at Radford Orthopedic Center provided patient consent to it.

Dr. Ken Gray
Dr. Kerry Donnelly

Appendix F

Tables 1-14

Table 1

Modified Latin Square

A=Tuning Fork

B=Compression Test

C=Percussion

33% of testing	A	B	C
33% of testing	B	A	C
33% of testing	C	B	A

Table 2

Possible Outcomes Of Tuning Fork Verses X-Ray

<u>Outcome 1</u> + tuning fork test + x-ray	<u>Outcome 2 (False +)</u> + tuning fork test - x-ray
<u>Outcome 3 (False -)</u> - tuning fork test + x-ray	<u>Outcome 4</u> - tuning fork test - x-ray

Table 3

Possible Outcomes Of Clinical Fracture Testing (Percussion) verses X-Ray

<u>Outcome 1</u> + Percussion + X-Ray	<u>Outcome 2</u> - Percussion + X-Ray
<u>Outcome 2</u> + Percussion - X-Ray	<u>Outcome 4</u> - Percussion - X-Ray

 Table 4

 Possible Outcomes Of Clinical Fracture Testing (Compression) verses X-Ray

<u>Outcome 1</u> + Compression + X-Ray	<u>Outcome 2</u> - Compression + X-Ray
<u>Outcome 3</u> + Compression - X-Ray	<u>Outcome 4</u> - Compression - X-Ray

Table 5

 Chi-Square Formula

$$X^2_{(1)} = \frac{(o-e)^2}{e}$$

 X= Chi-square, o=observed, e=expected

Table 6

Area Tested and Quantity

Area	Quantity
Shaft of Fibula	1
Great Tuberosity of Humerus	1
Humerus	1
Lateral Malleolus	7
Medial Malleolus	2
Metacarpal	3
Metatarsal	3
Phalange of Foot	2
Phalange of Hand	6
Radius	4
Shaft of Tibia	3
Ulna	4
Total	37

Table 7

Type and Quantity of Fractures

Type	Quantity
Avulsion	1
Comminuted	1
Impacted	1
Transverse	9*
Total	12

Note. Asterisk (*) indicate one transverse fracture was incorrectly evaluated with the tuning fork. It represented a false negative involving the hallux (Great Toe).

Table 8

Interrater Reliability – Correct Tuning Fork versus X-Ray Frequency and Percent Correct for Each Examiner

	Correct	Total	Percent Correct
Examiner	11	12	91.7%
Interrater (Student)	12	12	100%

Table 9

Frequencies of Assessment Outcomes Using The Percussion Test Versus X-Rays

	+ Percussion	- Percussion
+ X-Ray	7	5
- X-Ray	7	18

Table 10

Frequencies of Assessment Outcomes Using The Compression Test Versus X-Rays

	+ Compression	-Compression
+ X-Ray	8	4
- X-Ray	9	16

Table 11

Number of False Positives and False Negatives within Clinical Fracture Testing and Areas Examined

Percussion False +		Percussion False –	
Lateral Malleolus	3	Fibula	1
Phalange of Hand	3	Metacarpal	2
Tibia	1	Metatarsal	1
		Ulna	1
Compression False +		Compression False –	
Lateral Malleolus	2	Fibula	1
Medial Malleolus	1	Lateral Malleolus	1
Metatarsal	1	Metacarpal	1
Phalange of Hand	3	Ulna	1
Tibia	1		
Ulna	1		

Table 12

Frequencies of Assessment Outcomes Using The Tuning Fork Test Versus X-Rays

	+ Tuning Fork	- Tuning Fork
+ X-Ray	11	1
- X-Ray	3	22

Table 13

Frequencies Correct Versus Incorrect and Percent Correct Tuning Fork Test in Assessing Different Areas

Areas	Correct	Incorrect	Percent Correct
Shaft of Fibula	1	0	1/1=100%
Great Tuberosity of Humerus	1	0	1/1=100%
Humerus	1	0	1/1=100%
Lateral Malleolus	7	0	7/7=100%
Medial Malleolus	2	0	2/2=100%
Metacarpal	3	0	3/3=100%
Metatarsal	3	0	3/3=100%
Phalange of Foot	1	1	1/2=50%
Phalange of Hand	5	1	5/6=83.3%
Radius	4	0	4/4=100%
Shaft of Tibia	2	1	2/3=66.7%
Ulna	3	1	3/4=75%
Total	33	4	33/37=89.2%

 Table 14

Positive and Negative Readings for Fractures, Bones/Bony Landmarks and Swelling Measurements

Positive Readings		Negatives Readings	
Humerus	13.5cm	Lateral Malleolus	5cm
Metacarpals	4cm	Lateral Malleolus	3cm
Radius	3.5cm	Shaft of Tibia	4cm
Lateral Malleolus	3.5cm		

Curriculum Vitae

Michael Bryan Moore

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mbmoore@radford.edu

Experience:

Radford University (2003-Present)
Exercise, Sport, and Health Education
Clinical Coordinator, Athletic Training Education Program
P.O. Box 6957
Radford, VA 24142
Peters Hall B138
(540)831-6218

Education:

Virginia Polytechnic Institute and State University,
Expected May 2005
Blacksburg, Virginia
Doctor of Philosophy in Curriculum and Instruction
Dissertation: *The Use of a Tuning Fork and Stethoscope Versus Clinical Fracture
Testing in Assessing Possible Fractures*
Advisor: Dr. Richard Stratton
Co-Advisor: Dr. Gary Skaggs

Radford University, August 1997
Radford, Virginia
Master of Science in Physical Education

Radford University, May 1995
Radford, Virginia
Bachelor of Science in Sports Medicine

Birthdate:

May 24, 1972
Richmond, Virginia