Validation of the Ottawa Ankle Rules for Acute Foot and Ankle Injuries

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Validation of the Ottawa Ankle Rules for Acute Foot and Ankle Injuries

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Abstract

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Validation of the Ottawa Ankle Rules for Acute Foot and Ankle Injuries

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Context: The original and modified Ottawa Ankle Rules (OARs) were developed as clinical decision rules (CDRs) for the emergency department setting. However, these CDRs have not been validated as an acute clinical evaluation tool. Currently, there are no sport-specific CDRs relating to acute ankle injuries. Objective: The objectives of this study were: to test the validity of the OARs in acute foot or ankle injury in a sport related setting and to evaluate the measures of diagnostic accuracy of specific predictor variables. Patients or Other Participants: The participants were athletic trainers assigned to university athletics, club sports, and high schools. Conclusions: The OARs did not reduce the number of unnecessary radiographs referred. The OARs in an acute setting had a high sensitivity and are good predictors to rule out the presence of a fracture. Low specificity results led to a high number of false positives and low positive predictive values. Adding one or more predictor variables may improve the validity of the OARs in the acute setting.
Dedication

The ink is running
The words are taught
I’m sitting helpless with my paper and charts
I had to follow my passion

-KAG
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>3</td>
</tr>
<tr>
<td>Dedication</td>
<td>4</td>
</tr>
<tr>
<td>List of Tables</td>
<td>9</td>
</tr>
<tr>
<td>List of Figures</td>
<td>10</td>
</tr>
<tr>
<td>Chapter 1: Introduction</td>
<td>11</td>
</tr>
<tr>
<td>The Development of the Ottawa Ankle Rules</td>
<td>12</td>
</tr>
<tr>
<td>Influence of Time on Injury Recovery</td>
<td>13</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td>14</td>
</tr>
<tr>
<td>Time frames</td>
<td>15</td>
</tr>
<tr>
<td>Sport specific population</td>
<td>15</td>
</tr>
<tr>
<td>Gait patterns</td>
<td>16</td>
</tr>
<tr>
<td>Pain patterns</td>
<td>16</td>
</tr>
<tr>
<td>Purpose of the Study</td>
<td>16</td>
</tr>
<tr>
<td>Significance of the Study</td>
<td>17</td>
</tr>
<tr>
<td>Research Questions</td>
<td>18</td>
</tr>
<tr>
<td>Delimitations of the Study</td>
<td>18</td>
</tr>
<tr>
<td>Limitations of the Study</td>
<td>19</td>
</tr>
<tr>
<td>Definitions of the Key Terms</td>
<td>19</td>
</tr>
<tr>
<td>Chapter 2: Literature Review</td>
<td>23</td>
</tr>
<tr>
<td>Clinical Decision Rules</td>
<td>23</td>
</tr>
</tbody>
</table>
The need for clinical decision rules ................................................................. 23
Clinical integration of clinical decision rules. .................................................. 24
Ottawa Ankle Rules ............................................................................................. 24
Development of Ottawa ankle rules ................................................................. 25
Modified Ottawa ankle rules ............................................................................. 26
Development of physical examination findings .............................................. 27
Implementations of Ottawa ankles rules in sport ............................................ 28
Clinical evidence of accuracy of Ottawa ankle rules ...................................... 29
Disabilities Measures ......................................................................................... 29
Foot and Ankle Injuries ...................................................................................... 30
Epidemiology ....................................................................................................... 30
Risk factors prevalence ...................................................................................... 30
The Need for Sport Specific Ottawa Ankle Rule Modifications .................... 33
Application of Measures of Diagnostic Accuracy .......................................... 35
Specificity ............................................................................................................ 35
Sensitivity ............................................................................................................ 36
Specific Aims ....................................................................................................... 36
Chapter 3: Methods .......................................................................................... 37
Participants ........................................................................................................ 37
Development of the Ankle Inventory Form .................................................... 37
Study Design ....................................................................................................... 38
Setting ............................................................................................................... 38
List of Tables

Table 1: Interpretation of Likelihood Ratios ................................................................. 41
Table 2: Diagnostic Accuracy of the Original Ottawa Ankle Rules Following the Initial Examination ...................................................................................................................... 43
Table 3: Diagnostic Accuracy of Palpation Tenderness Only Following the Initial Examination ........................................................................................................................................................................ 48
Table 4: Diagnostic Accuracy of Weight Bearing Status Only Following the Initial Examination ........................................................................................................................................................................ 50
Table 5: Diagnostic Accuracy of Palpation Tenderness and Weight Bearing Status Together Following the Initial Examination ........................................................................................................ 54
Table 6: Initial Examinations Completed Within One Hour Based on Laxity .......... 56
Table 7: Initial Examinations Completed Within One Hour Based on Pain .......... 58
Table 8: Initial Examinations Completed Within One Hour Based on Pain and Laxity .. 58
List of Figures

| Figure 1: A 2 x 2 contingency table | 20 |

Page
Chapter 1: Introduction

There is a need to standardize the diagnosis and intervention of medical conditions. Clinical decision rules (CDRs) are decision support tools that provide evidence for use in medical practice. The development of CDRs includes identifying the need, measuring the predictor and outcome variables, and testing the newly developed CDR. To be valid, CDRs require a minimum of three predictor variables, which must effectively represent possible predictors of a targeted outcome. CDRs assist in injury examination. They can be used in a range of health care settings including medical, hospital, clinical, and other acute settings.

CDRs assist in the referral decision of acute injuries. The Ottawa Ankle Rules (OARs) were developed to identify the need to obtain radiographs for potential foot and ankle injuries. The rules were developed and primarily studied in a hospital emergency department setting. Because of the inherent delay in this setting, the OARs tend to be administered several hours after the onset of the injury. This thesis examines the validity of the OARs in an acute sport-specific population. This study will analyze the validity of the rules as they change over time by measuring different time points following the injury. The study also examined each of the predictor variables to assess their individual validity, as well as combined validity of the variables when used together, to determine the highest strength. The scientific validation of the presence or absence of predictor variables for patient care is necessary. Both outcome variables and predictor variables can affect the validity of CDRs.
The Development of the Ottawa Ankle Rules

The default for correct identification of soft tissue injury versus bony injury is to refer the patient for diagnostic imaging. Because of the risk of unnecessary radiation exposure and increased medical cost, these referrals are no longer acceptable in health care.²

The CDRs for the ankle and foot were developed over several years by many practitioners. In the early 1990s, Stiell et al began the development of the OARs in a hospital setting to determine predictor variables related to ankle and foot fractures.³ Stiell et al found that the best predictors were the ability to weight bear and the amount of bone tenderness exhibited by the patient. Exclusionary characteristics were developed and have remained the same throughout the evolution of the OARs.³,⁴ The developing rules identified general points of tenderness and zones of injury.³,⁵ The original rules were validated and condensed to a smaller number of specific palpation points.³,⁶ Research continued on the impact of these rules and sensitivity of 100% was found.³,⁷

The OARs help to determine if imaging is warranted in order to diagnose a fracture. This decision is based upon a set of criteria, which is divided into two zones: the malleolar zone and the midfoot zone.³ The malleolar zone comprises the medial and lateral malleoli, the distal 6 cm of both the tibia and fibula, and the talus. The midfoot zone is defined by presence of injury over the midfoot, navicular, cuboid, cuneiforms, the anterior process of the calcaneus, and the base of the fifth metatarsal.³ Because the OARs are CDRs, they must encompass three predictor variables. The original OARs include: (1) tenderness over the medial/lateral malleolus extending 6 cm proximally, or over the
styloid/navicular bones, (2) inability to take four steps, and (3) inability to weight bear (see Appendix B).

Following validity studies of the OARs, the Modified Ottawa Ankle Rules were developed. To increase validity, the modifications to the OARs specify palpations from both the anterior and posterior shafts to only the center third of the fibula or tibia.

**Influence of Time on Injury Recovery**

The OARs can be applied at any time postinjury. However, they have not been validated in acute settings, directly following the injury. The body has a specific reaction to acute injury. The inflammatory response is applicable when validating the rules in an acute time frame. There are three phases to the recovery process: (1) acute inflammatory, (2) proliferation, and (3) maturation.\(^8\)

The acute (active) inflammatory response begins immediately after an injury occurs, and commonly lasts between 24 and 72 hours. The primary goal of this phase is to increase cellular metabolism, which alters the balance between proinflammatory mediators and anti-inflammatory mediators at the cellular level.\(^8,9\) The acute inflammation stage also causes vasoconstriction of the arterioles which helps to separate the injured area to prevent further secondary damage. Scavenger cells are activated and help with the removal of debris and toxic particles.\(^8\) Shortly after, the vessels again dilate, increasing blood flow to the area.

The proliferation phase begins approximately 72 hours postinjury. There is no definite switch in periods, but rather a nonspecific transition that overlaps with the acute phase. Inflammatory proliferation includes repair of injured structures and regeneration
of damaged cells. Tissue repair involves deposition of scar tissue, which does not have
the same function as the original (injured) tissue. Regeneration then replaces the scar
tissue with cells, which have the same function as the original structures, but the amount
of regeneration depends on the type of tissue injured.\textsuperscript{8}

The final phase of the recovery process begins weeks after an injury and can last
up to a year or more. This phase is marked by increased strength of the collagen fibers
and restorative function of the injured structures.\textsuperscript{8}

Nerves are often among those structures that are damaged due to the inflammation
in the area. Certain inflammatory mediators such as bradykinin lower the pain threshold.
The rate of transmission is slower in nerves affected by surrounding trauma. If a nerve
itself is damaged, the recovery process is much slower and likewise affects the
surrounding healing process. If intramuscular nerves do not heal, then the recovery of the
associated muscle is also negatively affected.\textsuperscript{8,10}

Pain is the most obvious indicator of injury, but is a process that encompasses
physiological, sensory, motor, and emotional responses.\textsuperscript{8} For this reason, we cannot rely
only on pain to determine the severity of injury. The understanding of the injury recovery
process helps to determine the set time periods postinjury for this study. This particular
response is especially applicable to the validation of the OARs in an acute time frame.

\textbf{Statement of the Problem}

The original OARs were developed in a hospital setting. Prior studies have
examined findings from the OARs that were applied several hours to 10 days following
trauma.\textsuperscript{11,12} The physiological and psychological response to injury may render the
OARs criteria invalid when applied within 1 hour following injury. This study will determine if the OARs are valid in the acute setting.

In this study, we define the acute examination as occurring in less than 60 minutes following injury. Because of the variability in initial reaction to injury, findings in the initial 60 minutes do not always accurately reflect the severity of the injury. The patient may initially react disproportionately to the scope of the trauma, but after calming down may realize that the injury is not severe. This study examines the first 60 minutes to account for this variability.

**Time frames.** The following time frames have been assigned for this study:

- **Group One:** An examination performed less than 1 hour after the initial injury.
- **Group Two:** An examination performed 1 to 48 hours after initial injury.
- **Group Three:** An examination performed 2 to 10 days after initial injury.

**Sport specific population.** Because the OARs were developed in a hospital setting, all populations and ages were measured. This study delimits the population to only high school and collegiate athletes. As athletes generally show a more driven mindset and have higher pain tolerances, their results may show differences when compared to the general population. Many athletes cope with injuries differently because of intrinsic and extrinsic motivation to return to participation. The validity of the OARs may be affected by the high passion, intrinsic and extrinsic motivation, level of competition, and external pressures to return to activity.

Data collectors, licensed athletic trainers contracted through Ohio University, reported their foot and ankle examination findings conducted on high school and
collegiate athletes, with ages ranging from 14-23 years (mean = 16.68 ± 2.05). Previous research shows that the OARs have a high sensitivity and specificity in younger aged patients. In children aged 2-16, the OARs have a 100% sensitivity. Another study assessed the OARs in a sports medicine center, using patients with a mean age of 23.3 years ± 8.5 years. The study concluded that the use of the OARs in this setting reduced the number of unneeded radiographs and decreased costs in “relatively younger” patients.11,12

**Gait patterns.** Two of the three predictor variables indicated by the OARs are related to gait function. Therefore, we identified any antalgic gait patterns or changes in the gait phases resulting from foot or ankle injury. Many times athletes are initially unable to weight bear, but after a few minutes they regain this ability. We included any gait limitations in our study to help identify these deficits and/or patterns.

**Pain patterns.** The pain diagrams on our Ankle Inventory instrument were developed to assess pain patterns throughout the recovery of the injury. Analysis of pain upon palpation and patient reported pain will show if patterns appear through the recovery.

**Purpose of the Study**

The primary purpose of this study is to validate the OARs in an acute setting immediately following an initial foot or ankle injury. The secondary purpose is to analyze predictor variables over specific time periods, and determine measures of diagnostic accuracy for each of the time frames, for various clinical findings.
Significance of the Study

The OARs have previously shown to have great advantages in hospital settings. However, they have not been validated in acute settings or in a sport-specific population. We define the immediate setting as within 60 minutes following the initial injury. Prior studies have examined the efficacy of the OARs in the emergency department or other venues where significant time has elapsed between the initial trauma and the implementation of these decision rules. This study uses data obtained from various time points following foot and ankle injuries. This study also identifies potential influences and after effects following the initial injury, and whether or not the OARs are applicable during the immediate exam.

Validated OARs applied in an acute setting will decrease unnecessary hospital fees, provide a consistency of medical care, increase the quality of care, and save treatment time. The results of this study will increase the efficacy of decision making skills in acute injuries for immediate examinations, by reducing the number of false positives of foot or ankle diagnosis. The OARs are an effective tool to health care settings assisting in both evaluation and treatment of foot and ankle injuries.

Radiographic imaging is expensive. The implementation of the OARs led to a decrease in excessive medical costs. One study reported 35% (76 of 217) of radiographic images were not referred, because OARs criteria were not met, which yielded a cost savings of nearly $6,000. Use of the OARs eliminates unneeded imaging and avoidable referrals. The OARs encourage consistent care of the patient. When used during an injury examination, these rules provide a quick decision of whether or not to
refer the patient for further diagnostics. If the rules are invalid, the number of radiographs and the medical costs may increase. However, if valid, these rules can reduce postinjury treatment costs.²

**Research Questions**

The research questions guiding this thesis are:

1. Are the OARs valid when administered within 60 minutes following the injury?
2. How do the diagnostic measures of accuracy of the clinical findings change over time?
3. Which predictor variables of the OARs are the most valid?

**Delimitations of the Study**

Delimitations of this study include:

1. Setting and population: This study uses a specific data collection form, the Ohio University Ankle Inventory Form (see Appendix A). Athletic trainers who are contracted through Ohio University and provide clinical services in high schools and NCAA Division III colleges in Southeastern Ohio and bordering West Virginia, Ohio University club sports, and Ohio University intercollegiate athletics completed the forms.

2. Postinjury time periods: Analysis of the injury examination forms were separated by specific time periods between the initial injury and the first examination. The examinations were assigned to one of three groups. Immediate examinations were those in which the examination occurred less than 60 minutes after the foot or ankle injury. Acute examinations, group two, were categorized as those
examinations completed between 1 and 48 hours postinjury. Group three was comprised of examinations completed between 2 to 10 days. Injury examinations completed after 10 days were excluded from the study.

**Limitations of the Study**

Limitations of this study include:

1. The quality of data collected was dependent on the specific athletic trainer that completed the examination and re-examination form.
2. The accuracy of subjective data was dependent on what the specific athlete reported.
3. The variety of data and amount of data were dependent on the compliance and diligence of the participating athletic trainers.
4. The documentation of the referral status was not collected.
5. The experience level of the athletic trainers relates to referral status.

**Definitions of the Key Terms**

*2 X 2 contingency table:* Used to identify a clinical test’s ability to identify the presence or absence of a specific condition relative to the gold standard (Figure 1).

*Accuracy:* Percent of true results out of all tests performed.

*Acute setting:* Examinations completed in less than 60 minutes post initial foot or ankle injury.

*Clinical decision rules (CDRs):* Decision support tools that provide evidence for use in medical practice using predictor variables and outcome variables.
**Gold standard:** A diagnostic test that serves as the comparison for all other tests evaluating the same condition, disease, or physiologic response.\(^{14}\)

![A 2 x 2 contingency table.](image)

**Figure 1.** A 2 x 2 contingency table. (A) A count of a clinical test’s ability to accurately identify the presence (true positive) or absence (true negative) of a condition relative to the diagnostic gold standard. False negative results occur when the clinical test is negative, but the condition is actually present; false positive results occur when the clinical test is positive, but the condition is not present. (B) From these cells measures of diagnostic accuracy such as positive predictive value (PPV), negative predictive value (NPV), sensitivity (Sn), and specificity (Sp) can be calculated.

**Modified Ottawa Ankle Rules (MOAR):** The modified OARs specified palpations to only the center third of the tibia and fibula.
Negative likelihood ratio: The probability that the test is present even though the test was negative.

Negative predictive value: Ratio of true negatives over the sum of true and false negatives.

Ottawa Ankle Rules (OARs): CDRs that help to rule in or out the need for radiographs following foot and/or ankle injuries.

Outcome variables: Desired results determined from predictor variables.

Positive likelihood ratio: Shift in the pretest probability that the condition is present when the test is positive.

Positive predictive value: Ratio of true positives over the sum of true and false positives.

Predictor variables: All possible predictors of target outcome.

Reliability: Consistency of results over repeated tests.

- Interrater reliability. Multiple clinicians performing the same test to achieve the same results.

- Intrarater reliability. Performing the same test multiples times to achieve the same results each time.

Sensitivity: Percent of positive results which are actually positive; tests with a high sensitivity and negative finding rule out the condition.

Specificity: Percent of negative results which are actually negative; tests with high specificity and a positive finding rules in the condition.
**Time frames:** The following time frames have been assigned for this study:

- Group One: An examination performed less than 1 hour after the initial injury.
- Group Two: An examination performed 1 to 48 hours after initial injury.
- Group Three: An examination performed 2 to 10 days after initial injury.

**Validity:** How well the predictor variables determine the chosen outcome variable.
Chapter 2: Literature Review

A review of the literature presents a background for the study. This review includes a description of CDRs, a description of the original and modified OARs, and the need for additional analysis of these rules.

Clinical Decision Rules

CDRs are evidence-based support tools for use in clinical practice. By using CDRs, clinical practice can be standardized in the patient examination and subsequent interventions. The effect of the standardized CDRs will increase the probability of obtaining desired clinical outcomes, typically the diagnosis or course of care. After identifying the need for the CDRs, the predictor variables and the outcome variables must be identified. The predictor variables, for example the findings of an examination, must correctly represent all possible predictors of the desired outcome. The outcome variable, for example imaging, is needed when determining whether the CDRs are accurate in the prediction.¹

The need for clinical decision rules. The benefits of CDRs include identifying a clinically significant issue, inconsistencies in practice, and a desire to improve practice efficacy.¹ The implementation of well-designed CDRs should decrease unnecessary referrals such as radiographs, increase consistency of care, and standardize examinations.² Radiographs are often needlessly obtained to help rule in or rule out a diagnosis.³,⁴ With increased medical costs, radiographs are no longer cost effective.²

Standardizing the assessment and diagnosis procedures increases the probability
of obtaining the correct outcomes.¹ CDRs also reduce diagnostic and intervention variations and uncertainties, and improve competence throughout the medical process.¹

The development of CDRs begins with identifying the clinical problem. Specific predictor variables can be then defined, such as elements of patient history, physical exam, or laboratory results. The outcome variable must then be determined for the CDR. When the variable is specific, the accuracy of outcome variable is higher. The outcome of each predictor variable must be represented.¹ Testing is performed to evaluate the accuracy of the newly established CDRs in their ability to effectively identify those patients with the targeted outcome measure, ie, the sensitivity and specificity.¹

Clinical integration of CDRs. Research involving previous and current CDRs is useful when developing new CDRs. However, data collection is hampered by a lack of compliance of medical professionals. Because of insufficient evidence-based research among CDRs, clinicians are not always adherent to the rules.¹⁵ For example, studies have compared the use of OARs and the potential use of Ottawa Knee Rules. For 81% of the respondents in a hospital setting, 95% of those physicians reported they used the OARs and were open to using the Ottawa Knee Rules.¹⁵ The effectiveness of the rule and compliance of the clinicians should be taken into consideration when analyzing previous and current CDRs.

Ottawa Ankle Rules

The OARs were developed to improve practice efficiency in emergency department rooms by limiting the number of ankle radiographs ordered for patients presenting with acute foot and/or ankle injury. These rules identify the best clinical
predictors of a fracture, and, if those predictors are met, patients are sent for radiographs. Those who do not present with the predictor are not referred. If the patient was not referred, a low probability of a fracture was implied.\textsuperscript{11,12}

**Development of Ottawa Ankle Rules.** The formation of CDRs for the ankle and foot was developed over many years by several practitioners. Guidelines were reported for the assessment of these injuries by Dunlop et al and then separated into “important fractures” and “other injuries.”\textsuperscript{3,16} Physical findings specific to ankle injuries were observed. Dunlop et al found that the best predictors were the ability to weight bear and the amount of bone tenderness.

Exclusionary characteristics were developed and have remained the same throughout the evolution of the OARs.\textsuperscript{3,4} Exclusions for use of these rules are (1) pregnancy, (2) isolated injury of the skin, (3) referral from another hospital, (4) injury occurring more than 10 days before the examination, and (5) an obvious gross deformity of the foot or ankle.\textsuperscript{17} Original exclusions included patients under 18 years old. Leddy et al determined that the rules were also effective with patients younger than 18 years old.\textsuperscript{17}

The first set of official OARs were developed by Steill et al. The rules identified specific points of tenderness and zones of injury.\textsuperscript{3,5} The original guidelines were validated and condensed to a smaller number of palpation points.\textsuperscript{3,6} Research continued on the impact of these rules and sensitivity of 100\% was found.\textsuperscript{3,7} A 2-year study showed a decrease in 26.4\% of injuries needing referral for imaging.\textsuperscript{3,18} Another study was developed to validate these rules and found a 93\% sensitivity rate, only missing 7 out of 123 ankle and foot fractures.\textsuperscript{3,19}
Over the past decades these rules have been critically tested and researched. The original guidelines were modified to increase palpations extending 6 cm above both the medial and lateral malleoli. With this change, there was a 25% reduction in the need for radiology.\textsuperscript{11,12}

The collected studies supported that the OARs are an accurate instrument for excluding fractures in the ankle and mid foot. The rules have 100% sensitivity and reduce the number of unnecessary radiographs by up to 40%.\textsuperscript{20}

However, the original and modified OARs were initially established as CDRs for the emergency room atmosphere. The OARs as a decision tool in primary care has not yet been assessed. The evidence does show that the OARs are highly accurate in excluding ankle fractures after a sprain injury.\textsuperscript{20} Currently, there are no sport-specific CDRs for acute ankle injuries in the athletic population.\textsuperscript{11,12}

**Modified Ottawa Ankle Rules.** The current OARs suggest the need for a radiograph if the patient (1) is tender to palpate over the medial malleolus, the lateral malleolus, the styloid process of the fifth metatarsal, and/or the navicular tubercle, (2) is able to weight bear, and (3) is able to take four steps (see Appendix B).\textsuperscript{11,12,21} Palpations are specified to 6 cm proximal to the medial and lateral malleoli. In 1998, Leddy et al proposed a modification to the OARs to reduce the number of false positives. The palpation areas changed from the anterior and posterior halves of the distal fibula and tibia to only the midline of the distal 6 cm of the medial and lateral malleoli.\textsuperscript{3} This change was thought to increase the specificity because of the location that fractures usually occur. The anterior and posterior ligamentous attachments were thought to be the cause.
of tenderness at the anterior and posterior portions on the bone.\textsuperscript{3} Palpation along the midline of the bone rules out damage to the ligamentous structures and focuses on potential injury to only the bone.\textsuperscript{3}

The modifications reported a 100\% sensitivity and an increased specificity from 35\% to 66\%. The modified OARs have showed improvements in sensitivity and specificity which provides enough research for clinicians to use them in practice.\textsuperscript{3}

**Development of physical examination findings.** The development of the OARs was based upon physical findings from the injury examination. The formation was initiated because of the overreliance in obtaining radiographs. The physical findings used in the OARs were developed after being tested through interobserver agreement. A study examined 22 physical findings of a foot and ankle examination, using interobserver agreement between two emergency room physicians.\textsuperscript{4}

The physical findings of 100 foot or ankle injuries were recorded by any two of 21 designated emergency room physicians. The data collection included diagrams for 10 points of bone tenderness, and four areas of soft tissue tenderness. Other physical findings examined were ecchymosis, range of motion, degree of swelling in four different areas, anterior drawer sign, and the ability to weight bear for at least four steps.\textsuperscript{4}

The results of this study, overall, did not show good agreement. Restriction of range of motion proved fair agreement. Neither ecchymosis nor soft tissue tenderness were found to have substantial agreement. The anterior drawer sign had poor agreement. The most reliable factor was the ability to weight bear. This finding measured a kappa value of 0.83, which is nearly perfect agreement. The next highest kappa value was
found for localized bone tenderness. The points with highest interobserver agreement were tenderness over the base of the fifth metatarsal, the anterior and posterior portions of the lateral malleolus, and the inferior tip of the medial malleolus. However, the highest values were found when combined with multiple areas of tenderness.\textsuperscript{4}

The conclusion of this study reports nondependable findings as ecchymosis, range of motion, soft tissue tenderness, and the anterior drawer sign. High interobserver agreement was found for the clinical findings of combinations and grouping of specific areas of bone tenderness. The findings of high interobserver agreement are reliable during injury examination, with less emphasis on radiograph findings.\textsuperscript{4}

**Implementations of Ottawa Ankles Rules in Sport.** The use of the OARs have shown positive results in hospital settings, where 20\% of all orthopedic injuries are fractures.\textsuperscript{11,12} Fracture rates in family practices (8.5\%) are lower than hospitals, and even lower in sports medicine outpatient facilities, accounting for 2.4\% of total injuries.\textsuperscript{11,12} Evidence shows a lower incidence of clinical conditions or pathologies will yield a lower need for diagnostic testing, resulting in a lower accuracy rate of the CDR.\textsuperscript{11,12} In settings with low injury rates, the clinicians are more likely to refer for diagnostic testing, therefore not adhering to the rules. Consequently, settings with higher injury rates are more likely to follow the CDRs because of greater experience evaluating injuries.\textsuperscript{11,12} However, in both settings, the OARs were still shown to provide an objective, reproducible method to rule in or out a foot or ankle fracture. They help support uncertainties that clinicians may have with the injury examination and diagnosis.\textsuperscript{11,12}
Clinical evidence of accuracy of Ottawa Ankle Rules. The OARs have proven to exclude fractures with high accuracy in the ankle and mid-foot. Bachmann et al conducted a systematic review of the evidence of accuracy of the OARs. Twenty-seven electronic and hard copy research studies were analyzed. With the collected data, 2% of patients were negative for fracture by OARs actually had a fracture, revealing a low false negative type II error. Limitations found throughout the studies included clinicians’ level of experience, patients’ expression of pain, clinicians’ palpation techniques, and available resources. The systematic review reveals that the OARs are highly accurate at excluding ankle fractures after a sprain type injury.

Disabilities Measures

To determine which specific data were to be collected for our study, we used disability measures of the foot and ankle. After an injury is sustained, the limitations from the injury can be measured by a disability module or survey. Disability scales have been developed for each body part. Foot and ankle injuries are commonly referred to the use of the Foot and Ankle Disability Index (FADI), and the Foot and Ankle Ability Measure (FAAM). Each of these surveys aims to assess functional limitations, which have resulted from a foot or ankle injury. These measures are helpful when comparing healthy subjects and injured subjects, and assessing progressions or regressions in rehabilitation programs.

The FADI Score and Sports Module (Appendix C) is helpful in detecting limitations from chronic ankle instability, is sensitive to healthy and pathological ankles, and is receptive to increases in function with rehabilitation. The FAAM Sports Scale focuses on limitations in activities of daily living affected by a lower extremity pathology.
within a week time frame. After an injury is sustained, these surveys can help determine the amount of disability created by the injury.

**Foot and Ankle Injuries**

The most common injury sites recorded in the United States alone are to the ankle, knee, and lower leg, with the most common types of injuries being muscle strains, ligament sprains, and contusions. Specifically, soft tissue injuries of the foot and ankle are of the most common found in sports. Of these reported athletic injuries, foot and ankle injuries make up 15-42%.

**Epidemiology.** The cost of sports injuries worldwide has been estimated to reach $1 billion annually, and 3-5 million injuries are sustained by competitive and recreational athletes solely in the United States. Of these millions of injuries annually, more than 23,000 injuries require medical care daily to both athletes and nonathletes. In the United States alone, injury rate has been estimated at 1 per 10,000 persons per day. With the high occurrence of these injuries, ankle injuries are still considered undertreated by the medical profession.

**Risk factors prevalence.** There are many extrinsic and intrinsic risk factors that predispose athletes to these injuries. Even though many studies have focused on these factors there is still little agreement, and future studies are needed to develop conclusive results. Extrinsic risk factors include level of competition, skill level, shoe type, ankle bracing, and playing surface. The intrinsic factors include, but are not limited to age, gender, menstrual cycle, previous injury, general fitness, body size, limb dominance, generalized joint laxity, joint specific laxity, muscle tightness, range of motion, muscle
strengths, muscle reaction time, limb growth, postural stability, anatomical alignment, and foot morphology.  

Among the studies performed to evaluate these factors, research shows conflicting evidence. Level of competition becomes a central factor during the competitive season versus the off-season. There is agreement that the incidence of injury is much greater during competition than during practice. Additionally, research shows the incidence of lower extremity injuries is greatest in the first 4 weeks of the season. Evidence suggests that the athletes become more aggressive and more risk taking during competition, which puts them at a higher risk for injury.  

In addition to the competitive atmosphere, the athlete’s general sport-specific skill level should be taken into consideration. Research in this area is contradictory. Half of the research indicates that athletes with low skill levels are at an increased risk for injury; however, the other half reports those athletes with high skill level are at an increased risk. With these factors, skill level is still an extrinsic factor in injury rate, but has inconclusive results. Even though there is disagreement about the degree to which extrinsic factors increase injury rates, a vast majority of the research concludes that these factors do affect the likelihood of ankle injuries.

Research shows that males and females have different anatomical risk factors for ankle injuries. For males an increased talar tilt, and for females an increased tibial varum and increased calcaneal eversion were predisposers for increased ankle injuries.  

Prevention of ankle injuries is a necessary goal. To prevent these injuries, risk factors must be understood. Both extrinsic and intrinsic factors have been associated;
however, there is little agreement about their effect on injury. There is agreement that the incidence of injury is higher in competition than practice. Specifically for ankle injuries research has found that there is higher risk at the collegiate level than the high school level, which indicates that higher skill levels may increase the injury rate. There is no definitive research about differences among males and females.\(^ {23}\)

**Recovery period.** Residual symptoms for ankle sprain injuries have been recorded for 6-18 months post initial injury. Reinjury of the ankle was reported by 20% of participants in a clinic case study.\(^ {24}\) Residual symptoms were reported by most of the respondents, although many of these symptoms were only mild. However, at least one moderate to severe symptom was reported in 40% of the participants. This symptom was most commonly reported as perceived ankle weakness. Additionally, functional disabilities and limitations were also reported. Residual effects were reported on ambulation, the ability to jump, and the ability to turn or pivot on ankle. More than 38% of the participants related these limitations to their previous ankle injury. Although sport related activities were more greatly affected, participants reported limitations in daily activities such as attending school, social activities, and tasks around the house. These movements produced moderate to severe residual symptoms.\(^ {24}\)

While patients report residual symptoms long after initial injury, it does not appear related to the amount time from initial injury to the time of medical care or evaluation. This contrasts to previous hypotheses stating that time seeking care is related to recovery time and resulting symptoms. Although early care is needed and appropriate, it does not seem to have a relationship to the likelihood of residual symptoms.\(^ {24}\)
Guidelines which effectively and efficiently rule out injury to the bone need to be established. A fracture must either be ruled in or out in a proper time period if operative treatment is necessary to reduce secondary displacement injury.\textsuperscript{25}

Having these guidelines would both standardize the ankle and foot examination and lower medical costs. For these reasons, the CDRs were developed specifically for the ankle and foot, namely the OARs.\textsuperscript{3}

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**The Need for Sport Specific Ottawa Ankle Rule Modifications**

The OARs were developed in an emergency room setting for examinations occurring hours after initial injury. However, the rules are currently implemented in a variety of different settings. There is little research to support or refute the validity of the OARs in diverse settings.

**Issues in sport population.** There is currently little research relating the OARs to an athletic and sport-related population. Some research has focused on outpatient settings, but not specifically focused on sports injuries treated by a staff athletic trainers. The research conducted to validate the rules in a university sports medicine center has shown positive and correlating effects. These rules were applied to all pediatric and adult patients presenting to the clinic with acute ankle sprains.\textsuperscript{11,12} The rule application and exclusion criteria remained the same. Research concluded that the use of the OARs in this setting reduced radiography and saved the patients unnecessary medical costs, without missing significant fractures. In this setting, the Buffalo modifications were not shown to have a significant improvement in the diagnosis of a fracture.\textsuperscript{11,12} Previous research has been completed in the sports medicine field, but currently lacks in the
immediate application of OARs in a sport population. There is no strong evidence pertaining to the use of the OARs directly after a foot or ankle injury is sustained.

**Issues in gait analysis.** Gait function is an essential factor in recovery and rehabilitation after a foot or ankle injury. The biomechanics and gait cycle are commonly altered after injury and influence return to function of the athlete.

Gait patterns have been studied in chronic ankle instability, but nothing notable has focused on gait patterns directly following injury. Changes have been related back to increased stress applied to the ankle joint during the heel strike and loading response phases of the gait cycle. The position of the ankle is more inverted in patients with ankle injury possibly due to lack of motor control or proprioception detectors. These changes may have resulted from protective mechanisms sustained with the initial injuries, yet increase the work load of the evertor muscles.

An abnormal gait pattern can predispose an individual to an ankle or foot injury, but a change in gait can also be a result of the injury. Specific antalgic gait patterns have been linked to those who sustain ankle injury. These characteristics are (1) longer foot contact time, (2) higher loading medially and less loading laterally, (3) medially directed pressure distributed at first metatarsal contact, forefoot flat and heel off and less pressure displacements in the other phases, (4) delayed knee flexion, (5) laterally directed pressure in the forefoot push off phase, and (6) greater range of motion and the first metatarsal phalangeal joint. The enigma of this research is whether these characteristics are predisposers to injury, or result from an injury. There is need for research that correlates antalgic gait patterns immediately after ankle injury.
**Issues in pain pattern analysis.** Lasting effects of pain and chronic instability may occur after an individual sustains a foot or ankle injury. Long term effects have been recorded months postinjury, but there is no substantial evidence regarding pain patterns, or predictor variables, directly after a patient sustains injury. There is a need for research specifically directed towards pain patterns, areas of pain, and type of pain that is analyzed after the initial injury has occurred, and followed over the duration of the healing process.

**Deficits.** Through this extensive research there have been more studies developed on the palpation aspects of the rules, and less on the weight bearing factor. This study wants not only to determine the reliability of the OARs to diagnose a fracture and evaluate the measures of diagnostic accuracy of predictor variables, but also to determine the influence of time on the validity of the OARs. We want specifically to record the type of gait at the time of injury, and to keep track of the gait changes in comparison to the time frame postinjury. In addition, we collected patient recorded pain and pain upon palpation on an ankle diagram. By recording the gait pattern changes, the pain patterns, and the time frame postinjury, we aimed to develop a pain prediction pattern after initial injury.

**Application of Measures of Diagnostic Accuracy**

The acronyms “SpPIN” and “SnNOUT” are used to operationalize sensitivity and specificity measures.

**Specificity.** Specificity uses “SpPIN” to analyze the positive findings to rule in the condition. When the specificity results (Sp) captures a high number of true negative
results, all of the positive results have been captured and the condition can be confidently ruled in (IN).²⁹

**Sensitivity.** Sensitivity uses “SnNOUT” to analyze the negative findings to rule out the condition. When the sensitivity (Sn) produces a high number of true positive results, all of the negative results have been captured and the condition can confidently be ruled out (OUT).²⁹

It is rare when a single test effectively *rules in* and *rules out* a condition at the same time.²⁹ For this reason, an ideal situation would first use a test of high sensitivity to find all positive results, and then follow up using a test of high specificity to identify the true negative results. Positive and negative likelihood ratios should then be used to increase confidence level.

**Specific Aims**

With this study we tested the validity of the OARs, observed the gait deficits, and developed a pain prediction pattern for ankle and foot injuries.

The specific aims were:

1. To test the validity of the OARs in acute foot or ankle injury.
2. To calculate the diagnostic accuracy of select predictor variables over time.
Chapter 3: Methods

Participants

This is a record review of foot and ankle examinations conducted by certified athletic trainers contracted as graduate assistants at Ohio University. Data were collected from an injury report by the athletic trainer. There is a current contractual agreement established with the prospective athletes’ high schools and colleges and the Ohio University graduate assistants that are employed as the athletic trainer at that facility. No personally-identifiable information regarding the patient was collected.

Development of the Ankle Inventory Form

Data were collected using the Ohio University Ankle Inventory instrument “Inventory” (see Appendix A). This instrument was created using the Teleform Designer program. The athletic trainers transferred their foot and/or ankle examination findings to pen and paper form. The instrument included the diagnostic procedures and findings that were found during a standard foot or ankle examination. The Inventory information included demographic information on the patient, the time and date of the injury, the time and date that the examination was performed, diagrams describing patient-reported pain and pain elicited during palpation, examination findings (eg, joint and muscle function, stress tests, selective tissue tests), functional status, ambulatory status, diagnostic imaging, and diagnosis. These instruments were completed for each examination and re-examination until the athlete returned to full participation.
Study Design

This was a cross-sectional study developed to determine the validity of the OARs for an acute foot or ankle injury in an acute sport related setting and to evaluate the measures of diagnostic accuracy of predictor variables.

Setting

Ankle Inventory forms were completed at facilities associated with Ohio University intercollegiate athletics, Ohio University club sports, and high schools and colleges located in Southeastern Ohio and bordering West Virginia. The patient did not need to be present for the instrument to be completed.

Instruments

Data were collected from a record review of the completed initial examination and re-examinations. Information was transmitted to the research team using a paper and pen instrument that was then scanned, decoded, and entered into an electronic database.

The first section encompassed information about the athlete and the injury. This part asked for a case identification number, injury date, injury time, sex, age, sport, competitive level, and an examination time. The second section included pain characteristics where a diagram of the medial and lateral ankle was marked according to the locations where athlete reported pain and pain elicited upon palpation. The last section reported on examination findings of range of motion and strength deficits, joint stability testing, functional status, ambulatory status, and diagnostic images obtained. The reporter filled in a scan bubble for each of the characteristics. Examination findings included range of motion testing and manual muscle testing. Joint stability testing
included positive findings for both pain and laxity of the inversion talar tilt, eversion talar tilt, anterior drawer, and external rotation tests. Ambulatory status was measured by the ability to bear weight fully without walking restrictions, partial weight bear with limited steps or assisted by crutches, or unable to weight bear. The functional status questions were filtered from the FAAM and the FADI. Under images obtained, the reporter was asked to fill in positive or negative results for diagnostic images received. The last line was left blank for the reporter to fill in with their diagnosis.

**Procedures**

There was an instructional session held for the athletic trainers who acted as data collectors. The session included specific directions for the completion of the inventory and to standardize the nomenclature and examination procedure. Instructions were also printed on the reverse side of the inventory. The standard of care for foot and ankle examinations was followed and there was no alternation of the subsequent intervention(s).

The inclusion criteria included the records from those athletes that sustained an acute foot or ankle injury. Records were excluded from the study if the patient met the exclusion criteria for the OARs, ie, if the individual was pregnant, had an isolated injury of the skin, had an injury more than 10 days prior to the examination, or presented with a gross deformity.

Following the initial examination or re-examination of an acute foot or ankle injury, the athletic trainer completed the ankle inventory identifying the key diagnostic findings and the subsequent clinical or medical (physician-based) diagnosis. Once the
case was resolved, the patient either returned to competition, or a fracture or other disqualifying condition was diagnosed, the deidentified Inventory was returned to the research team.

**Data Processing**

Data were collected using scannable forms. The Teleform program incorporated point recognition and optical character recognition to convert the written data into electronic format. The program had an internal validity check that presents unrecognized characters for manual interpretation. The scanned data were imported into an Excel spreadsheet. The inventory forms were hand checked and validated against the imported spreadsheet.

**Data Analysis**

Data were categorized into the appropriate time frames postinjury. A 2 x 2 contingency table presents a count of a clinical test’s ability to accurately identify the presence (true positive) or absence (true negative) of a condition relative to the diagnostic gold standard. False negative results occur when the clinical test is negative, but the condition is actually present; false positive results occur when the clinical test is positive, but the condition is not present.

For all measures of diagnostic accuracy the confidence level was set 95%, $\alpha=0.05$. These results allow the calculation of specificity, sensitivity, positive and negative likelihood ratios, positive and negative predicative values, and diagnostic accuracy of the OARs relative to the time frame (see Figure 1). Likelihood ratio probabilities were determined by Table 1.
Table 1. Interpretation of Likelihood Ratios

<table>
<thead>
<tr>
<th>Positive Likelihood Ratios</th>
<th>Negative Likelihood Ratios</th>
<th>Shift in Probability Condition is Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;10</td>
<td>&lt;0.1</td>
<td>Large, often conclusive</td>
</tr>
<tr>
<td>5–10</td>
<td>0.1–0.2</td>
<td>Moderate, usually important</td>
</tr>
<tr>
<td>2–5</td>
<td>0.2–0.5</td>
<td>Small, sometimes important</td>
</tr>
<tr>
<td>1–2</td>
<td>0.5–1.0</td>
<td>Very small, usually unimportant</td>
</tr>
</tbody>
</table>

The following formulas were used to calculate the measure of diagnostic accuracy:

\[
Sensitivity = \frac{\text{True Positive}}{\text{True Positive} + \text{False Negative}}.
\]

\[
Specificity = \frac{\text{True Negative}}{\text{True Negative} + \text{False Positive}}.
\]

\[
LR^+ = \frac{\text{Sensitivity}}{1-\text{Specificity}}.
\]

\[
LR^- = \frac{1-\text{Sensitivity}}{\text{Specificity}}.
\]

Positive predictive value = \[
\frac{\text{True Positive}}{\text{True Positive} + \text{False Positive}}.
\]

Negative predictive value = \[
\frac{\text{True Negative}}{\text{True Negative} + \text{False Negative}}.
\]

Diagnostic accuracy = \[
\frac{\text{True Positive} + \text{True Negative}}{\text{Total Tests Performed}}.
\]
Chapter 4: Results

This chapter presents an analysis of the validity of the OARs at different time points. It also presents the diagnostic accuracy of other potential predictor variables used in the differential diagnosis process.

During the 13 months of data collection, 519 total examinations were submitted, of which 228 (43.9%) were unique initial reports. Three initial examination cases were excluded because more than 10 days had elapsed between the reported injury date and the date of the examination. Previous studies have used sample sizes ranging from 100 to 217 injuries per sample.\(^3,4,11,12,19\) Contingency tables for all time groups and all predictor variables were calculated (see Appendix D).

Original Ottawa Ankle Rules

The OARs criteria for referral were met in 168 of the 228 (74%) initial cases, with 11 (6.5%) being positive for a fracture via diagnostic imaging (Table 2). Of the 12 fractures, 8 were fibular fractures, 1 tibial fracture, 1 hairline fibular fracture, 1 Jones fracture, and 1 second metatarsal fracture were reported. The diagnostic accuracy of the OARs for all initial examinations was 0.30.

The average time between the injury and initial examination was 19.96 ± 37.02 h (median = 0.50 h, IQR = 0.05–22.04; mode = 0.00 h). Of the 228 initial examinations, 11 (4.8%) were true positive and 57 (25.0%) were true negative cases. False positive results occurred in 159 (69.7%) cases and 1 (0.4%) case produced a false negative finding.
Table 2. Diagnostic Accuracy of the Original Ottawa Ankle Rules Following the Initial Examination

<table>
<thead>
<tr>
<th>Application of the Original Ottawa Ankle Rules (95% CI)</th>
<th>All Cases (n = 228)</th>
<th>One Hour or Less (n = 124)</th>
<th>One to 48 Hours (n = 76)</th>
<th>Two to Ten Days (n = 28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average time of examination</td>
<td>19.96 ± 37.02 h</td>
<td>0.17 ± 0.25 h</td>
<td>21.25 ± 11.75 h</td>
<td>95.97 ± 57.84 h</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.92 (0.61–0.99)</td>
<td>1.00 (0.59–1.00)</td>
<td>0.75 (0.20–0.96)</td>
<td>1.00 (0.17–1.00)</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.26 (0.21–0.33)</td>
<td>0.21 (0.14–0.29)</td>
<td>0.40 (0.29–0.53)</td>
<td>0.22 (0.09–0.42)</td>
</tr>
<tr>
<td>LR+</td>
<td>1.25 (1.03–1.50)</td>
<td>1.26 (1.15–1.38)</td>
<td>1.26 (0.69–2.28)</td>
<td>1.29 (1.05–1.57)</td>
</tr>
<tr>
<td>LR−</td>
<td>0.32 (0.05–2.09)</td>
<td>NV</td>
<td>0.62 (0.11–3.47)</td>
<td>NV</td>
</tr>
<tr>
<td>PPV</td>
<td>0.06 (0.03–0.11)</td>
<td>0.07 (0.03–0.14)</td>
<td>0.07 (0.01–0.18)</td>
<td>0.05 (0.00–0.23)</td>
</tr>
<tr>
<td>NPV</td>
<td>0.98 (0.91–0.99)</td>
<td>1.00 (0.86–1.00)</td>
<td>0.97 (0.83–0.99)</td>
<td>1.00 (0.54–1.00)</td>
</tr>
</tbody>
</table>

LR+ = positive likelihood ratio; LR− = negative likelihood ratio; PPV = positive predictive value; NPV = negative predictive value; NV = No Value, the value could not be calculated due to absence of results, f = number of fractures
Of the 228 initial injuries, 182 (79.8%) occurred to high school athletes ranging from 14 to 17 years of age (mean = 15.93 ± 1.25). Intercollegiate athletes accounted for 25 (11.0%) injuries and 15 (6.6%) injuries occurred at the collegiate club level, with patients ranging from 17 to 23 years of age (mean = 20.10 ± 1.50). The level of competition was not reported in 6 (2.6%) of the cases.

Initial examinations were divided into three time groups: (1) examinations completed within 1 hour, (2) examinations completed between 1–48 hours, and (3) examinations completed between 2–10 days. Research question one, “Are the Ottawa Ankle Rules valid when administered within 60 minutes after the injury?” and research question two, “How do the diagnostic measures of accuracy of the clinical findings change over time?” are addressed in this section.

For cases with initial examinations occurring in less than 1 h (n = 124), the average time between injury and examination was 0.17 ± 0.25 h (median = 0.80 h, IQR = 0.00–0.25; mode = 0.00 h). For cases with initial examinations occurring from 1 to 48 h postinjury (n = 76), the average time between injury and examination was 21.25 ± 11.75 h (median = 212.25 h, IQR = 15.00–23.81; mode = 1.50 h). For cases with initial examination occurring 2 to 10 d postinjury (n = 28), the average time between injury and examination was 96.00 ± 57.84 h (median = 67.92 h, IQR = 65.15–105.56; mode = 66 h).

**Sensitivity.** The sensitivity for all cases was 0.92. The highest sensitivity (1.00) was obtained when the OARs were applied 1 h or less postinjury and 2 to 10 d postinjury. The lowest sensitivity was found when the OARs were applied 1 to 48 h postinjury.
**Specificity.** The specificity for all cases was 0.26. The highest specificity was found when the OARs were applied 1 to 48 h postinjury. The lowest specificity (0.21) occurred when OARs were applied within 1 h postinjury. There was a statistically significant difference in the specificity of the OARs administered within 1 h (0.21; 95% CI 0.14–0.28) and 1 to 48 h following injury (0.40; 95% CI 0.29–0.53, \( p < 0.05 \)).

**Likelihood ratio.** The positive likelihood ratio for all cases was 1.25, representing a small increase in the pretest probably that the injury occurred. The negative likelihood ratio for all time groups and 1 to 48 h were 0.32 and 0.62, respectively, which demonstrates a small shift in the probability that the condition is absent. In time groups of less than 1 h and 2 to 10 d, the negative likelihood ratio could not be calculated because no false negatives were reported. There were no statistically significant differences in the likelihood ratios when the OARs were administered at different times.

**Positive Predictive Value.** The positive predictive values for all groups were poor. The PPV for all examinations was 0.06 with the highest value of 0.07 found at time groups of 1 h or less and 1 to 48 h. The values decreased for examinations performed between 2 to 10 d following injury. There were no statistically significant differences in the positive predictive value when the OARs were administered at different time groups.

**Negative predictive value.** The negative predictive value for all examinations was 0.98. The highest negative predictive values were 1.00 for 1 h or less and 2 to 10 d time groups. The values decreased for examinations completed between 1 to 48 h time...
groups. Although there were no statistically significant differences between groups, the NPV yielded the highest diagnostic value of any tests we performed.

**Conclusion.** Negative OARs results definitively ruled out the need to obtain radiographs, as indicated by the high sensitivity and negative predictive values. However, the low specificity and positive predictive value indicated a high false positive rate, therefore the determination to obtain radiographs based on positive OARs results cannot be used to conclusively rule in the need for diagnostic imaging.

**Predictor Variables**

Research question three, “Which predictor variables of the Ottawa Ankle Rules are the most valid?” will be addressed in this section.

**Palpation tenderness only.** Based only on palpation tenderness, 169 (74.1%) of the 228 initial cases meet the referral criteria, with 11 (6.5%) fractures identified by diagnostic imaging (see Table 3). Fifty-nine cases were negative for referral based on palpation points only, yielding a diagnostic accuracy of 0.30.

**Sensitivity.** The sensitivity of palpation findings for all examinations was 0.92. Examinations performed within the first hour and those performed 2 to 10 d following the injury had the highest diagnostic sensitivity of (1.00). Sensitivity decreased when the palpation rules were applied between 1 and 48 h.

**Specificity.** The specificity of all examinations was 0.27. Specificity was highest when the palpation rules were applied between 1 to 48 h. Specificity decreased when applied between 2 to 10 d, and decreased again when applied within 1 h of the injury.
Likelihood ratios. The positive likelihood ratio for all examinations was 1.25, with all other time groups ranging from 1.26 to 1.29. The strongest probability was found during 1 to 48 h time frame. All positive likelihood ratios show a very small shift in probability for the presence of a fracture.

The negative likelihood ratio for all examinations was 0.31. Negative likelihood ratios were not calculated when the palpation rules are applied within 1 hour and during 2 to 10 d, because there were no false negatives reported.

Positive predictive value. The positive predictive value for all examinations was 0.07. The positive predictive value was the same for examinations occurring within 1 hour, and 1 to 48 hour time groups. The value decreased for examinations completed during 2 to 10 d.

Negative predictive value. The negative predictive value for all examinations was 0.98, yielding perfect prediction for examinations completed within 1 h and examinations completed between 2 and 10 d.

Conclusion. The palpation rules applied only reported a high sensitivity (1.00) and a high negative predictive value (1.00) when completed within 1 h and between 2–10 d.
**Table 3. Diagnostic Accuracy of Palpation Tenderness Only Following the Initial Examination**

<table>
<thead>
<tr>
<th>Application of Palpation Tenderness Only (95% CI)</th>
<th>All Cases (n = 228)</th>
<th>One Hour or Less (n = 124)</th>
<th>One to 48 Hours (n = 76)</th>
<th>Two to Ten Days (n = 28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.92 (0.61–0.99)</td>
<td>1.00 (0.59–1.00)</td>
<td>0.75 (0.20–0.96)</td>
<td>1.00 (0.17–1.00)</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.27 (0.21–0.33)</td>
<td>0.21 (0.14–0.29)</td>
<td>0.42 (0.30–0.54)</td>
<td>0.22 (0.09–0.42)</td>
</tr>
<tr>
<td>LR+</td>
<td>1.25 (1.04–1.51)</td>
<td>1.26 (1.15–1.38)</td>
<td>1.29 (0.71–2.34)</td>
<td>1.29 (1.05–1.57)</td>
</tr>
<tr>
<td>LR−</td>
<td>0.31 (0.05–2.05)</td>
<td>NV</td>
<td>0.60 (0.11–3.35)</td>
<td>NV</td>
</tr>
<tr>
<td>PPV</td>
<td>0.07 (0.03–0.11)</td>
<td>0.07 (0.03–0.14)</td>
<td>0.07 (0.03–0.11)</td>
<td>0.05 (0.00–0.23)</td>
</tr>
<tr>
<td>NPV</td>
<td>0.98 (0.91–1.00)</td>
<td>1.00 (0.86–1.00)</td>
<td>0.98 (0.91–1.00)</td>
<td>1.00 (0.54–1.00)</td>
</tr>
</tbody>
</table>

LR+ = positive likelihood ratio; LR− = negative likelihood ratio; PPV = positive predictive value; NPV = negative predictive value; NV = No Value, the value could not be calculated due to absence of results.
**Inability to weight bear only.** Based on weight bearing status only, 32 (14%) of the 228 initial cases would be referred for diagnostic imaging with six (18.6%) positive for fracture (see Table 4); of these, 197 were negative for referral. The diagnostic accuracy was 0.86. There were six true positive cases and 191 true negative cases. Twenty-six of the cases were false positive and six cases were false negative.

**Sensitivity.** The sensitivity for all examinations was 0.50. The highest sensitivity was obtained when the weight bearing rules were applied within 1 h. Sensitivity decreased for examinations completed between 1 to 48 h. Sensitivity could not be calculated examinations completed between 2 to 10 d because of the absence of true positive results.

**Specificity.** Specificity for all cases was 0.88. Specificity was the highest when the rules were applied between 1 to 48 h. Values decreased for 2 to 10 d, and when completed within 1 h.

**Likelihood ratio.** The positive likelihood ratio for all examinations was 4.17. The strongest positive likelihood ratio (18.00) occurred when the rules were applied between 1 to 48 h following injury. The positive likelihood ratio of 18.00 was large and is often conclusive for presence of a fracture. The positive likelihood ratio decreased for examinations completed within 1 h and demonstrated a low probability that a fracture would be present. The positive likelihood ratio for examinations completed between 2 to 10 d could not be calculated due to the absence of true positives.

The negative likelihood ratio for all examinations was 0.57. The probability of a negative condition decreased for examinations completed within 1 h and between 1 to 48 h.
Table 4. Diagnostic Accuracy of Weight Bearing Status Only Following the Initial Examination

<table>
<thead>
<tr>
<th>Application of Weight Bearing Status Only (95% CI)</th>
<th>All Cases (n = 228)</th>
<th>One Hour or Less (n = 124)</th>
<th>One to 48 Hours (n = 76)</th>
<th>Two to Ten Days (n = 28)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity</td>
<td>0.50 (0.21–0.79)</td>
<td>0.57 (0.19–0.90)</td>
<td>0.50 (0.08–0.92)</td>
<td>NV</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.88 (0.83–0.92)</td>
<td>0.82 (0.74–0.89)</td>
<td>0.97 (0.90–1.00)</td>
<td>0.93 (0.76–0.99)</td>
</tr>
<tr>
<td>LR+</td>
<td>4.17 (2.13–8.16)</td>
<td>3.18 (1.50–6.74)</td>
<td>18.00 (3.35–96.74)</td>
<td>NV</td>
</tr>
<tr>
<td>LR−</td>
<td>0.57 (0.32–1.00)</td>
<td>0.52 (0.22–1.23)</td>
<td>0.51 (0.19–1.37)</td>
<td>1.08 (0.97–1.20)</td>
</tr>
<tr>
<td>PPV</td>
<td>0.19 (0.07–0.36)</td>
<td>0.16 (0.05–0.36)</td>
<td>0.50 (0.08–0.92)</td>
<td>NV</td>
</tr>
<tr>
<td>NPV</td>
<td>0.97 (0.93–0.99)</td>
<td>0.97 (0.91–0.99)</td>
<td>0.97 (0.90–1.00)</td>
<td>0.96 (0.80–0.99)</td>
</tr>
</tbody>
</table>

LR+ = positive likelihood ratio; LR− = negative likelihood ratio; PPV = positive predictive value; NPV = negative predictive value; NV = No Value, the value could not be calculated due to absence of results
**Positive predictive value.** The positive predictive value for all cases was 0.19. The positive predictive value was highest for examinations completed between 1 and 48 h. The value decreased for examinations completed within 1 h. The positive predictive value could not be calculated for examinations completed between 2 to 10 d because of the absence of true positive results.

**Negative predictive value.** The negative predictive value for all examinations was 0.97. The highest negative predictive values were equal at 0.97 for examinations completed within 1 h and between 1 to 48 h. The value decreased when the rules were applied between 2 to 10 d.

**Conclusion.** When analyzing weight-bearing status only, a high specificity (0.97) was obtained when applies between 1 to 48 h. A strong positive likelihood ratio occurred when applied 1 to 48 h. A high negative predictive value (0.97) was attained when applied within 1 h and between 1 to 48 h.

**Palpation tenderness and weight bearing together.** When both positive palpation tenderness and weight bearing status were used as the diagnostic metric, 30 (13.2%) of the 228 cases were positive for referral of diagnostic imaging, with 6 (20%) positive for fracture and 198 cases were negative (Table 5). The diagnostic accuracy was 0.87. This method also missed 6, or half, of all fractures.

**Sensitivity.** The sensitivity for all examinations was 0.50. The sensitivity was the highest when the combined rules were applied to examinations occurring within 1 h postinjury. Sensitivity decreased for exams completed between 1 and 48 h. The sensitivity could not be calculated for examinations completed between 2 to 10 d.
**Specificity.** The specificity for all examinations was 0.89. The specificity was the highest when the rules were applied to examinations occurring between 1 and 48 h. The specificity decreased respectively for 2 to 10 d and examinations completed within 1 h.

**Likelihood ratio.** The positive likelihood ratio for all examinations was 4.50. The positive likelihood ratio was the strongest when the rules were applied between 1 and 48 h. This ratio shows a large, conclusive probability that there is a presence of a fracture. Ratios decrease examinations completed within 1 h, which demonstrates a low probability for the presence of a fracture. A positive likelihood ratio for exams completed between 2 to 10 d could not be calculated.

The negative likelihood ratio for all examinations was 0.56. The negative likelihood was the strongest when the rules were applied within 1 to 48 h. The ratio decreased in probability for the absence of a fracture when the rules were applied respectively to examinations completed within 1 h and between 2 to 10 d. These time groups demonstrate a very small probability that a fracture is absent. There are statistically significant differences for all time groups; examinations completed within 1 h (0.52; 95% CI 2.31–11.29, \( p < 0.05 \)) between 1 to 48 h (0.51; 95% CI 0.19–1.35, \( p < 0.05 \)), and within 1 h between 2 to 10 d (1.08; 95% CI 0.97–1.20, \( p < 0.05 \)).

**Positive predictive value.** The positive predictive value for all examinations was 0.20. The positive predictive value was highest when the rules were applied during 1 to 48 h. The value decreased for examinations completed within 1 h. The value could not be calculated when the rules were applied between 2 and 10 d.
Negative predictive value. The negative predictive value for all examinations was 0.97. The negative predictive value was the highest and equal for examinations completed within 1 h and examinations completed between 1 and 48 h.

Conclusion. When using palpation tenderness and weight bearing status together, a high specificity (0.99) was obtained when applied to examinations completed between 1 to 48 hours. A strong positive likelihood ratio (36.00) was determined when examinations were completed between 1 to 48 h. A high negative predictive value (0.97) occurred when applied within 1 h and between 1 to 48 h.
Table 5. Diagnostic Accuracy of Palpation Tenderness and Weight Bearing Status Together Following the Initial Examination

<table>
<thead>
<tr>
<th></th>
<th>Application of Palpation Tenderness and Weight Bearing Status Together (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Cases (n = 228)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.50 (0.21–0.79)</td>
</tr>
<tr>
<td>Specificity</td>
<td>0.89 (0.84–0.93)</td>
</tr>
<tr>
<td>LR+</td>
<td>4.50 (2.28–8.88)</td>
</tr>
<tr>
<td>LR−</td>
<td>0.56 (0.32–0.99)</td>
</tr>
<tr>
<td>PPV</td>
<td>0.20 (0.08–0.34)</td>
</tr>
<tr>
<td>NPV</td>
<td>0.97 (0.94–0.99)</td>
</tr>
</tbody>
</table>

LR+ = positive likelihood ratio; LR− = negative likelihood ratio; PPV = positive predictive value; NPV = negative predictive value; NV = No Value, the value could not be calculated due to absence of results.
Change in Diagnostic Values Over Time

The clinical findings analyzed were the joint stability tests of the ankle: inversion stress, anterior drawer, eversion stress for medial ligaments, eversion stress for syndesmosis, and the external rotation test for the syndesmosis. Analyses of the joint stability tests were either positive for laxity only, positive for pain only, or positive for both pain and laxity.

Changes in laxity over time. The following measures of diagnostic accuracy were calculated for joint stability tests which were positive for laxity only (see Table 6).

Sensitivity. The highest sensitivity was 0.49 with the anterior drawer test. The sensitivity decreased when performing the inversion stress test. For both tests of eversion stress and external rotation the sensitivity was zero.

Specificity. The highest specificity occurred with both eversion stress tests. The specificity decreased respectively with the external rotation test, the anterior drawer, and the inversion stress test.

Likelihood ratio. The positive likelihood ratio was strongest with the anterior drawer and the inversion stress test. Ratios for these tests show a small shift in the probability of the presence of a positive condition. The three remaining tests had a positive likelihood ratio of zero, which shows a very small probability. The strongest negative likelihood ratio was also found with the anterior drawer, with a very small shift in the probability of a negative condition. The strengths of the negative likelihood ratios decreased respectively with the inversion stress test, both eversion stress tests equally, and the external rotation test.
Table 6. Initial Examinations Completed Within One Hour Based on Laxity

<table>
<thead>
<tr>
<th></th>
<th>Inversion Stress</th>
<th>Drawer</th>
<th>Eversion Medial Ligaments</th>
<th>Eversion Syndesmosis</th>
<th>External Rotation Syndesmosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn</td>
<td>0.30 (0.20–0.42)</td>
<td>0.49 (0.38–0.61)</td>
<td>0.00</td>
<td>0.00 (0.00–0.21)</td>
<td>0.00 (0.00–0.27)</td>
</tr>
<tr>
<td>Sp</td>
<td>0.81 (0.65–0.91)</td>
<td>0.82 (0.66–0.92)</td>
<td>0.98 (0.94–1.00)</td>
<td>0.98 (0.93–1.00)</td>
<td>0.95 (0.89–0.99)</td>
</tr>
<tr>
<td>LR+</td>
<td>1.55 (0.76–3.15)</td>
<td>2.68 (1.32–5.43)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LR−</td>
<td>0.87 (0.70–1.07)</td>
<td>0.62 (0.47–0.81)</td>
<td>1.02 (0.99–1.05)</td>
<td>1.02 (0.99–1.05)</td>
<td>1.05 (1.00–1.10)</td>
</tr>
<tr>
<td>PPV</td>
<td>0.74 (0.55–0.88)</td>
<td>0.84 (0.70–0.93)</td>
<td>0.00</td>
<td>0.00 (0.00–0.81)</td>
<td>0.00 (0.00–0.60)</td>
</tr>
<tr>
<td>NPV</td>
<td>0.38 (0.28–0.50)</td>
<td>0.45 (0.34–0.57)</td>
<td>0.99 (0.95–1.00)</td>
<td>0.85 (0.77–0.91)</td>
<td>0.87 (0.79–0.93)</td>
</tr>
</tbody>
</table>

Sn = Sensitivity; Sp = Specificity; LR+ = positive likelihood ratio; LR− = negative likelihood ratio; PPV = positive predictive value; NPV = negative predictive value
**Positive predictive value.** The highest positive predictive value occurred with the anterior drawer. The value decreased for the inversion test, and was 0.0 for both eversion stress tests and the external rotation test.

**Negative predictive value.** The highest negative predictive value was found with the eversion stress test for the medial ligaments. The value decreased respectively for the external rotation test, the eversion stress for syndesmosis, the anterior drawer, and inversion stress test.

**Changes in pain over time.** The following measures of diagnostic accuracy were calculated for joint stability tests which were positive for pain only (see Table 7).

**Sensitivity.** The highest sensitivity was obtained with the eversion stress test for the medial ligaments at 1.00. The sensitivity decreased respectively with the inversion stress test, the anterior drawer, the external rotation test, and the eversion stress test for the syndesmosis.

**Specificity.** The highest specificity occurred with the external rotation test. Specificity decreased equally for both eversion stress tests. The value decreased respectively for the anterior drawer and the inversion stress test.

**Likelihood ratio.** The strongest positive likelihood ratio was with the eversion stress test for medial ligaments with a small shift in the probability. Ratios decreased respectively with external rotation test, the anterior drawer, the inversion stress test, and the eversion stress test for the syndesmosis. All ratios show a small shift in the probability of the condition being present.
Table 7. Initial Examinations Completed Within One Hour Based on Pain

<table>
<thead>
<tr>
<th>Inversion Stress</th>
<th>Drawer</th>
<th>Eversion Medial Ligaments</th>
<th>Eversion Syndesmosis</th>
<th>External Rotation Syndesmosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn</td>
<td>0.83 (0.73–0.91)</td>
<td>0.72 (0.60–0.82)</td>
<td>1.00 (0.17–1.00)</td>
<td>0.38 (0.15–0.65)</td>
</tr>
<tr>
<td>Sp</td>
<td>0.54 (0.37–0.69)</td>
<td>0.66 (0.49–0.80)</td>
<td>0.71 (0.61–0.79)</td>
<td>0.71 (0.61–0.80)</td>
</tr>
<tr>
<td>LR+</td>
<td>1.79 (1.27–2.53)</td>
<td>2.10 (1.32–3.34)</td>
<td>3.41 (2.55–4.56)</td>
<td>1.31 (0.64–2.65)</td>
</tr>
<tr>
<td>LR–</td>
<td>0.32 (0.18–0.56)</td>
<td>0.43 (0.28–0.65)</td>
<td>0.00</td>
<td>0.88 (0.59–1.31)</td>
</tr>
<tr>
<td>PPV</td>
<td>0.77 (0.66–0.85)</td>
<td>0.81 (0.69–0.89)</td>
<td>3.03 (0.05–0.16)</td>
<td>0.18 (0.07–0.36)</td>
</tr>
<tr>
<td>NPV</td>
<td>0.63 (0.45–0.79)</td>
<td>0.54 (0.39–0.69)</td>
<td>1.00 (0.95–1.00)</td>
<td>0.87 (0.77–0.94)</td>
</tr>
</tbody>
</table>

Sn = Sensitivity; Sp = Specificity; LR+ = positive likelihood ratio; LR– = negative likelihood ratio; PPV = positive predictive value; NPV = negative predictive value
The strongest negative likelihood ratio was found with the eversion stress test for medial ligaments, with a conclusive shift in the probability of the condition being negative. The ratios decreased in strength respectively for the inversion stress test, the anterior drawer, the external rotation test, and the eversion stress test for syndesmosis.

**Positive predictive value.** The highest positive predictive value was found at 3.03 for the eversion stress test of the medial ligaments. The values decreased respectively for the anterior drawer, the inversion stress test, the external rotation test, and the eversion stress test for syndesmosis.

**Negative predictive value.** The highest negative predictive value was found at 1.00 for the eversion stress test for the medial ligaments. The values decreased respectively for the external rotation test, the eversion stress test for the syndesmosis, the inversion stress test, and the anterior drawer.

**Changes in both laxity and pain over time.** The following measures of diagnostic accuracy were calculated for joint stability tests which were positive for both laxity and pain (see Table 8).

**Sensitivity.** The highest sensitivity was found with the eversion stress test for medial ligaments at 0.50. The sensitivity decreased respectively for the drawer and the inversion stress test. Sensitivity for both the eversion stress test for the syndesmosis and the external rotation test were 0.00.

**Specificity.** The highest specificity was with the eversion stress test for medial ligaments at 0.99. The value decreased respectively for the eversion stress test for the syndesmosis, the external rotation test, the anterior drawer, and the inversion stress test.
<table>
<thead>
<tr>
<th></th>
<th>Inversion Stress</th>
<th>Drawer</th>
<th>Eversion Medial Ligaments</th>
<th>Eversion Syndesmosis</th>
<th>External Rotation Syndesmosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn</td>
<td>0.29 (0.19–0.41)</td>
<td>0.40 (0.29–0.52)</td>
<td>0.50 (0.08–0.92)</td>
<td>0.00 (0.00–0.21)</td>
<td>0.00 (0.00–0.25)</td>
</tr>
<tr>
<td>Sp</td>
<td>0.83 (0.68–0.93)</td>
<td>0.84 (0.69–0.94)</td>
<td>0.99 (0.95–1.00)</td>
<td>0.98 (0.93–1.00)</td>
<td>0.97 (0.91–0.99)</td>
</tr>
<tr>
<td>LR+</td>
<td>1.70 (0.79–3.63)</td>
<td>2.53 (1.16–5.55)</td>
<td>54.00 (0.49–591.15)</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>LR–</td>
<td>0.86 (0.70–1.05)</td>
<td>0.71 (0.57–0.90)</td>
<td>0.50 (0.13–2.02)</td>
<td>1.02 (0.99–1.05)</td>
<td>1.03 (1.00–1.07)</td>
</tr>
<tr>
<td>PPV</td>
<td>0.76 (0.57–0.90)</td>
<td>0.83 (0.67–0.94)</td>
<td>0.50 (0.08–0.92)</td>
<td>0.00 (0.00–0.81)</td>
<td>0.00 (0.00–0.70)</td>
</tr>
<tr>
<td>NPV</td>
<td>0.39 (0.28–0.50)</td>
<td>0.42 (0.30–0.53)</td>
<td>0.99 (0.95–1.00)</td>
<td>0.85 (0.77–0.91)</td>
<td>0.88 (0.80–0.93)</td>
</tr>
</tbody>
</table>

Sn = Sensitivity; Sp = Specificity; LR+ = positive likelihood ratio; LR– = negative likelihood ratio; PPV = positive predictive value; NPV = negative predictive value
Likelihood ratio. The strongest positive likelihood ratio was found with the eversion stress test for medial ligaments at 54.00, with a large and often conclusive shift in the probability that the condition is present. The values decrease in strength for the anterior drawer and inversion stress test, respectively. The ratio for both syndesmosis tests were 0.00.

The strongest negative likelihood ratio was found for the eversion stress test for the medial ligaments, with a small shift in probability that the condition is absent. The values decreased in strength respectively for the anterior drawer, the inversion stress test, the eversion stress test for the syndesmosis, and the external rotation test. All values show a low probability.

Positive predictive value. The highest positive predictive value was found for the anterior drawer. The value decreased respectively for the inversion stress test and the eversion stress test for medial ligaments. The values for the eversion stress test for the syndesmosis and the external rotation test were both found to be 0.00.

Negative predictive value. The highest negative predictive value was found for the eversion stress test at 0.99. The values decreased respectively for the external rotation test, the eversion stress test for the syndesmosis, the anterior drawer, and the inversion stress test.
Chapter 5: Discussion

The OARs were developed to improve practice efficiency in emergency department rooms. The main goal of the rules were to limit the number of ankle radiographs ordered for patients presenting with acute foot and/or ankle injury. The findings of this study demonstrated that the OARs were not valid when administered in the immediate setting. If the OARs were applied to all immediate examinations, 159 (93.5% of all positive results) needless radiographs would have been ordered. The benefit of applying the OARs is that a negative finding accurately rules out the need for diagnostic imaging.

Diagnostic Imaging

When the OARs criteria were applied to all of the initial examinations, 170 (75%) suggested the need for diagnostic imaging. Of those, 35 images (21%) were actually obtained, with only 12 (34%) positive for fractures. One fracture was negative on a radiograph, but returned a positive finding on magnetic resonance imaging (MRI). Of the 170 that warranted referral based on the OARs decision tree, 135 (79%) did not obtain further diagnostic imaging. The reason for this may have been based on factors such as the competitive level of patients, the age of patients, and the influence of parents. The clinical judgment of the athletic trainers may have superseded the diagnostic suggestion offered by the OARs.

Many of the schools and communities we collected data from are rural and classified as medically underserved. The financial aspect of obtaining radiographs (and the associated physician or emergency department visit) is a possible reason why many of
the images were not obtained. However we do not know whether or not a referral was made by the clinician and the patient did not follow the suggestion, or if the referral was not made by the clinician at all. In some cases the referral for radiographs may have been made outside of the athletic trainers’ clinical diagnosis.

**Injury demographics.** Of the 228 initial injuries, 182 (79.8%) occurred to high school athletes ranging from 14 to 17 years of age (mean = 15.93 ± 1.25). Intercollegiate athletes accounted for 25 (11.0%) injuries and 15 (6.6%) injuries occurred at the collegiate club level, with patients ranging from 17 to 23 years of age (mean = 20.10 ± 1.50). With the majority of the data collected from high school athletes, age and injury experience may be a limiting factor. The relative youth and a low level of competitive experience of high school athletes may create a cognitive filter in determining specific areas and severity of pain.\(^{13}\) This may have altered the results in regards to location of reported and palpated pain.

**Acute time frame.** Prior studies have examined findings from OARs implemented several hours following trauma.\(^{11,12}\) Because of the physiological and psychological response to injury the criteria may not be meaningful in the immediate setting. The OARs have been validated in acute time frames within 10 days following the injury.\(^{11,12}\) However, by day 10 injuries are no longer considered acute pathologies. In this study we define the acute examination as one completed in less than 60 minutes following injury.

We analyzed all initial examinations, and assigned each examination to a specific time group. Examinations were analyzed using the original OARs criteria, palpation
tenderness only, inability to weight bear only, and the combination of palpation
tenderness and weight bearing status. The changes in diagnostic measures over time
groups were also analyzed for positive results based on pain only, laxity only, and the
combination of pain and laxity.

Validity of the Ottawa Ankle Rules Completed Within 60 Minutes

Historically the OARs have demonstrated high accuracy at excluding fractures.20 While the OARs in an acute setting have proven to effectively rule out the presence of a fracture, they have not shown the ability to rule in the condition. They are not a dependable method to rule in the presence of a fracture. To obtain a stronger validity and based on our findings of the diagnostic measures, the OARs need to be more reliable in ruling in the presence of a fracture.

Our study revealed one initial false negative result. The fracture was then caught with follow up examinations and imaging. Our study remains consistent with previous research, which found few type II errors.20 While the use of the OARs captured all but the one fracture in the initial examination, there was an unacceptably high number of false positives. Of the positive findings, 159 (94%) were false positive. The positive predictive value was only determined to be 0.19, which is not an acceptable accuracy measure. The OARs demonstrated validity in determining which injuries are actually fractures, however the rules do not effectively rule out injuries that are not fractures.

Limitations

The cases assigned to each time group had inconsistencies in the number in each group. Group one included 124 initial examinations completed within 60 minutes. Group
two dropped to 76 examinations completed between 1 and 48 hours. Group three dropped even lower to 28 examinations completed between 2 to 10 days. These numbers vary, and may have altered our measures of diagnostic accuracy because of the lowered prevalence rates in specific groups.

The biggest limitation to this study was the documentation of referral warranted. We did know which examinations should have been referred based on the OARs and which patients actually obtained diagnostic imaging. However, we did not know if patients were referred but did not actually obtain images, or if patients were not referred but obtained images anyways. In follow-up studies documentation of referral status needs to be added to the Inventory instrument.

Another limitation was the level of experience of the clinicians. The clinicians we received data from were all licensed athletic trainers with only 1 to 2 years of experience. With less experienced athletic trainers, we do not know if confidence or skill level interfered with or altered the referral decision process.

**Significance**

The OARs have been used in hospital settings to decrease the number of unnecessary diagnostic imaging to determine the presence of fracture after a foot or ankle injury. In the emergency room setting, the standard of care is for all patients to receive diagnostic imaging to rule out a fracture. The dependence on imaging is based on patient demands and legal responsibilities. However, in the athletic training profession, this is not the standard of care unless the pathology specifically warrants diagnostic imaging.

The use of the OARs did not decrease the number of images warranted. Many
images met the OARs criteria for referral, but a small number of fractures were actually present. The rules are an effective method in ruling out the presence of a fracture, with strong sensitivity and negative predictive values. Measures of accuracy suggest that the OARs are not dependable indicators of ruling in the presence of a fracture, however fractures are rarely missed when applying the rules.

We attribute this high percentage of difference between those examinations which met the criteria and those examinations that did not obtain radiographs to the circumstance that all initial examinations were completed by an athletic trainer. We believe experience level, confidence level, and logic play a role in the referral process to help decrease unnecessary diagnostics as well. With the help of licensed athletic trainers and the use of OARs, injuries can be adequately referred, without being over-referred. This study analyzed many different factors and variables of the OARs. These variables were analyzed over multiple periods of time.

**Predictor variables.** Our study specificity broke down the predictor variables of palpation and weight bearing status. Palpation tenderness revealed a higher sensitivity, but weight bearing status revealed a higher specificity. Both variables had low positive predictive values, and high negative predictive values. Through palpation tenderness only, 158 false positive and 1 false negative results were captured. Weight bearing status only captured 26 false positives and no false negative results. With a high sensitivity, palpation tenderness seems to be a better predictor of ruling out fractures. With a higher specificity, weight bearing status seems to be a better predictor of ruling in the presence of a fracture. When used in combination the sensitivity and specificity both increase from
the weight bearing status only. With these results, we should not rely on either variable alone, but should rely on both variables in combination.

**Diagnostic imaging.** According to the OARs criteria, 75% of initial examinations should have been referred for diagnostic imaging to determine the presence of a fracture. However, only 5% of those injuries actually had a fracture present. If all of the injuries that met the criteria actually received further diagnostics, 70% of the radiographs would have been unnecessary. Previous studies report that the use of the OARs decreased unnecessary radiographs by 40%. This study demonstrates an increase in 70% of unnecessary diagnostics. These values are not consistent with previous data which indicated the OARs decrease the number of unnecessary radiographs.

With this result alone, we can determine that the OARs are not a valid tool in decreasing the number of unneeded diagnostic imaging. Of the 75% of cases that met the OARs criteria, only 21% actually obtained the imaging. Although we cannot support with evidence because referral suggestion was not documented, we attribute the difference in suggested and obtained to an athletic trainer completing the examinations. An additional predictor variable must be established to improve the validity of the OARs criteria.

**Future Data Analysis**

For the OARs to be useful in the acute setting, the number of false positive results must be reduced. Our data should be further analyzed by including additional predictor variables (eg, range of motion deficits, strength deficits, additional pain locations, equal populations) to better delineate between fractures and nonfractures.
Conclusion

With the high number of false positives, even if the OARs were positive, it does not necessarily indicate that they are a good predictor of determining the presence of a fracture. The OARs in our study did capture all positive results, and no fractures were missed. However, a main reason the OARs were established was to eliminate unnecessary radiographs.\(^3,11,12,19\). With this, another predictor variable is needed to increase the confidence of the OARs at ruling in a fracture.

With the low specificity findings of the OARs, we cannot confidently rule in the presence of a fracture. With this, a degree of clinical decision making is still needed to decide whether a referral is necessary. In the acute setting, the OARs are a useful tool in the referral process, however, further interventions and research are required to increase the diagnostic confidence level.

Our study of the OARs in acute and initial examinations of foot and ankle pathologies reveals a consistency in the overall sensitivity and a slight decrease in the specificity. Our findings did not reduce the number of radiographs obtained. However, the use of an athletic trainer completing the initial examinations did save some of the unnecessary referrals.

If the OARs are positive, we cannot depend on the rules to rule in the presence of a fracture. However, if the OARs are negative, there is a high confidence level that the patient does not need to be referred for diagnostic imaging to determine a fracture. This study suggests that negative OARs are a good predictor variable appropriate in ruling out the presence of a fracture, but not reliable or dependable in ruling in a fracture.
References


Appendix A: Ohio University Ankle Inventory Form

Ohio University Ankle Inventory

Case ID  
Injury Date  
Time Injury Occurred  
Age  
Sport  
Level  
Sex  

- Baseball
- Softball
- Basketball
- Track/cross country
- Field hockey
- Volleyball
- Football
- Wrestling
- Soccer
- Other

This Examination was Completed On:

- Examination Date
- Time Examination Occurred

Patient-Reported Pain  

Pain Elicited During Palpation

Please fill in the bubbles relative to where the patient reports pain.
Please fill in the bubbles relative to where pain is elicited during palpation.

ROM Deficits
- A: Active
- P: Passive

NT A P  
- Plantar flexion
- Inversion
- Dorsiflexion
- Eversion

Strength Deficits
- NT
- Plantar flexion
- Inversion
- Dorsiflexion
- Eversion

Joint Stability Testing
- Inversion Talar Tilt
- Eversion Talar Tilt
- Anterior Drawer
- External Rotation

Diagnosis
- NT = not tested

Functional Status
- Restricts sport participation
- Restricts activities of daily living
- Affects school function
- Alters sleep patterns

Ambulatory Status
- Full weight-bearing (no walking restrictions)
- Partial weight-bearing
  - Limited steps
  - Number of Steps
  - Crutch assisted
- Non-weight-bearing

Diagnostic Images
- Radiographs: 
- CT Scan: 
- MRI:
- Other:

Excellence in Rural Health Care
Appendix B: Ottawa Ankle Rules

1. Bone tenderness at A, B, C, and/or D
   
   OR

2. Inability to bear weight
   
   OR

3. Inability to take four steps
Appendix C: The FADI Score and Sports Module

The Foot and Ankle Disability Index (FADI) Score and Sports Module

Name: ______ Date: ______

Please answer every question with one response that most closely describes your condition within the past week by entering the appropriate number in the box. If the activity in question is limited by something other than your foot or ankle, mark N/A.

<table>
<thead>
<tr>
<th>Unable to do</th>
<th>Extreme difficulty</th>
<th>Moderate difficulty</th>
<th>Slight difficulty</th>
<th>No difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

- Standing
- Walking on even ground
- Walking on even ground without shoes
- Walking on uneven ground
- Stepping up and down curves
- Sleeping
- Walking initially
- Walking approximately 10 minutes
- Home responsibilities
- Personal Care
- Heavy work (push/pulling, climbing, carrying)
- Walking up hills
- Walking down hills
- Going up stairs
- Going down stairs
- Squatting
- Coming up to your toes
- Walking 5 minutes or less
- Walking 15 minutes or greater
- Activities of Daily Living
- Light to moderate work (standing, walking)
- Recreational activities

Sports Module:
- Running
- Jumping
- Landing
- Squatting and stopping quickly
- Cutting, lateral movements
- Low-impact activities
- Ability to perform activity with your normal technique
- Ability to participate in your desired sports as long as you would like

Pain related to the foot and ankle:

<table>
<thead>
<tr>
<th>Unbearable</th>
<th>Severe Pain</th>
<th>Moderate Pain</th>
<th>Mild Pain</th>
<th>No Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

- General level of pain
- Pain at rest
- Pain during your normal activity
- Pain first thing in the morning

Office Use Only: Score: _____/136 points [FADI 104 points & SPORTS 32 points; No Disability 136]
Number of PT Sessions: _____ ☐ Discharged ☐ Male ☐ Female Age: _____ PT Initials: _____
ICD-9 Code: ___________________________ Referred By: ___________________________

Available online at: http://sapphirept.com/wp-content/forms/Foot_and_Ankle_Disability_Index_and_Sports_Module_(FADI).pdf
Appendix D: 2 x 2 Contingency Tables

OAR- All Initial Examinations N= 228

<table>
<thead>
<tr>
<th>OAR</th>
<th>Fracture Present</th>
<th></th>
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OAR- Group 1 (<60 min) N= 124

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OAR- Group 2 (1 hr- 48 hrs) N= 76

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OAR- Group 3 (2 days- 10 days) N= 28

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### Palpations Only-All Initial Examinations N= 228

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### Palpations Only- Group 1 (<60 min) N= 124

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### Palpations Only- Group 2 (1 hr- 48 hrs) N= 76

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### Palpations Only- Group 3 (2 days- 10 days) N= 28

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### Weight Bearing Only-All Initial Examinations N= 228
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### Weight Bearing Only- Group 1 (<60 min) N= 124

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### Weight Bearing Only- Group 2 (1 hr- 48 hrs) N= 76

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### Weight Bearing Only- Group 3 (2 days- 10 days) N= 28

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### Palpations AND Weight Bearing- All Initial Examinations N= 228
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Palpations AND Weight Bearing- Group 1 (<60 min) N= 124

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Palpations AND Weight Bearing- Group 2 (1 hr- 48 hrs) N= 76

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Palpations AND Weight Bearing- Group 3 (2 days- 10 days) N= 28

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