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Example
A STUDY TO ASSESS THE ABILITY OF RADIOGRAPHERS TO APPLY PATTERN RECOGNITION CRITERIA AND INTERPRET RADIOGRAPHS.

By

Lynne Janette Hazell

A dissertation submitted in fulfilment of the requirements of the

MAGISTER TECHNOLOGIAE IN RADIOGRAPHY (DIAGNOSTIC)

In the
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Johannesburg 2012
DECLARATION
I declare that this dissertation is my own, unaided work. It is being submitted for the Master of Technology at the University of Johannesburg, Johannesburg. It has not been submitted before for any degree or examination in any other institution.

_______________________________________
(Signature of Candidate)

________________ day of _______________________.

ABSTRACT

In order to meet the needs of the country South African radiographers need to become multi skilled radiographers. Empowering diagnostic radiographers with pattern recognition skills to enable them to comment on images could address the problem in many South African departments where a shortage of radiologists’ results in delayed reports or no reports to referring doctors.

The research assessed the ability of qualified diagnostic radiographers in two Gauteng Government Hospital’s to apply pattern recognition and provide a comment on a radiograph after training in musculoskeletal pattern recognition.

The study employed a pre- and post-test model with an intervention which comprised training of radiographers in musculoskeletal pattern recognition. The post- test results showed a significant improvement in the accuracy of identifying abnormal images and the comments provided were more complete than before training.

Thus the intervention was successful in improving the ability of the radiographers to recognize normal and abnormal images, however, the training would need to be more extensive for an accurate comment to be provided on musculoskeletal images.
DEDICATION

I dedicate this dissertation to my husband, Roy and my children Matthew and Lauren for their support throughout this long process.
ACKNOWLEDGEMENTS

There are so many people who have helped me along the way with this process I would like to recognise their help and expertise during this time.

To my supervisor Jenny Motto and my co-supervisor Lucky Chipeya for their support and guidance.

The STATKON department of the University of Johannesburg for the statistical analysis of the data.

Juliana van Staden for her patience and assistance in interpreting the statistical information.

The radiology departments at Tambo Memorial Hospital and Chris Hani Baragwaneth Hospitals for allowing their staff to participate in my research.

All the participants who gave up their time.

Dr Peter Evan and Dr Ash Ranchod the radiologists who provided the expert knowledge and images for the research.

The Staff Qualification Project of the University of Johannesburg for the financial support and guidance.

Mavis Arthur for editing the dissertation so expertly.

Roy, Matthew and Lauren for always supporting me and inspiring me to continue on and complete the task.
To my Dad Geoff Fisher who inspires and motivates me to achieve the best I can and always believed in me.
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CHAPTER ONE

INTRODUCTION

1.1. INTRODUCTION

In South Africa at present challenges exist in the radiology departments of Government hospitals. One of the challenges is a lack of radiography staff in radiology departments. For this reason radiography in South Africa has been declared a scarce skill by the Department of Labour and the Department of Health in terms of the National Scarce Skills List (2008: 11). The shortage of staff can be attributed to the low employment retention rate of qualified diagnostic radiographers. According to Nightingale and Hogg (2003:81), in a study conducted in the United Kingdom (UK), diagnostic radiographers perform below the level of their professional potential. Diagnostic radiographers, in turn expressed the opinion that they are not highly regarded by their peers professionally. A study by Gqweta (2012:24) concluded that radiographers from the Western Cape were of the opinion that they should acquire skills that allow them to move into new roles that would improve the status of radiographers. In the South African context a possible way to empower diagnostic radiographers is to provide training in pattern recognition skills, which could lead to image interpretation becoming part of role extension for radiographers. The promotion of role extension for radiographers could also provide an increase in motivation and improve the retention of staff in the profession.

Another challenge in radiology departments is that many radiographs/images leave the radiology department without any form of report or interpretation. Due to the shortage of radiology staff, it is not possible for a radiologist to report on all radiographs. This may result in delayed reports on plain radiographs to referring doctors or in some instances no reports at all. Radiographers could be used to meet the radiographic needs of the country by becoming multi skilled professionals.
One way in which this could be done is to empower radiographers by enabling them to acquire pattern recognition skills and then with further training they could interpret images in an x-ray department. This would go some way to alleviate the current problem faced by many South African radiology departments.

In order to empower diagnostic radiographers with the necessary skills to interpret radiographs research is required to establish the type of training required in the Gauteng area. To establish whether musculoskeletal pattern recognition training can provide the skills necessary for qualified radiographers to provide image interpretation at the front-line in Government hospitals of Gauteng, such training needs to be investigated and assessed to establish whether radiographers are able to interpret images accurately when using these skills. Nightingale and Hogg (2003:83) found that with the correct formalised training in pattern recognition radiographers are able to interpret images in the UK. The South African setting, however, has different challenges to those in the UK. According to Williams (2009: 17) 68% of radiologists in the Western Cape are supportive of radiographers extending their role. However, 54% of the respondents were of the opinion that radiographers were not capable of interpreting trauma images without further training. Therefore although radiologist may have expressed support for role expansion they are not prepared for radiographers to interpret images without further training and the research was restricted to the Western Cape. Anecdotally radiologists in Gauteng have not appeared supportive of role expansion into image interpretation although research has not been conducted in Gauteng to confirm this opinion. Secondly the pathology seen in South Africa particularly in the government hospitals is significantly different to that seen in the UK. The high prevalence of the human immunodeficiency virus (HIV) in the South African population introduces a significantly different pathology than that found in the UK There are an estimated 5.38
million people living with HIV in South Africa this would be 10% of the population (Mid-year population estimates, 2011:5).

This study aimed to assess the ability of qualified diagnostic radiographers to apply pattern recognition criteria and interpret musculoskeletal images. Pattern recognition for the purpose of the study was the recognition of normal anatomy and those variants from the norm which indicated an abnormality (Corr, 2001:3). Once assessed, it could be established whether a formalised post qualification course in pattern recognition of the musculoskeletal system could provide the basis for image interpretation as a form of role extension for radiographers. Image interpretation in the context of the study was a comment on the image that identified the type and location of the abnormality. In turn, the burden on radiologists could be alleviated and a better service implemented for referring doctors and patients should the role of radiographers be extended to provide an initial comment on an image.

1.2 HEALTH SECTOR IN SOUTH AFRICA

In support of expanding the role of the diagnostic radiographer in the National Health Service in South Africa the Department of Health (DOH) published The Charter of the Private and Public Health Sectors of the Republic of South Africa which cited the need to use the human resources available in the public health sector effectively and efficiently (2005: 4). The Charter of the Private and Public Health Sectors of the Republic of South Africa identified a shortage of staff in the radiology department as a human resource problem that needs to be addressed (2005:14). Training in pattern recognition could produce diagnostic radiographers with the skills required to interpret images and effectively improve the quality of patient care, thereby improving the efficiency of the radiology department. The DOH (in: The Charter of the Private and Public Health Sectors of the Republic of South Africa, 2005:28-29) in proposing solutions to the
problem of staff shortages the DOH identified the provision of continued professional development (CPD) education, training and skills development as necessary for a coherent health system. The DOH (in: The Charter of the Private and Public Health Sectors of the Republic of South Africa 2005:11) defined skills development as the:

“......process of enhancing individuals’ specialised capabilities in order to provide them with career advancement opportunities”.

The Health Charter requires that human resources be used in a way most beneficial to the Health Service. The Modernisation of Tertiary Services – Diagnostic Radiology Report of the 13th February 2003 identified pattern recognition as a possible skill, which with post diploma training could lead to role extension for radiographers. The Charter of the Private and Public Health Sectors of the Republic of South Africa endorses the need to establish training for diagnostic radiographers which, if implemented could lead to the development of skills enabling them to play a role in the image interpretation of musculoskeletal radiographs, thereby utilising their full potential and improve their career path.

1.3 DEFINITION OF KEY CONCEPTS

The following concepts and terms are relevant to the study:

1.3.1. Diagnostic Radiographer

A diagnostic radiographer is a healthcare professional who performs various specialised diagnostic imaging techniques using different types of equipment to produce high quality images, which will enable the diagnosis of trauma or disease (http://www.sor.org/about-radiography).

1.3.2. Radiologist

A radiologist is a medical practitioner who has specialised in the interpretation of radiographic images to provide diagnoses of trauma and disease. The report of a radiologist on a radiographic image is
considered the “gold standard” for reporting (Murphy, Loughran, Birchenough, Savage & Sutcliffe, 2002: 216).

1.3.3. Radiograph

A radiograph is an image that is obtained using x-ray techniques and equipment. This radiographic image is then used to provide a diagnosis (http://www.radiologyinfo.org/en/glossary/glossary1.cfm).

1.3.4. Pattern Recognition

Pattern Recognition is the ability to recognise normal anatomy on an image and the variants in a normal image and to identify the variants from the normal which could indicate abnormal pathology on the image (Corr, 2001:3). The normal patterns can then be compared with patterns or shapes that demonstrate abnormalities particularly of the musculoskeletal system in terms of this research.

According to the minutes of the HPCSA Professional Board for Radiography of date November 1996, quoting from a letter N.M.Prinsloo (Registrar, South African Medical and Dental Council, 23rd January 1997), pattern recognition is defined as:

“.....the recognition of a variation of normal images, which simultaneously recognised the competency of radiographers to recognise normal images. This could, however under no circumstances be considered as making a diagnosis”

Pattern recognition is the foundation of radiographic reporting (Reeves, 2004:213). Pattern recognition “involves comparing mental images of patterns (anatomical, pathological) to arrive at a diagnostic opinion” (Higgs & Jones, 1995: 121).

1.3.5. Image Interpretation

For the purposes of this study image interpretation is a radiographer providing a comment on the appearance and position of an abnormality
based on their knowledge of pattern recognition criteria. According to Robinson (1998: 155) the report or interpretation on an image includes a description of the location of the pathology and observational information which incorporates pattern recognition and therefore leads to an explanation of the findings and possibly their significance for the treatment of the patient. Thus pattern recognition leads to the comment or image interpretation (Robinson, 1998:155).

1.3.6. Musculoskeletal

In this study the appendages to the body, namely the upper and lower extremities and the spine and pelvis constitute the musculoskeletal system. The areas included in the study are the appendicular system and the axial system excluding the skull.

1.4 PROBLEM STATEMENT

In 2006 the South African Government recognised the ability of qualified diagnostic radiographers to provide an interpretation of a radiographic investigation to the practitioner as approved by The Professional Board for Radiography. According to the Government Gazette, 4th August 2006, No 29079: Annexure 10 regarding Rules of Conduct Pertaining Specifically to the Profession of Radiography and Clinical Technology:

“A radiographer shall not interpret radiographical investigations, report thereon or furnish information in regard to any work performed by him or her profession to any other person other than a practitioner approved by the board at whose request such work was undertaken.”

By implication a radiographer can, therefore provide a comment on a radiograph for the medical practitioner who requested the radiographic examination. Thus when a patient is referred from the Accident and Emergency (A&E) department to the radiographer and provides image
interpretation to the clinician who referred the patient to the radiology department. However, it is a skill that is not used within the overextended health system in South Africa. Unfortunately the majority of research in the field of radiographer image interpretation and training has been conducted in overseas settings, which are not necessarily transferable to the South African setting. These studies demonstrated that with the correct training radiographers can provide image interpretation to a very high standard. A study of this kind would be appropriate in the government hospitals of Gauteng as role extension for radiographers could alleviate the burden on radiologists and casualty staff and improve job satisfaction for radiographers, which may in turn persuade them to remain in the Government Sector. This would in turn be of benefit to the patient and according to Nightingale and Hogg (2003:81) there is much evidence that points to improved patient experiences as a result of role extension such as pattern recognition.

1.5 RESEARCH AIMS AND OBJECTIVES

1.5.1 Aim of the Research

The aim of the study was to assess the ability of qualified diagnostic radiographers in two Gauteng Government hospitals to apply pattern recognition and interpret a radiograph after training in musculoskeletal pattern recognition.

1.5.2 Objectives:

The objectives of the study were to:

• To train qualified radiographers in musculoskeletal pattern recognition.

• To assess the ability of radiographers to interpret musculoskeletal radiographs accurately after undergoing training.
1.6 PATTERN RECOGNITION

Pattern recognition skills are taught at diploma level in South Africa in some institutions. Pattern recognition provides the radiographers with criteria that allows them to identify specific patterns distinguishing normal and abnormal appearances on a radiograph. Based on communication from N.M.Prinsloo, South African Medical and Dental Council, (23rd January 1997) the Professional Board of Radiography recommended that pattern recognition be adopted as part of the scope of all qualified radiographers in 1997 and proposed that training centres implement pattern recognition in their curriculum. However to date no formal postgraduate training in pattern recognition exists for South African radiographers and as a result pattern recognition and interpretation of images are not formally put into practice in the workplace.

1.7 POSTGRADUATE TRAINING AND THE ““RED DOT”” SYSTEM

Postgraduate training for qualified radiographers in musculoskeletal pattern recognition leading to image interpretation has proved very successful overseas particularly in the United Kingdom (McConnell & Webster, 2000: 608). The ““red dot”” system has been a widespread precursor to image interpretation in the UK and was introduced in the 1980’s to alleviate the delay in reporting radiographs due to the shortage of radiologists, which is similar to the situation South Africa faces at present.

Image interpretation has not been undertaken locally except in the form of the ““red dot”” system of identifying abnormal radiographs. However, in an interview with Ms. I. Williams, Lecturer in Radiography, Cape Peninsula University of Technology. (2007) she stated that the ““red dot”” system of image interpretation has been implemented in parts of the Western Cape region.
The system requires that a “red dot” be affixed to the radiograph to indicate that the radiographic image is abnormal. The “red dot” system allows radiographers to identify radiographs, which are abnormal without commenting on the type or position of the abnormality. This may not provide adequate diagnostic value without some formal identification of the abnormality in the form of a comment on the image. The aim of providing pattern recognition skills and image interpretation is to improve the service provided to the patient in the form of a timely interpretation of the radiograph to the patient and clinician, so that treatment can be implemented accurately and efficiently. According to Nightingale and Hogg (2003:81), the introduction of trauma image interpretation in the A&E environment has been largely due to the fact that previously radiographs were unreported or the availability of reports were available too late to affect the treatment of the patient. The introduction of radiographer image interpretation provides for immediate comments which are useful in patient treatment.

Commenting on images expands on the “red dot” system thus further training in pattern recognition skills could enable trained radiographers to go beyond a “flagging system” not merely identifying the normal and abnormal images. The extended pattern recognition training would provide additional skills to enable a description and location of the abnormality identified on a musculoskeletal image.

Previous research into the ability of radiographers to interpret images after training in pattern recognition and the application of this knowledge in providing image interpretation has been undertaken in the United Kingdom. Research conducted in the UK by Nightingale and Hogg (2003:77-83) indicates that with the necessary formalised training radiographers are capable of pattern recognition. The researcher felt that it was necessary to conduct research in the South African context. Research
to demonstrate the ability of radiographers in providing a comment on a radiograph to a high standard, when provided with the correct training, would provide evidence in support of role extension for radiographers. The pathology seen on radiographs from developing countries may be very different from that seen in developed countries. Therefore, any musculoskeletal pattern recognition training in image interpretation would need to be adapted for specific needs within the South African context.

Research on training radiographers in pattern recognition to the required high standard could provide the basis for establishing appropriate training courses in the future.

1.8 SUMMARY

When considering the South African context, radiographers could be trained to provide an essential service; such as image interpretation in the Government hospitals, which at present cannot be provided for all radiographic examinations performed. Anecdotal evidence suggests many radiographers are disillusioned with the profession and would like training to provide them with skills, which could lead to role extension in radiography. Therefore training in pattern recognition leading to radiographers capable of image interpretation could increase the status of radiographers. The South African Department of Health has a challenge at present in that radiography is classified as a scarce skill and therefore the profession needs to retain qualified diagnostic radiographers in the profession. Empowering diagnostic radiographers with the pattern recognition skills necessary to accurately interpret images could impact on retention of diagnostic radiographers. At present many x-ray images leave the department with no indication of the abnormality seen on the image. A diagnostic radiographer capable of interpreting images could lead to improved patient care and treatment.
CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Both radiography and radiology in South Africa have been declared scarce skills by the Department of Health and the Department of Labour (National Scarce Skills List: 2008). Due to the lack of radiology staff, radiographers could be used to meet the needs of the country by becoming multi skilled professionals. One way in which this could be done is to empower radiographers with pattern recognition skills that would allow them to provide an immediate interpretation in the form of a comment on musculoskeletal images. This would alleviate the current problem faced in many South African radiology departments where a shortage of radiologists results in delayed reports to referring doctors or in some instances no reports are available. The aim of this literature review is to examine existing knowledge and consider the outcome of previous research and the methods used in their research (Mouton, 2001: 86-7).

Research concerned with the ability of radiographers to accurately interpret images and the training required to achieve this outcome has been conducted predominately in the UK. and more recently in Australia. One research study has been conducted in South Africa by Williams (2009:15-17). This study was concerned with the ““red dot”” system and excluded the training of radiographers in image interpretation. Therefore a review of the implementation of pattern recognition training and image interpretation from the perspective of the UK, Australia and the United States of America (USA) provided the background to the study undertaken in the South African context and assisted in identifying the gap in the knowledge of South African radiographers. This chapter considers the evolution of image interpretation from the ““red dot”” system to reporting radiographers and the types of training required to establish a standard of
image interpretation acceptable in the clinical environment. Issues concerning the anatomical areas most appropriate for image interpretation are discussed with consideration given to the type of commenting required and the appropriate environment for the implementation of image interpretation to be of benefit to the patient. An insight is provided into changes in the role of diagnostic radiographers that will occur as a result of the acquisition of image interpretation skills in a global context.

In the past, the most common radiographer abnormality detection system (RADS) has been the “red dot” system. Evidence has shown, however, that ambiguity can occur within this system. Therefore, this flagging system has changed to one in which radiographers provide comments on the radiographs. This is a progression from merely indicating that there is an abnormality on the radiograph to describing the abnormality type and location seen on the image (Hardy & Culpan, 2007:66).

Qualified diagnostic radiographers providing a comment on an image may require additional training beyond that offered at qualification level. Pattern recognition provides knowledge of the normal and abnormal characteristics of the anatomical region. Musculoskeletal radiographs have been shown to be successfully interpreted following training in the UK (McConnell & Webster, 2000:608; Piper & Paterson, 2009:46; Hargreaves & Mackay, 2003:288). According to the Royal College of Radiologists (RCR) (in: Standards for Reporting and Interpretation of Imaging Investigations, 2005:11) non-medical professionals could undertake image interpretation. However, they should be trained in radiological observation and analytical skills before providing image interpretation. The areas interpreted by non-medical staff should be single areas where a yes/no response is required and the radiographer must have a radiologist available to consult with in difficult and complex cases (RCR, 2010:2-3).
According to the Society and College of Radiographers (SCoR) (2006: 6) there was a shortage of radiologists in the UK in 2006. At this time there was an increase in the demand for radiologists to perform Computerized Tomographic (CT) imaging examinations and interventional studies. The reporting service provided for A&E images was compromised as a result of this increased workload SCoR, (2006:6) which created a shortage of radiologists. As a result it was advocated that radiographers with the appropriate training could provide a timely report on A&E images. The UK implemented training for diagnostic radiographers at a postgraduate level to provide for the establishment of reporting radiographers. Due to this initiative in 2006 the UK became the most advanced country with respect to radiographers providing an image interpretation service. Many other countries including South Africa are still in the process of deciding the type of role extension that would be most beneficial for diagnostic radiographers. Some countries are opposed to radiographers providing a comment on an image, as it is felt that radiographers do not have the same clinical background as is required of radiologists. In Australia, Cook, Oliver and Ramsay (2004:65) found that there would need to be more cooperation on the part of the radiology community before role extension could be effectively established. Cook et al., (2004:65) stressed that a formal training programme was required for radiographer reporting to be implemented and that this should take place in conjunction with continued education by radiologists in the clinical environment.

2.2 BACKGROUND TO INITIAL FLAGGING SYSTEMS

Research involving radiographers’ capability in identifying abnormalities on radiographs dates back to the 1980’s in the UK. In 1982, a scheme was introduced at Ealing Hospital where radiographers undertook to mark the envelopes where the mark indicated that the radiographs in the envelopes demonstrated an abnormality. The images were referred to the radiographers from the A&E department and were therefore trauma
images (Berman, De Lacey, Twomey, Twomey, Welch & Eban, 1985: 421).

The original scheme was suspended in 1983. However, in 1984 at the same hospital a slightly different system was implemented whereby qualified radiographers completed a form where they provided a comment on the image identifying it as normal or they identified the image as abnormal and described the abnormality on the image. One thousand six hundred and twenty eight images from the A&E department were interpreted and referred back to the A&E department. The casualty officers were not informed that the radiographers had interpreted the images and the casualty officers did not receive the forms. The casualty officers interpreted the images themselves as no report on the images was provided. Within 24 hours two consultant radiologists conducted an analysis of the comments received from the radiographer’s and the notes made by casualty officers on their interpretation of the images (Berman et al., 1985:421). The radiologists found that the radiographers missed abnormalities on 4.5% of the patient’s radiographs and the casualty officers missed 4.2%. Initially this result appears to suggest a similar ability to interpret images by both the radiographers and the casualty officers. However, the images incorrectly interpreted were different for each group therefore it was recommended that a scheme where radiographers provided an opinion would be considered beneficial to the casualty officer and the patient (Berman et al., 1985:421). In the light of the fact that the research highlighted the ability of radiographers to identify clinically significant abnormalities not seen by the casualty officers, such a scheme would reduce the errors in image interpretation so that a more accurate decision could be made regarding the treatment of the patient (Berman et al., 1985:422).
2.3 THE ““RED DOT”” SYSTEM

2.3.1 The Origin of the ““red dot”” System

The “red dot” system is the adhesion of a red sticker to a radiographic image that the radiographer has identified as abnormal. The absence of a red sticker implies the absence of an abnormality (Hardy & Culpan, 2007:66).

The “red dot” system has been well documented overseas. According to a report issued by the Society of the College of Radiographers (SCoR, 2006:12) in the UK the “red dot” system has been used since the 1980’s for A&E referrals in radiology departments. This report by the SCoR suggested the “red dot” system has been the standard practice for radiographers on qualification for 20 years. In the A&E environment the qualified radiographer provides a minimum of a “red dot” on a film indicating an abnormal image. Since 1994 the College of Radiographers (2006:5) has advocated that radiographers should expand on the “red dot” system by providing a verbal or/ and written comment on an abnormal image. Therefore SCoR (2006:10) recommended that image interpretation and clinical reporting by radiographers should become a core competence and that all undergraduate qualifications should include a module in image interpretation in their curriculum. In order to be accredited or reaccredited for a degree course the institution needed to comply with this requirement before September 2010. Any qualified radiographer who wished to participate in image interpretation but who had not received pre-registration training in image interpretation would be required to enrol in a post graduate programme in image interpretation (SCoR, 2006:12).

In terms of the SCoR document (2006:10) the images to be interpreted by newly qualified diagnostic radiographers would be those that were
normally “red dotted” in respect of the skeletal and trauma images from the A&E department.

According to Hargreaves and Mackay (2003:283) the ““red dot”” system as previously explained is usually used within the A&E department. In the UK, Radiographers with their knowledge and skills obtained during the diploma or degree course, along with their experience in the clinical environment are therefore far more capable of providing an accurate assessment of normal versus abnormal radiographs than an inexperienced casualty officer. In further research Hardy and Barrett (2004: 657) found that the Senior House Officer or Casualty Officer is often the least experienced clinician in their first position of post registration experience and therefore a junior doctor with very little clinical experience. The casualty officer is also inexperienced in image interpretation. The researchers were of the opinion radiographers could be used for immediate image interpretation as their experience in observing trauma images is far greater than that of the casualty officer (Hardy & Barrett, 2004:661). According to Wood (1999: 2) the difference between a novice and an expert when perceiving and interpreting images is the experience gathered from viewing a large number of images. When comparing the casualty officer and the radiographer it would appear the radiographer is more likely to have more experience in observing radiographic images.

2.3.2 The ““red dot”” System in the South African Context

South African undergraduate programmes are not nationally uniform in the modules they offer. Only certain institutions provide pattern recognition training to assist with image interpretation, although as stated previously (cf 1.4) pattern recognition is part of the scope of practice of radiographers. For example at the University of Johannesburg pattern recognition that is applied to specific systems relevant to the year of study is an expected learning outcome for all students in radiographic practice.
Within the learning outcomes for the modules where pattern recognition is taught the "red dot" system is identified as a flagging system and the students understand the role of such a system. Thus, at diploma level students receive the preliminary skills to differentiate between normal and abnormal radiographic patterns, which could allow them to comment on radiographs after additional training. However, at present a system for using these skills is not in place in either the Government or Private sector in Gauteng.

In an interview conducted with Ms. I. Williams, Lecturer in Radiography, Cape Peninsula University of Technology. (2007), she stated that the "red dot" system had been introduced in 50-65% of the Western Cape hospitals whereas the "red dot" system is not currently used in the Gauteng region. In the context of this research the introduction of the "red dot" system into the Government hospitals in Gauteng would extend the role of radiographer's in the Gauteng Health Services. When considering that most of the research undertaken on this topic produces results indicting that the introduction of a commenting system rather than the "red dot" system appears more beneficial to the A&E practitioner and the patient (Hardy & Culpan, 2007, McConnell & Webster, 2000, Hardy & Barrett, 2004), a strong argument emerges for the introduction of pattern recognition training and a commenting system in the Gauteng Health Services.

2.3.3 Advantages and Disadvantages of the "red dot" System

Hardy and Culpan (2007:66) found the "red dot" system to be extremely popular in the UK and operational in 89% of its hospitals. However, the authors expressed a concern that the system although prevalent in such a large number of hospitals has an element of ambiguity in its application. A "red dot" when applied to a radiograph expresses that it is the opinion of
the radiographer that there is an abnormality present on the radiograph. Therefore the absence of a “red dot” would indicate a normal radiograph. However, this not necessarily the case. Hardy and Culpan (2007:66) found that participation in the “red dot” system was on a voluntary basis. If a radiograph is produced by a radiographer who does not wish to participate in the “red dot” programme, the absence of a “red dot” could lead to an abnormality being overlooked by A&E practitioners because of their reliance on the presence of a “red dot” to highlight an abnormality. In addition, the “red dot” system in the UK can be interpreted differently in each location as no national guidelines exist (Hargreaves & Mackay, 2003:284). Thus in some locations this could potentially lead to patients in A&E departments not receiving the correct treatment. It would also be more beneficial to patients if radiographers provided a comment on any abnormality seen rather, than limiting it to the “red dot” and to restrict their interpretations to traumatic abnormalities.

Coleman and Piper (2009:197) suggested that the “red dot” system is an inefficient method of identifying an abnormality, unless the abnormality is very obvious to the referring doctor. The referring doctor would otherwise require clarification on the position and type of pathology either verbally or in writing from the radiographer. Coleman and Piper (2009:198) therefore requested the participants in their study to provide a description of the nature and location of any abnormality identified. The participants were thus demonstrating image interpretation and not merely an application of a “red dot” to a radiograph they assessed as being abnormal.

Hargreaves & Mackay, 2003:283 stated that the “red dot” system has largely been implemented to identify traumatic abnormalities in the A&E environment. A further concern expressed by the researchers in respect of the “red dot” system was the lack of consistency in the interpretation of abnormalities of the musculoskeletal system that are non-traumatic, for example degenerative diseases and other pathologies. Although
Hargreaves and Mackay (2003, 284) identified this gap in their study they only provided training on the image interpretation of traumatic abnormalities of the skeletal system. No commenting was provided if the abnormality lay outside the scope of traumatic pathology. Therefore an underlying chronic condition could go unacknowledged.

Brealey, Scally, Hahn, Thomas, Godfrey and Crane (2006:605) reviewed research to determine the accuracy of radiographers interpreting images. Brealey et al., (2006: 605) differentiated between those using the “‘red dot’” system to identify abnormal images or a triage system to assess and comment on abnormalities on the images. In the context of their research the “red dot” system was defined as: “..... using a red sticker to indicate the presence of an abnormality on a radiograph.” Their definition of triage was: “.... to provide a comment on the abnormality once the presence of an abnormality had been established.”

The studies that used a triage system used a classification system to identify the image as normal, significantly abnormal or insignificantly abnormal plus a comment in the case of a significant abnormality. The systematic review of the relevant studies highlighted many methodological errors that affected conclusions drawn concerning the accuracy of radiographers applying either the “red dot” system or commenting on the radiographs. However, Brealey et al., (2006: 613), found that although the SCoR wanted radiographers to provide image interpretation on skeletal images after qualification and that the undergraduate curriculum included image interpretation this was inadequate for accurate interpretation of images. They recommended that preregistration education was not sufficient to enable implementation of their policy of all entry-level radiographers providing image interpretation for trauma cases. Brealey et al.,(2006:613) suggested that reporting radiographers require postgraduate training. Brealey et al., (2006, 613) concluded that it is not
that radiographers do not have the ability to interpret images but that the systems require modernisation. In its present form the “red dot” system does not maximise the potential of radiographers to provide a comment, which they are capable of doing with the correct training. It was also noted that the “red dot” system was 20 years old and consideration should be given to extending this system to provide radiographers with opportunities to identify the location, pathology and the clinical significance of the condition whilst also making them accountable for their decisions.

Coleman and Piper (2009:198) conducted research to compare the interpretation skills of radiographers, nurse practitioners and casualty officers. All the radiographers participating in the research had participated in the “red dot” system in the A&E department and had a minimum of 5 years radiographic experience. The nurses and casualty officers did not have specific radiographic interpretation training. The radiographers had far greater experience than the A&E staff in image interpretation in the clinical environment. Sixty seven percent of the radiographers had at least five years experience compared to only 31% of the nursing practitioners who were employed in the A&E department requesting and interpreting images for the same time period. Coleman and Piper (2009: 199) compared the ability of all the participants in the study to provide accurate image interpretations and found that radiographers were more accurate at a 71% accuracy rate compared to either the nursing practitioners or casualty officers at 53% and 54% respectively. Thus, Coleman and Piper (2009: 201) suggested that their research supports findings that radiographers should be the health professionals who provide accurate initial interpretation on the radiographic image. The researchers also concluded that the “red dot” system should be replaced with a tick sheet for identifying normal and abnormal radiographic patterns together with space for a comment on any abnormality. In addition, Coleman and Piper (2009:202) they concluded that radiographer would be more motivated in their role as part of the A&E department team, gain greater job satisfaction
and a more accurate image interpretation for the A&E team and therefore an improved service to the patient.

An additional aspect of the research that Coleman and Piper (2009: 198) wanted to establish was how the participants rated their ability to interpret radiographic images. The participants were asked to rate themselves on a scale of 1-10 as to how accurate their image interpretation skills were on a day-to-day basis. The radiographers were more realistic in assessing their ability to accurately interpret images in contrast to the nursing practitioners and the casualty officers who overrated their level of accuracy in image interpretation. Coleman and Piper (2009:201) suggested that this overconfidence in their ability to correctly interpret images could lead to misdiagnosis and incorrect treatment, which supports the premise that radiographers interpreting images give a more accurate initial interpretation of the radiographs in the A&E department.

The “red dot” system has been a stepping-stone towards diagnostic radiographers providing a comment on the image. Price and Le Masurier (2007:23) considered a RADS or “red dot” system in their research not as a form of role extension, but rather as a precursor to radiographers providing image interpretation with a comment on the radiograph, which in turn would then be a specifically identified form of role extension for the diagnostic radiographer.
2.4 IMAGE INTERPRETATION AND ITS INTRODUCTION INTO THE CLINICAL ENVIRONMENT

2.4.1 The Accident and Emergency Department

Over the last twenty years RADS has become well organised and has evolved from the “red dot” system to radiographers commenting on images also known as image interpretation in the UK. According to Hardy and Barrett (2004: 658) image interpretation has become part of the role extension of radiographers in the A&E department in the UK. The authors anticipated that radiographers could provide image interpretation to a standard equivalent to a radiologist if they had the correct education, had gained experience in the field and were suitably motivated (Hardy & Barrett, 2004:658).

Hardy and Barrett (2004: 658) conducted a study that compared the role of radiographers and nurses in image interpretation in the A&E environment. A questionnaire was compiled and two pilot studies were conducted. After the initial pilot study alterations were made to the questionnaire, in that more questions were included with the addition of profession specific questions using the appropriate terminology relevant to the specific profession. The second pilot study involved four radiographers and four nurses working in the A&E department. The participants in the second pilot study found the questionnaire easy to understand. The participants in the pilot study did not complete the final research questionnaire. Hardy and Barrett (2004:658) sent out the revised questionnaires to 263 radiographer managers and 263 nurse managers in National Health Service Hospitals of which 198 responses were received from the radiographer managers. From this information Hardy and Barrett (2004:659) deduced that only 34.3% hospitals used radiographers to interpret trauma radiographs. By way of contrast 182 responses were
received from the nursing managers in the A&E departments in which 52.7% of the nursing managers indicated that nurses were used to interpret images. Hardy and Barrett (2004: 660) found that 92.6% of the radiographers interpreting radiographs had a postgraduate qualification in image interpretation whereas the majority of the nurses had no formal structured training. The nurses either had in-house training or had attended a short course in image interpretation. Therefore, the level of education and training of each profession in image interpretation varied considerably. Hardy and Barrett (2004: 660) believed that a different emphasis was placed on the accuracy of image interpretation by the different professions. Radiologists provided the direction for the radiographers and were therefore anticipating that reporting by radiographers would be at an equivalent standard to that of a radiologist. The A&E clinician was responsible for the nursing staff and therefore, their degree of accuracy in image interpretation would be of a standard similar to that of the clinician. As such a less formal training approach was provided with less accuracy anticipated from the nursing staff. The research conducted by Coleman and Piper’s (2009:201) found only a 53% and 54% accuracy rate in image interpretation for nurses and casualty officers/clinicians respectively. The result supports the premise that there is a lower standard of reporting accuracy amongst these professionals compared to the 71% accuracy rate for radiographers. Hardy and Barrett (2004:661) concluded that radiographers are competent in image interpretation. However, due to the present structure of radiology departments and restrictions on radiographers providing information to patients, they are not utilised in A & E departments for image interpretation. Thus nurses will continue to assume this role in A & E departments with little training and less experience and accuracy in image interpretation.

Hardy and Barrett (2004:659) reported that 68 hospitals out of 198 had radiographers formally interpreting images. Of the 68 hospitals 60 had
radiographers who were formally undertaking image interpretation and the radiographers’ comment was considered the only comment required. From this result Hardy & Barrett (2004:660) inferred that radiographers interpret radiographs in line with the reports of the radiologists and are therefore more accurate in reporting than the nursing staff.

In A&E departments the anatomical areas for which image interpretation is provided vary according to the hospital. A radiograph can be an extremely useful tool in the diagnosis of the condition of the patient. However, this is only valid when the health professional providing the interpretation performs the task accurately. Hardy & Barrett (2004:659) researched the specific type of trauma images radiographers and nurses interpret. Radiographers in the 67 hospitals where image interpretation was undertaken all interpreted on appendicular images and 34/67 reported on the axial skeleton (Hardy & Barrett, 2004:659). By way of contrast the nurses interpreted very specific regions. Ninety-six hospitals had nurses interpreting images of which 64/96 interpreted the lower limb to the knee, 62/96 the upper limb to the elbow and 32/96 hospitals restricted the image interpretation according to the age of the patient. Image interpretation on paediatric cases by nurses was not permitted. It could therefore be inferred that the standard of radiographer image interpretation as being more accurate over a large number of anatomical areas in comparison to image interpretation by nurses (Hardy & Barrett, 2004: 660).

2.4.2 “Cold” versus “Hot” Reporting

In the UK the SCoR (2006:9) stated that all trauma images should be “hot” reported by a qualified radiographer. This would provide an immediate interpretation on trauma images by a qualified radiographer at the first consultation with a patient and this could be undertaken as a “first post competency” for graduate radiographers. The SCoR (2006:6) identified
this role for all radiographers as being the most beneficial in assisting A&E staff and patients. Thus it is important to understand the difference between a “hot” report and a “cold” report. In the past when radiographers provided a comment on an image, it has often followed the same pattern as that used by radiologists for their reports. This meant that a report is provided retrospectively which is “cold” reporting. The report is not immediately available with a potential 24-hour delay before becoming available. The lack of an immediate report is in conflict with the expectation that all A&E images are interpreted timeously. The advantage of radiographers providing an image interpretation as a “hot” report implies an immediate interpretation when the patient is present in the A&E department. If the patient is available then a clinical examination could assist with the interpretation of the radiographs and any further images that are required could be taken without delay. The benefits to the A&E staff would be to assist them in providing appropriate and timely treatment to the patient (Hardy & Barrett, 2004:661).

Hardy, Spencer and Snaith (2008: 301) assessed the role of “hot” reporting and its effect on service delivery in the A&E environment. According to Hardy et al., (2008: 302) reporting radiographers in the A&E department perform the same role as that of radiologists. Thus the reporting radiographers were reporting “cold” cases within 24 hours of the patient attending the A&E department in the same way as a radiologist reports. The report may still not be available to the clinician in the A&E department for 72 hours, which is after the patient attended the A & E department for treatment, thereby possibly preventing an amendment to treatment in line with the report by the radiologist or the reporting radiographer. Reporting “cold” cases is not in line with the vision of SCoR (2006:9); as it requires “hot” reporting namely an immediate image interpretation provided for the clinician. Reporting radiographers have postgraduate qualifications in reporting and are therefore employed to fill the gaps left by a shortage of radiologists and not to provide an additional
service in “hot” reporting images. As a consequence of Hardy et al., (2008: 304), study the researchers advocated that “cold” reporting of radiographs is not beneficial to the patient or the clinician and a reporting radiographer with the correct training should provide a “hot” report.

Previous research has suggested that conditions in the department are not conducive to “hot” reporting because there is too much noise and too many responsibilities for reporting radiographers to operate to the highest standards. This prompted Hardy et al., (2008, 302) to compare the accuracy of the reports on musculoskeletal radiographs under “hot” and “cold” reporting conditions. The participants, under “hot” reporting conditions reported the images as a hard copy within the radiographic viewing area of the department and then subsequently, under “cold” reporting conditions, reported on the same images blind to the “hot” report over a period of four months to try to prevent recall of the results. The reporting radiographers who participated in this research had all completed a Masters level qualification in musculoskeletal image interpretation and had 3 years of clinical reporting experience. The hand written “hot” report they provided was the definitive report on the A&E images (Hardy et al., 2008, 302).

The researchers found that the results showed no statistical difference between the “hot” and “cold” reporting (Hardy et al., 2008:303). The results demonstrate that reporting radiographers are capable of accurately commenting under both “hot” and “cold” reporting conditions. Thus the circumstance under which the reporting is conducted appears not to affect the outcome. As a result of these findings Hardy et al., (2008, 304) suggested that “hot” reporting may actually have a beneficial aspect due to the fact that the radiographer has the opportunity to correlate the clinical appearances of the patient with the radiographic image. “Cold” reporting provides no such opportunity to request additional projections or
modalities or to examine the patient. “Cold” reporting can be extremely monotonous and could lead to less vigilant application of the image interpretation criteria. Furthermore Hardy et al., (2008:303) found that the “hot” report was the definitive report and was essential for optimum clinical care. They also felt that the introduction of Picture, Archive and Communication Systems (PACS) could provide opportunities for remote reporting. PACS could allow diagnostic radiographers to interpret images even where the X-ray department was not located in the A&E environment. Thus more opportunities would be created for role extension into trauma image interpretation (Hardy et al., 2008: 303). Job satisfaction could be improved with an opportunity to play a vital role in patient management and therefore clinical care (Hardy et al., 2008:303). According to SCoR (2006:10) “hot” reporting is envisaged in A&E department as a first post competence for qualifying radiographers by 2010. Undergraduate programmes need to assess the ability of qualifying radiographers to interpret plain film radiography and standard contrast media examinations to ensure radiographers are competently equipped to carry out this vision of the SCoR by 2010. According to a discussion paper by Tucker (2010: 1), the undergraduate curriculum does include image interpretation skills for a comment on plain films and contrast media studies. Therefore qualifying radiographers should be able to provide a comment on the type of abnormality seen on the image (Tucker, 2010:2).

2.5 ANATOMICAL AREAS FOR WHICH DIAGNOSTIC RADIOGRAPHERS COULD PROVIDE IMAGE INTERPRETATION

2.5.1 The Musculoskeletal System

Hardy et al. (2008:302) identified the musculoskeletal system in their study into the feasibility of “hot” reporting in the A&E department as the area of image interpretation most appropriate to A&E referrals. The participants in the study had all completed their Master’s Degree in musculoskeletal...
image interpretation (Hardy et al., 2008: 302). The images of the axial and appendicular systems were assessed for image quality and a handwritten comment entered into the clinical files of patients by the reporting radiographer. The comment provided was not limited to trauma image interpretation but included any pathology observed on the musculoskeletal image utilising the pattern recognition skills learnt during the postgraduate qualification.

Musculoskeletal images are the most common images to be interpreted in an A&E department. The appendicular and axial skeleton trauma images specifically require the recognition of fractures. Therefore fracture detection is an integral part of the pattern recognition required for accurate image interpretation in the A&E department. According to Barron & Branfoot (2003:324) approximately 50% of the cases seen in the A&E Department are from trauma. Barron & Branfoot (2003:327) stressed the importance of plain radiography image interpretation as it is the modality that is available 24 hours a day and is cost effective. In their conclusion Baron and Branfoot (2003:339) found that optimum reporting on trauma images needs a good reporting technique, quality images and appropriate clinical information.

Hardy et al., (2008, 304) highlighted the anatomical areas that are most difficult to interpret accurately as the skull and facial bones and the hand and wrist, specifically the carpal bones. These areas have been identified previously as areas of discrepancy for accurate image interpretation in the musculoskeletal system (Hardy & Barrett, 2004:659). According to Hardy and Barrett (2004:659-660) the axial system, which includes the skull and facial bones was only interpreted by diagnostic radiographers in 50% of the hospitals where image interpretation was undertaken by radiographers. These limitations appear to support the principle that these are images that radiographers struggle to interpret accurately. Reporting
radiographers even with training appear to be capable of image interpretation to a high degree if the skull and facial bones are excluded from the axial system (Hardy et al., 2008: 304).

An area of concern for Hardy et al., (2008: 303) was that reporting radiographers were unable to accurately identify anatomical structures and failed to recognise the incorrect anatomical marker on an image they were reporting on. Recognition of these factors is fundamental for any accurate image interpretation and should be included in pattern recognition training. The radiographers who participated in this research had postgraduate qualifications and 3 years of reporting experience. The radiographer would, therefore be expected to establish the adequacy of an image before continuing to comment on an image. It could be anticipated that experienced radiographers would not make this type of error. When considering an image for pattern recognition assessment the first assessment should be on image quality that is, is the radiograph of optimum exposure, medico legally correct and the correct anatomical area demonstrated with the correct anatomical marker. An image, which is substandard, is not conducive to pattern recognition and therefore image interpretation. The images produced for “hot” reporting in Hardy et al., (2008, 304) were produced by all of the radiographic staff in the A&E x-ray department. Therefore, the images were not necessarily taken by those radiographers who reported on the images. Thus the reporting radiographers appear to have assumed the radiographers, had already carried out the appropriate quality assurance. According to Hardy et al., (2008: 304) the lack of quality assurance reflects poorly on the training of the radiographers as “a fundamental assessment of the radiograph,” is essential to image interpretation and raises concerns about the accountability of radiographers.
2.5.2 Paediatric Musculoskeletal Images

Hardy et al., (2008:304) found that paediatric musculoskeletal cases as commonly demonstrated a discrepancy between “hot” and “cold” reporting. This finding is in line with previous research done by Hardy and Barrett (2004:659) and may suggest that the interpretation of paediatric images requires specialised training as the pattern recognition of paediatric images could be more complicated than those of adults due to the different growth patterns and ossification centres. In the research conducted by Hardy and Barrett (2004:659) nurses participating in image interpretation were limited to those images for patients over 16 years of age. Paediatric cases were considered too complex for them to interpret accurately. As a result of their research findings in 2004 and 2008 and due to the difficulty in image interpretation, Hardy et al., (2008:304) suggested double readings of paediatric images, particularly if a radiologist acts as a mentor to the reporting radiographer to help with normal variants seen on paediatric images.

2.5.3 Trauma Radiographs

The A&E environment has been identified as an area where radiographers can interpret radiographs as a “hot” report (Hardy & Barrett, 2004: 660). Trauma radiography should include image interpretation of the axial, appendicular, chest and abdominal systems. Hardy and Snaith (2009:104) maintain that the assessment of the the ability of a newly qualified radiographer in the interpretation of accurate trauma images appears to be the responsibility of the clinical department employing the radiographer. Jones and Manning (2008:202) conducted a survey on the auditing of image interpretation competencies. They identified that the basic competency of the newly qualified radiographer is not assessed by the clinical department which indicates that there is a deficiency in ensuring
the accuracy of image interpretation. However, for postgraduate reporting radiographers’ guidelines are provided by the SCoR as to the auditing mechanisms which should be adhered to by radiographers undertaking a reporting role (Jones & Manning, 2008: 203). Furthermore Jones and Manning (2008:203) indicated that the response rate to their survey was very poor only 37% of the questionnaires returned in the designated time frame. Jones and Manning (2008:204) concluded that as the respondents were probably the more motivated radiographers the results could not be generalised to the whole population of radiographers providing image interpretation. Of the radiographers who responded to the questionnaire 25% did not follow the SCoR guidelines and a further 19% indicated they did not compile portfolios necessary for auditing purposes. Jones & Manning (2008:204) expressed concern as these could be required in the case of litigation against a reporting radiographer.

Hardy and Snaith (2009:103) undertook research into education and curriculum development in the area of image interpretation for radiographers during the course of which they investigated the content in image interpretation modules in the Higher Education Institutes (HEI). At pre-registration level the appendicular system is offered at all HEI’s. The axial skeleton was offered by 94.7% of the HEI’s, the chest at 84.2% and the abdomen at 63.2% respectively. The emphasis on the appendicular and axial systems shows that musculoskeletal trauma imaging is the priority for undergraduate education.

Post registration courses in image interpretation were offered at 12 out of 19 HEI’s (Hardy & Snaith, 2009:103). The emphasis was again on the appendicular and axial skeleton. The appendicular system was offered at all the HEI’s, the axial skeleton at 91.7%, the chest at 75% and the abdomen at 33.3% of the institutions. The majority of these courses were either as postgraduate qualifications or modules leading up to a post
graduate qualification. The need for training in image interpretation at a post registration level reinforces that although pattern recognition and image interpretation is taught at pre-registration level it is not adequate for the needs of the clinical environment.

2.6 VIEWING REQUIREMENTS FOR OPTIMUM IMAGE INTERPRETATION
The images used in the research by Hardy et al., (2008, 302) were hard copy radiographs, which is considered the optimum radiographic image. Hardy and Culpan (2007: 70) used PowerPoint presentations for their twenty musculoskeletal cases to be interpreted. When discussing the limitations of the research they indicated that these images were not comparable with original hard copy radiographs and that images on a soft copy reporting screen did not reflect the same quality as a hard copy radiograph. With the advent of PACS and bearing these limitations in mind research may be required regarding the ability of reporting radiographers to interpret images from the monitor. Should radiographers be required to interpret images from a monitor within the A&E x-ray department, then the monitor used would need to be of an equivalent standard to that used by radiologists to draw up their reports.

Hardy et al. (2008, 304) identified the PACS system as an innovation, which could provide more opportunities for radiographer reporting and enable the reporting radiographer to report radiographs remotely. X-ray departments used to be located within or alongside the A&E department. To enable the reporting radiographers to “hot” report images and communicate with the A&E staff. A PACS system would allow hot reporting to take place without the co-location of the x-ray department and the A&E department (Hardy et al., 2008, 304). It is important that the monitor is of a high quality to report on images, however, the monitors in the X-ray rooms have been found not to be of a high enough standard.
Radiologists have specific high grade monitors when reporting to enhance the image. Therefore similar monitors must be installed in departments where image interpretation is offered by radiographers (PACS/ RIS Conference 2009). In South Africa PAC’s systems are becoming more common, however, conventional analogue radiography is still available in the majority of departments.

2.7 EDUCATION AND TRAINING REQUIRED FOR IMAGE INTERPRETATION

Hardy and Snaith (2009: 103) found that HEI’s incorporated image interpretation of the musculoskeletal system in their pre-registration programme as part of a discrete module that included the appendicular system and the axial system. In the majority of HEI’s image interpretation was confined to trauma skeletal radiographs. None of the pre-registration programmes provided any competency specific outcome in image interpretation as a precursor to graduation or awarded a specific certificate of competence in image interpretation. However, all the HEI’s assessed the students using an Objective Structured Clinical Examination (OSCE).

Hardy and Snaith (2009:102) found in their unpublished research conducted in 2007 that in 60% of hospital sites in the UK radiographers were reporting trauma radiographs. However Hardy and Snaith (2009:103) expressed concern about the standard of the image interpretation education offered to qualifying radiographers in both academic and clinical terms in relation to the expectation that all newly qualified radiographers in the UK are capable of providing an “hot” initial image interpretation for musculoskeletal trauma radiographs by 2010 (Hardy & Snaith, 2009:102). Consideration was given as to whether the appropriate education standards are in place to fulfil the expectation of image interpretation by newly qualified radiographers and whether post-registration qualifications are of an appropriate national standard that enables radiographer’s to
comment on all systems on plain radiographs (Hardy & Snaith, 2009:104). Although chest radiography is the most common radiographic examination and one radiographers are often asked to comment on in the A&E department, image interpretation of the chest is only offered at 84.2% of the HEI’s at pre-registration level. Hardy and Snaith (2009:103) found that 63.2% of the HEI’s offered postgraduate courses in image interpretation. The major limitation even in postgraduate qualifications was the emphasis placed on skeletal radiography. All the HEI’s (100%) offered the appendicular and 91% offered the axial systems as courses in image interpretation, whereas chest image interpretation was only offered at 75% of the HEI’s. In conclusion, Hardy and Snaith (2009: 102) were of the opinion that the content of the programmes was varied and should be assessed in terms of academic and clinical outcomes in order to provide a criterion by which competency in image interpretation could be measured. There is no exit level assessment of image interpretation as a stand-alone competence in the current pre-registration qualification in the UK. Hardy and Snaith (2009:103) found that the emphasis for pre-registration image interpretation remains the skeletal system although the chest is the most common radiographic image taken. Future employers do not know the standard of the newly qualified radiographer in terms of trauma image interpretation or chest and abdomen image interpretation. Therefore in the UK where image interpretation is well established there is still a need for improvement in image interpretation education (Hardy & Snaith, 2009:104).

Whether education in image interpretation can be achieved with the current undergraduate course in the UK, is questionable, as according to Hardy and Barrett (2004:659), most of the radiographers who provide image interpretation have completed a postgraduate education programme. Although in-house training is offered this is in addition to the postgraduate qualification and does not replace the degree (Hardy & Barrett, 2004: 658). Short courses in image interpretation are also offered
as a form of continuous professional development (Hardy & Snaith, 2009:103). It would appear that although it is recommended that all qualifying radiographers in the UK, are able to provide image interpretation on musculoskeletal images, inaccurate diagnoses could result without some additional form of postgraduate training being given.

Reporting on radiographic images in the research conducted by Price and Le Masurier (2007:23) was divided into nine different categories of which the two areas relevant to this research were reporting on plain films of the appendicular and axial systems. Price and Le Masurier (2007:20) sent a questionnaire to 258 imaging managers in 2004 to establish the extent to which radiographers were reporting on radiographic images throughout the UK at the National Health Service acute trusts. The researchers had previously conducted a similar survey in 1998 and 2000 and were interested to ascertain if any expansion of role extension for radiographers had occurred, whether specific regions had introduced role extension and if curriculum changes had been made to advance the implementation of these practices.

In respect of the above questions, Price & Le Masurier (2007:23) established that in 2004, the findings were as follows:

177 responses were received with a response rate of 68.6%:

46% of the trusts had radiographers reporting on the appendicular system;

40% of the trusts had radiographers reporting on the axial system;

89% of the trusts had radiographers reporting independently of a radiologist.

Comparison with previous research showed that the appendicular and axial systems were combined as the musculoskeletal system as follows:

In 1998, only 16% of the trusts had reporting by radiographers of the musculoskeletal system;
By 2000, reporting by radiographers of the musculoskeletal system had increased to 36%.

In 2004, 43% of the trusts had reporting by radiographers of the musculoskeletal system.

The figures demonstrate that image interpretation has become a significant form of role extension for radiographers (Price & Le Masurier, 2007:23). They also noted that by 2004 many of the radiographers were reporting independent of a radiologist and it was suggested to a standard equivalent to that of a radiologist. The “red dot” system was practiced by 82% of the trusts in 2004. However, only 6 trusts had implemented the system since 2000. Thus there has been a significant increase in reporting on images rather than “red dotting,” which would tie in with the promotion of role extension for radiographers. The “red dot” system was largely implemented in the 1990’s and is not considered as role extension for radiographers (Price & Le Masurier, 2007:23).

According to Price and Le Masurier (2007:22-24) the response to the questionnaire demonstrated a regional change in the number of trusts adopting various forms of role extension. With the emphasis placed on role extension it was suggested that radiographers might choose regions, which promoted career development when applying for a position rather than areas such as London with a significantly lower number of extended role activities. In recent years radiographer retention has been a problem in the UK and the expansion of role extension has been identified as an incentive to maintain staff (Price & Le Masurier, 2007: 19).

From the survey, Price and Le Masurier (2007:24-25) identified the tasks already performed by radiographers and those that would be introduced in the following 12 months. Axial and appendicular reporting would be
implemented in 14 more centres in the following 12 months. From their research Price & Le Masurier (2007:26) also placed emphasis on the importance of identifying the future educational needs of radiographers. Continued professional development programmes were suggested as a method of maintaining the impetus. Programmes identified as areas for role extension were intravenous injections by radiographers, gastrointestinal imaging, mammography and reporting and plain film reporting independent of a radiologist (Price & Le Masurier, 2007:26).

2.8 METHODS OF PROVIDING TRAINING IN PATTERN RECOGNITION FOR ACCURATE IMAGE INTERPRETATION

Pattern recognition has been used as a tool to teach the skills required for diagnostic radiographers to accurately interpret images in training programmes in the UK (Hughes, Hughes & Hamill, 1996: 267, Loughran, 1994:945 and Mc Connell & Webster, 2000:610). Therefore the researcher reviewed the use of pattern recognition and incorporating pattern recognition into a training programme.

2.8.1 Pattern Recognition for Accurate Image Interpretation

Reeves (2004:213-215) stated that pattern recognition was the “foundation of radiographic reporting” and would assist the radiographer to provide a comment on an image. She acknowledged that radiographers may find other factors that would impact on their abilities to recognise these patterns successfully. However, from her experience Reeves (2004:214) found that optical illusions and normal variants were the two perceptual errors that accounted for her inaccurate interpretation of images. Furthermore, Reeves (2004:214) suggested that when offering a course to radiographers in image interpretation there should be an emphasis on the
anatomy of the normal image and the normal variants. In her experience the normal variants were an area of weakness for radiographers when interpreting images (Reeves, 2004:214-15). To assist with reducing perceptual errors, Reeves (2004:215) advocated a mentor (a radiologist) to assist radiographers with reducing their perceptual errors. She found that the pattern recognition taught in the classroom can be difficult to implement in practice but with a personal expert to offer guidance, radiographers gain practical knowledge in the clinical environment and the accuracy of image interpretation improves. Mentors also encourage radiographers to continue their education by using reference books particularly on normal variants. The mentor could also provide an audit of the radiographer's image interpretations (Reeves, 2004: 214-215).

Hughes, Hughes & Hamill (1996:267) acknowledged that chest radiography is difficult to interpret for radiographers. Therefore they devised a pattern recognition tutorial for specific chest conditions that are significant for the treatment of patients. The conditions identified were pneumothorax, effusion and collapse and a pre and post-tutorial assessment was conducted on chest images of these conditions. The radiographers participating in the study had no previous training. The pre-tutorial assessment required that participating radiographers identify normal and abnormal images. When the same radiographers took part in the post-tutorial assessment, they were asked to classify the abnormality according to the pattern recognition they had been taught. The performance of the radiographers was measured in terms of false negatives and false positives. The number of false negatives decreased in the post-tutorial assessment which means that the number of images incorrectly interpreted as normal decreased, the number of false positives also decreased, namely incorrectly identifying a normal image as abnormal image thereby refuting the findings of a previous study by Renwick (Hughes et al., 1996:283). The researchers also found that pattern recognition allowed radiographers to assess chest radiographs
and identify pathological conditions in a systematic way. Hughes et al., (1996:284) stated:

“Pattern recognition is a valuable technique and should be an integral part in developing and extending the role of the radiographer.”

Hughes et al., (1996:283) demonstrated that when radiographers are provided with tutorials in pattern recognition for image interpretation of chest radiographs their performance improved in terms of the identification of abnormal images and the pathological group that the abnormality belonged to.

2.8.2 Training Courses of Extended Duration

Loughran (1994:945) demonstrated that training over an extended period of time in pattern recognition skills is a tool for accurate image interpretation. He identified the skeletal system as a region where radiographers could provide image interpretation. Three selected radiographers were given six months training in pattern recognition and fracture detection of the skeletal system. The radiographers were evaluated as to their accuracy on a monthly basis over a six month period. There was a significant change in accuracy from the first two months to the last two months for two out of three of the radiographers. The radiographers were more accurate in their fracture detection with a difference in their sensitivity (interpreting abnormal images correctly) from 81.1% to 95.9% (Loughran, 1994:945). The number of images incorrectly interpreted as normal when an abnormality was present and those interpreted as abnormal when they were normal was comparable with the accuracy rate of a radiologist.

A limitation of the study was that only three radiographers participated in the study and they had five years experience in trauma radiography. The
research indicated that training improved their image interpretation skills, but the improvement could be attributed to the fact that these particular radiographers had experience in trauma radiography and were motivated to improve their image interpretation skills. Therefore the research demonstrated that while training is beneficial, it may not apply to all radiographers. Loughran (1994:945) provided training in the specific area of fracture detection that has limitations for role extension of diagnostic radiographers.

Hargreaves and Mackay (2003:285) used a pre-test, post-test, single group design with an intervention in between the tests to investigate whether providing training would improve the ability of radiographers to detect fractures and accurately apply a “red dot” to an image.

The tests were conducted in accordance with the following:

The pre-test:
measured the dependent variable, which in this case was the ability of the participants to accurately detect a fracture on an image before the intervention (Neutens & Rubinson, 2010:85);
an audit of the participants over a period of 8 weeks;
the detection of a fracture indicated by a red dot on the film with no comment required to indicate the type, position or abnormal pattern seen on the image.

The training (the intervention):
ten tutorials offered over a period of four months;
each week the tutorials focused on a different skeletal area;
thirty minute sessions to ensure maximum attendance by participants;
training in image interpretation using pattern recognition of trauma abnormalities, fracture detection techniques, frequently missed fractures and normal variants;

due to the demands of a busy radiology department, it was not possible for all seven participants in the study to be available for the tutorials at the same time (Hargreaves & Mackay, 2003:285);

the same tutorial was offered three times in a week to give the participants the opportunity to attend all 10 tutorials over the four-month period (Hargreaves & Mackay, 2003:285).

The post-test:

This test was conducted to measure the dependent variable, namely the accurate detection of a fracture post-training.

The researchers understood that the pressure of a busy radiology department meant that it would be very difficult to provide only one opportunity for all participants to attend a tutorial. Therefore they repeated the tutorials. A concern was that the tutorials would not be identical as the interaction of the participants with the facilitator may change the information gained from the tutorial. Hargreaves and Mackay (2003:285) did not state whether a participant could attend the same tutorial more than once and if so, whether the additional tutorial would effect the level of accuracy achieved by the participants in fracture detection.

The tutorials offered to the participants in the Hargreaves and Mackay (2003:285-6) study concentrated specifically on the subtle fracture mechanisms, commonly missed fractures and the normal variants seen on trauma radiographs. Thus this study highlighted the detection of fractures and excluded non-traumatic pathology that could be seen on A&E images. These images would then be returned to the A&E without a “red dot”
because there is no evidence of a fracture although the image might
demonstrate a degenerative or bone density change. The lack of
interpretation could well be detrimental to the welfare and treatment of
patients. According to Hardy et al., (2008:302) the trained radiographer
should be capable of providing a definitive written report that requires no
further radiological review. Therefore image interpretation should not be
restricted to fracture detection on trauma images as this would
compromise the patient’s treatment. Hargreaves and Mackay (2003:287)
highlighted the areas in which radiographers performed poorly; namely the
identification of joint effusions, hand fractures, lower limb fractures and
epiphyseal.

2.8.3 Short Course Training

Mackay (2006: 469) conducted a prospective study on the effect of a short
course on the ability of radiographers to apply a “red dot” to abnormal
images. A short course for radiographers in the “red dot” system was
conducted seven times between April 1999 and September 2003 at the
University of Salford in the UK. The training provided was for two days and
included adult and paediatric images of the musculoskeletal system. All
the radiographers who participated in the courses were assessed before
the course, directly after the course and six months later in their clinical
practice. The radiographers all chose to participate in the course as
continuous professional development of their radiographic interpretation
skills and they all consented to have the results of their tests used for
research purposes. The median scores were calculated for sensitivity and
specificity for each performance of the radiographer’s pre and post training
and six months after the training was completed. Sensitivity is the
proportion of positive cases correctly identified as being abnormal.
Conversely specificity is the proportion of negative cases correctly

The results revealed the following:

- The results of the participants at pre-training demonstrated:
  - A sensitivity of 78.9% and a specificity of 76.9%.
- Post-training the results showed that:
  - Sensitivity improved from 78.9% to 88.2% and specificity remained constant
- Follow up test results conducted six months later:
  - Demonstrated that the sensitivity of radiographers declined to 76.5%, a level below that of their initial pre-training results, while the specificity remained constant.

These results were compared to the sensitivity and specificity of 90% and 95% expected of reporting radiographers who completed postgraduate training and were participating in image interpretation within their departments (Mackay, 2006:472). The level of performance of the participants was not adequate for the clinical environment. The pre-training ability of radiographers was based on the pattern recognition training that had been taught during the undergraduate programme. The data supports the need for radiographers to have further training to improve their sensitivity and specificity levels beyond that taught at undergraduate level. The post-test result suggests that training was effective in improving the ability of the participants to recognize abnormal images.

All the participants were invited back to the university to complete the six month follow-up test. Not all participants were able to return to the university. Those unable to return were given the opportunity to view the images for the test on a CD. It was difficult to monitor the conditions under which they viewed the radiographs and so the results of the six month
follow up were difficult to validate (Mackay: 2006, 470). Only one third of the participants completed the 6 month follow-up test. However, the six month follow up test demonstrates that training must be ongoing and reinforcement of the skills taught in the short course needs to take place before the six months elapsed (Mackay, 2006: 471).

For specificity the median remained constant at 76.9% for all the tests. However, the distribution was different and the participants level actually fell immediately post training. It would appear that from this study that training should take place over an extended period with subsequent opportunities to update the knowledge (Mackay: 2006, 472).

According to Mackay (2006: 472) training improves the ability of radiographers to perform image interpretation. The study actually assessed the ability of the participants to differentiate between normal and abnormal images, but not provide a comment on the images, this is a requirement for image interpretation.

The Mackay study (2006: 472) identified the increase in false positives after the short course was completed. Radiographers appear to over report radiographs after training and report more abnormalities than are actually present. The reason for the number of false positives was identified by Mackay (2006, 471) as being due to the emphasis on fracture detection during training. Mackay (2006: 472) suggested that in future, when radiographers are trained using a short course, the increase in false positive results should be factored in. Therefore it is important to train radiographers to identify patterns seen in normal images and normal variants, that to the untrained eye could mimic pathology and/or fracture. Mackay (2006: 469) stated that paediatric images were included in the two day course. The paediatric images constituted three images out of the thirty test bank images. Paediatric images were previously identified as
difficult to interpret and the epiphysis hard to recognise (Hardy et al., 2008:304).

2.8.4 Short Course Training with Mentorship

McConnell and Webster (2000:608) conducted research into providing a short course for radiographers who were already participating in the ““red dot”” system in the A&E environment. A survey of 280 radiology departments was conducted by McConnell and Webster (2000: 609) to identify which departments operated a ““red dot”” system and the extent of training offered. They received responses from 73% of the departments; the ““red dot”” system was used in 85% of the departments and 80% of the departments had all their radiographers’ participating in the ““red dot”” system. However, the training provided varied with the majority actually not offering any formal training. Those that made provision for training provided it on an informal in house basis. Of the departments who responded to the survey 92% indicated that the radiographers would benefit from a structured course of training in the ““red dot”” system. They identified that there was a gap in such training for the ““red dot”” system and that a short course would be a valuable intervention (McConnell & Webster, 2000: 609).

The short course that McConnell and Webster (2000: 609) devised for qualified radiographers was an attempt to provide training in pattern recognition of trauma images of the appendicular and axial systems. Initially, the course was offered as a residential two day course using interactive workshops and lectures. This training provided the radiographers with the skills to support the “red dot” with a brief comment to identify the abnormality (McConnell & Webster, 2000:610). The rationale for offering the short course was based on findings that the more extensive postgraduate courses in image interpretation required a level of
commitment that limited access to post graduate courses to a select few (McConnell & Webster, 2000:608). They were trying to develop a programme of a shorter duration with a substantial clinical input and the support of a radiologist as a clinical mentor to overcome the lack of training received by the majority of radiographers. The radiologist would provide the assessment of the performance of the student in the clinical A&E environment and would validate the radiographer’s ability to accurately provide image interpretation on trauma radiographs. An interesting aspect of this research was that each participant did have a radiologist as a clinical mentor in their department. This provided an option for the continuation of the training process. The radiographer would thus not be required to attend follow up courses at educational institutions, but would be mentored by the radiologist in their own department. The continuation of training is endorsed by Mackay (2006, 472) who indicated that it is essential for tuition to continue to maintain the accuracy in image interpretation.

McConnell and Webster (200:609) devised a short course and the participants were selected for the pilot course in 1998. The short course was successfully piloted and became part of the postgraduate programmes offered by the University of Bradford. Twenty two radiographers who participated in either the pilot or subsequent course were then assessed to determine the success of the course. Tests were undertaken before the short course, and at the conclusion of the course run over two days and then at a period of between 6-10 weeks after completion of the course. Although the short course aimed to improve the “red dot” system the participants were required to provide a comment identifying the abnormality and their reasoning behind the identification (McConnell & Webster, 2000:609-10).
The test used the same 42 images for all three tests (McConnell & Webster, 2000: 609). No breakdown as to the composition of the images or the number of normal and abnormal images was stated in the research article. Also the skeletal areas were not identified as appendicular and/or axial areas although the training included trauma of the axial skeleton, lower limb, upper limb and craniofacial systems. The results demonstrated a substantial increase in false positives directly following training. However this decreased on the third assessment and specificity and accuracy increased significantly on the third assessment (McConnell & Webster, 2000:610). The researchers concluded that the course was valuable and that it could be a precursor to full postgraduate training. When considering the results the significant improvement was demonstrated after a period of time in the clinical environment with a mentor. Therefore when considering training the importance of clinical support post training cannot be ignored.

In another aspect of McConnell and Webster’s (2000:609) research they found support for the introduction of a course for graduate radiographers from the radiographers who had completed post graduate radiographer reporting courses. The radiographers with a postgraduate qualification felt that graduate radiographers are not able to adequately identify abnormalities on plain radiographs in the trauma situation post registration. The requirement by the SCoR (cf 2.3.1:16) in the UK for all qualified radiographers to provide image interpretation on A&E radiographs means that in their opinion, their colleague radiographers with only undergraduate training skills do not have the skills to perform this role. Radiographers with post graduate qualifications in the UK have been employed to report on images, which radiologists are unable to do due to the lack of radiological staff. They are not there to provide image interpretation on all A&E images, as suggested by the SCoR as this was not the role anticipated for them (McConnell & Webster, 2000: 609). Therefore there is support for training to enable graduate radiographers to
fill the role that postgraduate reporting radiographers are unable to provide.

2.9 CORRELATION OF ACADEMIC TRAINING AND CLINICAL TRAINING

When the researcher considered the optimum training for this research the literature reviewed made it difficult to choose the best structure for the course. The courses offered in the UK vary considerably ranging from the duration of the course, the clinical application and the method of instruction and the emphasis on trauma radiography or all musculoskeletal pathology. Prime, Paterson and Henderson (1999:66) looked at the six institutions offering training programmes in image interpretation and found a diverse range of aims and objectives. However, the one common theme was the strong link between academic training and clinical learning. Training could be provided in pattern recognition, which in turn could lead to accurate image interpretation of radiographic images. However, without the support of the workplace and particularly the radiologists the implementation of this learning would not be possible. Prime et al., (1999:70) found that image interpretation skills could only be developed with cooperation between the radiologist and the radiographer.

Prime et al., (1999:69) regard radiologists as being fundamental to the success of radiographers participating in these courses by providing both formal and informal roles. Primarily radiologists would provide the quality assurance required as external examiners. In all of these training programmes the gold standard for validating the reports/image interpretation would be a radiologist (Prime et al., 1999:68). Informally the radiologist would support the radiographers in the clinical environment and provide teaching and mentoring to the diagnostic radiographers undertaking training in image interpretation.
Participants in five out of the six postgraduate courses considered by Prime et al., (1999, 68) required an assessment of their clinical departments before being accepted onto the course. The departments were required to demonstrate that they would undertake to support the student with tuition and feedback (Prime et al., 1999: 68). To confirm their commitment to the postgraduate education three of the institutions required a written memorandum between the institution and the clinical department. Mentorship by a radiologist in these departments was considered an essential part of the programme (Prime et al., 1999: 68). The need for radiologist mentorship as a requirement for radiographers to participate in postgraduate image interpretation training is supported by the findings of Mackay (2006:472) and McConnell and Webster (2000:611). The provision of knowledge by an institution can contribute to the ability of radiographers to accurately provide image interpretation. Clinical application with clinical support in the workplace is an essential component of the environment that is required to develop these skills (Prime et al., 1999:70).

A systematic approach to image interpretation is essential. An understanding of the clinical information and the patterns of the possible injuries are necessary for accurate image interpretation (Barron and Branfoot, 2003:327). Image interpretation is not possible with substandard images in that the radiographer interpreting images must be able to request additional images or modalities for optimum image interpretation. These are skills which are reinforced in the clinical environment with support from radiology staff (Snaith and Lancaster, 2008:152). Snaith and Lancaster (2008: 152) identified a clinical assessment as an essential requirement for role extension in image interpretation. The radiographer would then be able to correlate the patient’s history, the physical examination of the patient and the images thereby providing a complete picture of the patient’s condition and the possible diagnosis.
Snaith and Lancaster (2008: 152) also highlighted the underutilisation of radiographers in referring patients for imaging either as an initial or follow-up investigation. In the UK role extension in the form of requesting radiographic images has been a nursing role. However radiographers with their imaging experience and understanding of radiographic examinations would appear to be more qualified to provide an appropriate referral for a radiographic examination. Therefore referring patients for radiographic procedures could be a role that radiographers may undertake in the future with the appropriate clinical training.

Currently in the UK a grey area exists between the approach of radiologists and radiographers towards skill mix and role extension. The RCR has indicated that they will only support role extension for radiographers into image interpretation after adequate training. In the report on standards required for reporting the RCR states, “An individual who reports on a radiological image must have been trained in radiological observation and analytical skills” (RCR, 2006:11).

Smith and Baird (2007:629) considered how role extension for radiographers into image interpretation should be incorporated into the Australian context. The UK has been the leader in role extension for radiographers as a result of the shortage of radiologists in the 1990’s (Brealey & Scally, 2008: e47). Therefore Smith and Baird (2007:629) looked at the UK example for direction when implementing image interpretation in Australia. The RCR also recommended a distinction between a report provided by a radiographer and a radiologist in that the radiographers’ reports are descriptive reports in the sense that they describe observations made based on their pattern recognition knowledge and not a medical report such as a radiologist would provide. The reasoning is that radiographers do not have the same medical training as radiologists and therefore are not conversant with the clinical knowledge
associated with a particular diagnosis; Smith and Baird (2007:630) concluded from the RCR recommendation that radiographers have the opportunity to provide a non-medical descriptive report as advancement from the “red dot” system. In Australia three Universities already provide postgraduate courses in image interpretation in-line with the recommendation by the RCR that appropriate training be provided before image interpretation by radiographers takes place.

Smith and Baird (2007: 629) identified that in Australia there had been a growth of 16% in plain radiography over the period July 2000 to June 2006. Therefore radiographers could alleviate some of the pressure on radiologists by interpreting some of the plain radiographic images. An area that Smith and Baird, (2007:630) identified for radiographers to provide image interpretation was “hot” reporting in the emergency department. Immediate interpretations could be provided to the clinicians, which would be of benefit to the treatment of patients.

Smith and Baird (2007:630) acknowledged that although the radiologists report is the “gold standard" the descriptive report provided by radiographers interpreting an image in terms of observations could be significant. According to Berlin (2001:321) errors by radiologists account for approximately 30% of all the images reported. However, this was in studies in which the radiologists retrospectively reported images with no knowledge of the clinical history. A more realistic error rate would be 4.4% when images are reviewed in practice with a large percentage of normal images. Thus Smith and Baird (2007:630) concluded that a well-trained observer could reduce the number of errors in identifying abnormalities. According to Smith and Baird (2007:630) medical training is not required to provide a descriptive report. Therefore radiographers with the skills to recognise abnormal and normal images and describe the observations to a referring doctor would be capable of performing this function.
2.10 METHODS OF ASSESSMENT TO ESTABLISH THE ABILITY OF DIAGNOSTIC RADIOGRAPHERS TO INTERPRET IMAGES

In an effort to select the most appropriate method of assessment to establish the ability of diagnostic radiographers to provide accurate image interpretation of musculoskeletal images. The researcher reviewed the following research on assessment methods.

2.10.1 The Objective Structured Clinical Examination

Role extension has been identified as a method to increase the job satisfaction and the retention of radiographers (Price & Le Masurier, 2007:27). One aspect of role extension that has been researched predominantly in the UK is that of image interpretation particularly in the A&E situation. According to Brealey and Scally (2008:e49) the best method for the assessment of the ability of radiographers to interpret radiographs requires clarification. With the goal of identifying the various methods of evaluation and considering the supporting evidence, Brealey and Scally (2008:e46) discussed the methodological approaches used to assess the ability of radiographers in the interpretation of plain radiographs. Thereafter the gaps and points requiring more investigation were determined.

In all but one of the six institutions offering postgraduate training in image interpretation an Objective Structured Clinical Examination (OSCE) was used to assess competence (Prime et al., 1999:68). The OSCE comprises a bank of images on which the participants are required to give an interpretation, under optimum conditions in a controlled environment and within a certain period of time. The bank of images includes a selection of relevant pathologies as well as normal images including normal variants- to assess the effectiveness of the postgraduate training
(Brealey & Scally, 2008:e49). Research confirmed that this type of assessment is the most relevant for assessing the ability of radiographers to provide a comment on an image. A definitive interpretation is required for these images, provided by a minimum of two radiologists who reached a consensus on the report for these images. The radiologist is considered the “gold standard” for image interpretation (Prime et al., 1999: 68).

2.10.2 The Observational Assessment

The OSCE has been used in many of the studies to assess the ability of radiographers to accurately interpret images. The observational method can be used where radiographers are observed in the clinical environment over a period of 6-8 weeks in place of an OSCE assessment (Brealey & Scally, 2008:e49). Allowing radiographers to report on the radiographs in the clinical environment would improve opportunities for an accurate representation of the broad spectrum of images that require interpretation. The accuracy of the interpretations would be assessed under normal workplace conditions. In the UK due to seasonal related pathologies, which may not occur all year round and may not have been observed within the 6-8 week period the observational assessment maybe invalid. This could result in a gap in knowledge in the future as the radiographers have not been exposed to these particular cases. Therefore an OSCE tests a wider range of pathologies (Brealey & Scally, 2008: e49).

The OSCE does not assess the ability of radiographers to interpret images in the clinical situation. Therefore the use of log books and summative assessments are potential tools that could contribute to the assessment of the ability of radiographers to interpret images in the clinical situation in addition to the OSCE (Hardy & Snaith, 2009: 104).
2.11 IMAGE SELECTION FOR TESTING THE ABILITY OF DIAGNOSTIC RADIOGRAPHERS TO INTERPRET IMAGES WITH TRAINING

The images required to appropriately test the ability of radiographers in the interpretation of images has to include a variety of areas and pathologies. The following criteria were found to be important in the compilation of images for the tests.

2.11.1 Normal versus Abnormal Images

In previous research (Hardy & Culpan, 2007:68, Piper & Paterson, 2009:42-43) suggested that at least 50% of the images should be normal. The inclusion of normal images was required as radiographers have a tendency to identify an increased number of false positives after training. Therefore the ability to test for the correct interpretation of normal images is important (McConnell & Webster, 2000:610 and Mackay, 2006:472). Studies have used radiographs in a ratio of 50:50 of normal to abnormal images to demonstrate an ability to recognise varied pathology on a radiograph. In addition, the findings of Brealey and Scally (2008:e49) indicated that the bank of images was not representative of the clinical situation where more normal cases are seen and therefore conclusions could not necessarily be generalised to the larger population.

McConnell and Webster (2000: 610) and Mackay (2006:472) did not provide the proportion of normal to abnormal images. Therefore it is difficult to identify how significant the increase of false positives was in the overall context of image interpretation. In the research by McConnell and Webster (2000:611), the results of the third test undertaken six to ten weeks after the short course, indicated that accurate identification of the abnormal images increased specificity and increased accuracy when compared to the initial test. With the third test being six to ten weeks after the course was completed, the improvement could have been due to the
experience gained within the clinical departments and observation of similar abnormalities and not only to the training provided. In addition, all the participants had a clinical mentor in their department, which may also have contributed to the improvement in their accuracy. The students were also provided with comprehensive notes at the conclusion of the course for revision purposes and application in the clinical situation. McConnell and Webster (2000: 611) concluded that many contributing factors may have led to the improvement in participating radiographers image interpretation capabilities and that training alone cannot be credited with this improvement. McConnell and Webster (2000:611) were specifically interested in image interpretation of trauma images but gave no indication whether the distribution of normal to abnormal images was 50:50.

Hardy and Culpan (2007:67) used a test bank consisting of twenty images, eleven of which were abnormal and nine were normal, in order to assess the accuracy of radiographers in respect of “red dot” in comparison with commenting. The test bank formed the pre and post-test assessment tool to establish the accuracy, sensitivity and specificity of the radiographers. The 115 participants in the research took the pre-test followed by a short course intervention on musculoskeletal trauma (Bradford “red dot” course). On completion of the 2 day course they took the post-test. The radiographers were asked to “red dot” the images and provide a comment on the abnormal images. Hardy and Culpan (2007:68-9) also incorporated images that were considered to be subtle abnormalities. The images that demonstrated subtle abnormalities were inaccurately commented on in both the pre and post-tests by the majority of radiographers.

The accuracy rates of the following images were:

- Image 4: the dislocated acromio-clavicular joint comments were 23.5% accurate in the pre-test and 34.8 % accurate in the post-test;
- Image 10: the comments on the supra-condylar fracture of a paediatric case were accurate at 24.4% and 18.3% respectively in the pre- and post-test;
- Image 18: the comments on the fracture of the base of the 5th metatarsal on an ankle image were accurate at 0.9% and 43.5 % respectively in the pre- and post-test;
- Image 9: osteoarthritis of the hip mistaken for a sub-capita fracture was accurate in the pre-test at 15.7% and 7.8% in the post-test;
- Image 15: cervical spine bifid spinous process C5 mistaken for a fracture was accurate in the pre-test at 47.0% and 40.9% in the post-test;
- Image 19: epiphyseal line humerus confused with a fracture was accurate at 39.1% in the pre-test and 40.9% in the post-test.

The interesting aspect regarding these cases was that the three images interpreted incorrectly were subtle abnormalities, which although correctly “red dotted” in the post-test, the radiographers were unable to describe the abnormality. The other three images were normal images where the radiographers interpreted normal variants as abnormalities. From these results Hardy and Culpan (2007:70) concluded that radiographers who participate in “red dot” schemes do not necessarily have the ability to comment on images. Training is therefore, required to improve the ability of radiographers to interpret images and a short course is possibly inadequate in achieving this goal.

Piper and Paterson (2009:42) also used a bank of 20 images and based their bank of images on those from a study by Meek, Kendall, Porter and Freij (1998:106). Thirteen images were abnormal and 7 were normal. As they were comparing the ability of radiographers and nurses to accurately interpret images they selected images that would help distinguish the differences between the two groups. Meek et al., (1998: 105) were also
interested in the abilities of nurses to interpret images so they restricted their bank of films to only the distal arm below the elbow and the distal leg below the knee. Piper and Paterson (2009:42) replicated this criterion as they were also looking at the ability of nurses compared to radiographers. The only projection outside of this range was a normal shoulder image. Difficult and hard to diagnose cases were therefore selected in the belief that more subtle cases would be discriminatory for the groups. Piper and Paterson (2009:43) conducted a pre and post-test study with a short course in image interpretation of the appendicular system as the intervention. Twenty two nurses and 18 radiographers participated in both tests and the short course. Piper and Paterson (2009:46) were of the opinion that both groups improved with training. However the radiographers achieved higher scores than the nurses and the pre-training scores of the radiographers were equal to the post-training scores of the nurses. The research, therefore, indicates that radiographers should consider providing an initial written comment to the A&E staff in preference to a flagging system (Piper & Paterson, 2009: 46).

Piper, Paterson and Godfrey (2005:29) conducted research with postgraduate radiographers and when compiling their Objective Structured Examination (OSE) used 50% abnormal images. The postgraduate students assessed using the OSE had successfully completed a course in clinical reporting of the appendicular and axial systems. To establish the ability of radiographers to interpret images, the sensitivity, specificity and accuracy were calculated and for the results to be accurate, a bank of discriminatory images was required. The bank of images was not representative of the clinical situation as there would be a higher percentage of normal images in the clinical environment. The inclusion of 50% abnormal images was important in order to assess the performance of the radiographers in terms of correctly identifying the true positive images. That is to calculate the sensitivity of the radiographers to accurately interpret abnormal images. Thereafter the students reported on
eight banks of 25 images and had to identify normal and abnormal images. In respect of the abnormal images they were required to provide a handwritten report on appearances and possible pathologies (Piper et al., 2005: 29). The results of the study demonstrated accurate interpretation of images of the axial and appendicular systems. The result was not unexpected as the participants had completed a postgraduate course. However, the interesting result was that the images were not all trauma images as the banks included referral images from non A&E sources and the radiographers maintained their level of accuracy for these images. Therefore Piper et al., (2005:34) concluded that radiographers could provide image interpretation for musculoskeletal images from the A&E and non A&E environment.

2.12 METHODOLOGICAL ISSUES REGARDING THE EVALUATION OF RADIOGRAPHERS’ ABILITY TO INTERPRET IMAGES

2.12.1 The Control Group

When considering research into radiographer image interpretation Brealey and Scally (2008:e49) initially considered primary research using three types of methodology; the observational study; the quasi-experimental study and the experimental study using an intervention and then evaluated its effectiveness by measuring the accuracy of image interpretation (Brealey & Scally, 2008: e47). The researchers identified the lack of a control group as a threat to the internal validity of previous primary research (Brealey & Scally, 2008:e49). Without a control group, it becomes difficult to attribute the effect on the accuracy of image interpretation to the training alone. If an observational study is performed then a certain amount of learning would be achieved through experience in the clinical environment over the time period of the study,. In addition the knowledge of being observed could alter the performance and not
necessarily be attributed to the training in image interpretation. The same would be true of an experimental study, in that the improvement could be due to motivation to achieve a higher standard of performance as the radiographers know they are participating in a study. In addition, depending on the time frame for the tests to be conducted, a learning effect from the clinical environment could be a contributing factor. Therefore a control group is required to demonstrate the amount of learning that takes place due to motivation in the clinical environment without training. In the opinion of Brealey and Scally (2008:e49) only once a control group has been identified can the impact of training be measured.

2.12.2 The Sample Size

When Brealey and Scally (2008:e52) reviewed previous research to assess the ability of radiographers to accurately provide image interpretation, the sample size was not generally a consideration in determining the validity of the research. In previous research relating to the assessment of diagnostic performance, the size of the sample was relatively small. This was a source of concern for Brealey and Scally (2008:49-50) as the method was very selective in nature with participating radiographers drawn from one centre only. For external validity a larger sample from multiple sites would be required. The researchers recognised that a multi-site approach may not always be feasible. Therefore they suggested a systematic review of these research projects in which audits could supply the broader database required for a more valid result.

2.12.3. Image Interpretation Accuracy versus Patient Outcome

A large amount of research has been conducted into the ability of radiographers and other health professionals to interpret images
accurately (Hardy & Culpan, 2007:70. Piper & Paterson, 2009:46). The assessment of the ability of radiographers and nurses to interpret images has been done predominantly through the use of a test bank of images assessed in an OSCE format. According to Brealey (2001:342) there needs to be a framework that could be used by researchers to measure the ability of radiographers and health professionals to assess their ability to interpret images in conjunction with the impact their contribution could make to the outcome of patient care in terms of diagnosis and treatment. Brealey (2001:342) wanted to consider whether an accurate image interpretation was effective in the clinical environment and had a positive impact on the treatment of the patient. Previous research suggested that radiographers are able to accurately interpret images, whereas nurses are less accurate (Piper & Paterson, 2009:45). Therefore Brealey (2001:342) wanted to establish whether non-medical health professionals could provide an effective outcome for clinicians and patients with immediate accurate image interpretation. The accuracy of the image interpretation can impact on the time the patient spends in hospital, the number of investigations carried out, the radiation dose received by the patient and the treatment received by the patient.

Fineberg’s hierarchy has been used previously to establish five different levels involved in MRI image interpretation. Brealey (2001:342) used Fineberg’s hierarchy to provide a framework to assess the effectiveness of radiographer driven image interpretation.

The five stages applied to MRI image interpretation and the effectiveness of the accurate image interpretation were:

Technical performance
Diagnostic accuracy
Diagnostic impact
Therapeutic impact
Impact on health

Brealey (2001:343) adapted the following stages of the framework to assess the effectiveness of image interpretation in the clinical situation.

**Level one - Technical performance:**

Technical performance is the production of good quality images to enable accurate image interpretation followed by the application of search patterns to detect abnormalities. When considering level one of the hierarchy a systematic review of the research showed that radiographers have the ability to utilise the search patterns to the same level as the radiologist (Brealey, 2001:343). Search patterns are used by radiologists in viewing images and demonstrate the visual process required to ensure that the image has been searched extensively for the presence or absence of an abnormality. Thus, if radiographers demonstrate the competency required and are capable of applying search patterns accurately, they have the potential to report images (Brealey, 2001:343).

**Level Two - Diagnostic accuracy:**

This competency has, in the majority of cases, been assessed by using an OSCE to provide a measurement of the accuracy, sensitivity and specificity of participants in interpreting a bank of selected radiographs. An OSCE is carried out in a controlled environment and therefore external factors, which may influence the ability to interpret radiographs accurately, are not considered (Brealey, 2001:343). Brealey (2001:343-4) highlighted the fact that viewing conditions, time constraints and length of reporting sessions can influence the accuracy of the interpretation of the radiographs in the clinical situation. This indicates that there is a qualitative dimension in the clinical environment aspect that has rarely been considered in this type of research. When an OSCE is used as a method of assessment, the environment is controlled and the participants
have optimum viewing conditions. They are aware of the time allocated for the assessment and can use the time effectively by spending longer on more difficult cases. In the clinical environment pressure is often exerted for a quick diagnosis to be made in sub-optimal conditions for example, poor viewing conditions and noisy environments. An assessment of radiographers’ ability to interpret images in the clinical environment when under pressure may provide a more accurate assessment of their abilities than an OSCE; however, further research would be needed to validate this (Brealey, 2001:344).

**Level Three- Diagnostic impact:**

Brealey, King, Hahn, Crowe, Williams, Rutter and Crane (2005:712) compared the ability of radiographers and radiologists to report on A&E and general practitioner referrals and the management of the treatment of the patients based on the clinicians confidence in the report. The sample size for this study was small, namely two radiographers trained in musculoskeletal image interpretation and eight consultant radiologists. The participants reported on 800 images retrospectively under controlled conditions. The researchers considered the performance of the participants in comparison to a reference standard (a radiologist with 11 years experience) and then considered the incorrect interpretations and how the clinicians could be influenced by these reports in their diagnosis and treatment of the patient. Brealey *et al.*, (2005:716) demonstrated that with training the radiographer could accurately interpret images. However, the level of confidence of clinicians in reporting by radiographers was not conclusive from the study. Research into the cost-effectiveness of the radiographer in providing an accurate diagnostic interpretation to the clinician has not been undertaken (Brealey, 2001:344).
Brealey *et al.*, (2005:715-6) expressed a similar concern as Brealey (2001:343), namely that all the participants were aware that they were taking part in a study and, therefore, the research took place under controlled conditions and not in the clinical environment. Therefore could the results be used in a clinical situation? The research environment in the Brealey *et al.*, (2005:711) study was common for all participants in the study. However, it was felt these results did not reflect clinical practice. Further research is required to establish an accurate comparison between the two groups under routine circumstances. Brealey (2001:344) in this systematic review considered whether a single consultant radiologist could be the reference standard for the study on account of inter-observer variation between consultant radiologists when considering plain radiograph reporting.

**Level Four and Five - Therapeutic impact and impact on health:**

Brealey (2001:344-5) considered the previous steps of the framework in relation to the effectiveness of the interpretation of the radiograph by radiographers. These steps were related to the diagnostic confidence of the clinician, patient management based on the report and the outcome for the patient. The clinician would only base his/ her treatment of the patient and the outcome of such treatment if confident in the accuracy of the radiographer’s interpretation. In this context it was found that it is important that the readability of the report is assessed. The clinician requires a report that is clear and brief and one that demonstrates a certainty regarding the diagnosis. Although training may provide the radiographer with the skills to accurately interpret radiographs the communication of the results must be accurate and readable. Therefore when providing training it should be emphasised that the clarity and certainty conveyed in the report is as important to the diagnosis and treatment of the patient as is accurate film interpretation (Brealey: 2001:344).
Radiologists need to be supportive of reporting by radiographer in order that clinicians accept the image interpretation provided by a radiographer. According to Forsyth and Robertson (2007:54) radiologists with less experience that is less than 16 years, were far more supportive of a multi-professional approach, whereas radiologists with more experience had a more traditional outlook and were resistant to change. One concern arising from the study was that although role extension in Scotland was supported by many of the younger radiologists as a result of the staff shortages experienced in radiology departments, this left no time to mentor radiographers in their new roles. The radiographers expressed a concern that the undergraduate training could be compromised because of the drive to provide postgraduate training in specialist areas thereby leaving gaps in the undergraduate training. According to Brealey (2001:345), none of the research conducted and reviewed considered the final two levels of the framework, namely the therapeutic impact or the impact on health.

2.13: GLOBAL PERSPECTIVE OF RADIOGRAPHER IMAGE INTERPRETATION

Cowling (2008, 28-32) considered the global perspective for changes in the role of the radiographer. According to Cowling (2008:29) the advancements in the role of radiographers can be considered in four tiers. The United Kingdom and the United States of America comprise the first level as they have educational programmes in place and have the support of government organisations to implement advanced practice for radiographers. South Africa and Australia are at the second level where the educational structures are providing the foundation for role advancement. However, there is no structure for the implementation of the advanced practice. South Africa has included basic pattern recognition towards image interpretation in the scope of practice for radiographers, but
no structures are in place for the implementation of this practice in the future. The need for research into the implementation of role extension in these countries is essential to highlight the potential that is available in the country and to provide a better service to the Public Health Sector in South Africa where a large percentage of films go unreported. At the third level are countries that are working towards the introduction of a degree qualification and role extension, but this still lies in the future and finally, at the fourth level are those countries where the profession is not recognised and education standards have not yet been established (Cowling, 2008:29-30).

In Australia image interpretation courses are offered, but there is no legal infrastructure for radiographers to implement this skill (Cowling, 2008:31). There is a need for image interpretation by radiographers in the rural areas of Australia. Due to the large geographical area of Australia radiologists tend to be centred in the large urban areas so that there are no radiologists in rural areas. According to Smith, Traise and Cook (2009:2) it is common practice for the radiographers in Australian rural hospitals to work closely with medical practitioners and provide image interpretation in the absence of a radiologist. Very few of the radiographers have training in image interpretation. However, due to their imaging experience, their opinion for a professional image interpretation is sought (Smith et al., 2009:3). This scenario resonates with the situation in South Africa where the majority of radiologists are also found in the urban areas. Cowling (2008:31) suggests that teleradiography could provide the means for radiologists to carry out reporting on plain radiographic images remotely and then transmit their report to the rural areas. Radiographers would then not be required to undertake image interpretation as a form of role extension. However, if radiologists are under pressure to perform specialised examinations for example interventional procedures and report on Computerised Tomography and Magnetic Resonance Imaging examinations in their urban practices, they will not have the time to report
on the cases sent via teleradiography. Whereas radiographers with the necessary image interpretation skills in these rural locations would be able to provide a timely comment, which could benefit diagnosis of the condition and the treatment of the patient (Smith, Yielder, Ajibulu & Caruana, 2008: e21).

Cowling (2008:31) considered global advances in the role extension of radiographers. While the role of the radiographer has evolved, there is a lack of international coordination in the establishment of a universally recognised path for role extension for radiographers.

According to Hardy, Legg, Smith, Ween, Williams and Motto (2008:15) there is no common structure, which identifies role extension for radiographers internationally. The study by Hardy et al., (2008:17) identified that training beyond the entry level qualification would be a requirement in providing radiographers with the skills required for extended practice. An important aspect identified by Hardy et al., (2008:18) was the need for more research globally by radiographers. Without identifying the benefits of role extension to the clinician and the patient, role extension for radiographers would not be adopted in the clinical situation. Radiographers have a poor record with regard to research globally, in spite of the importance of providing appropriate research relevant to the geographic, educational and cultural environment of a specific region. Therefore radiographers need to conduct research that is relevant to the specifics of their healthcare system and identify the gaps in the service provided within their healthcare system (Hardy et al., 2008:18).

Due to global differences in the health services where gaps exist a different emphasis would be placed on particular aspects of role extension. For this reason it could be difficult to provide an internationally
unified structure for role extension (Hardy et al., 2008:19). Hardy et al., (2008:18) suggest that benefits could accrue from knowledge already gained in some countries and cooperation in developing a support structure to promote role extension.

In 2007 the Australian Institute of Radiography (AIR) undertook to appoint an advanced practice working group to compile an analysis of a model of advanced practice for diagnostic imaging and their report was produced in 2009 (http://www.air.asn.au). Education was identified as essential to achieving role extension with collaboration between the universities and the workplace. The document supported the need to research the format of the training required to provide radiographers with the skills for advanced practice. The Australian working group also identified the importance of a clinical component to any role extension programme. When deciding on the scope for role extension research must establish the “appropriateness” and the “effectiveness” of the programme according to the working group (http://www.air.asn.au).

The AIR (http://www.air.asn.au) provided a definition of advanced practice as the:
“Circumstances in which a Diagnostic Radiographer or Radiation Therapist performs a clinical practice, duty or task on a regular basis that is beyond the established core practice boundaries of their profession.”
Role extension has not been recognised in Australia and progress has been slow in comparison to the UK. The AIR identified in 2005 that 54% of diagnostic radiographers were providing an unofficial interpretation of trauma images (Smith et al., 2008: e21).

According to Smith et al., (2008: e21) an immediate comment provided by the radiographer is necessary in the Australian rural areas due to the lack of radiological staff in these areas. The only form of reporting using a
radiologist is via teleradiography but this can be time consuming and detrimental to the patient receiving treatment timeously. Smith et al., (2008: e23) identified that opposition from within the medical imaging team remained in respect of radiographers providing image interpretation. There is resistance to change as radiographers providing this service cross the traditional boundaries between the role of the radiologist and radiographer. The authors suggest that with the increased demand for imaging procedures radiologists cannot meet the demand and a change in current practice is necessary to provide a prompt service to the patient (Smith et al., 2008: e23). Therefore image interpretation by radiographers with training should fill the gap that radiologists are unable to fill in rural areas in Australia.

Smith et al., (2008, e22) considered the Island Nations of the South Western Pacific where diagnostic radiographers often work in complete isolation. The radiographers have a degree in radiography and are often asked for their opinion although no formal training has been introduced for image interpretation. A project was established in the South Pacific Islands at the Fiji School of Medicine from 2004-2006 to assist these radiographers in the recognition of abnormalities and describing them accurately to clinicians (Cowan, Smith, Nakabea, Ajibulu & Hennessy: 2007, 528). The World Health Organisation (WHO) approached the Royal Australian and New Zealand College of Radiologists to establish a centre of excellence in the South Pacific region to improve radiodiagnosis (Cowan et al., 2007: 528).

A similar project has been undertaken in Kenya. The course offered was a two week course in plain radiographic image evaluation and interpretation (Cowan et al., 2007: 528-529). In order to facilitate this training, the participants had a mentor, ideally a radiologist, to guide them in difficult cases and to provide them with support. According to Cowan et al. (2007: 529) the images provided for the participants were presented as
PowerPoint images and WHO textbooks were provided for them. The participants were asked to evaluate the course. The radiographers expressed satisfaction with the course and stated that they had “gained new knowledge from the course.” Cowan et al., (2007:530) identified a problem in that the workloads of the radiographers were already excessive and in order to implement their new skills it was only possible for them to provide a comment when images were abnormal or when a comment was requested.

In mainland Australia a similar situation was identified by Smith, Traise and Cook (2009: 2) where in rural areas the diagnostic radiographers and the medical practitioners worked closely together for image interpretation. The authors assessed the ability of the diagnostic radiographers to accurately interpret musculoskeletal images prior to an intervention (Smith et al., 2009:3). The pre-test took the form of 25 cases, which the radiographers viewed on a conventional monitor. They were able to manipulate the images in terms of density, contrast and magnification of the area of interest. The radiographers were not aware that all the images they viewed were abnormal in respect of trauma or non-trauma pathology. Smith, Traise and Cook (2009: 3) used a radiographer opinion form (ROF) for the assessment. This form used tick boxes firstly to identify an abnormality, then the type of abnormality was selected from a list of possibilities and finally a written comment on the appearance was required. Smith, Traise and Cook (2009:3) set a target of 85% accuracy compared with a radiologist.

The intervention was a course, which took the form of distance tuition comprising PowerPoint presentations, videoconferences and directed reading. The course was delivered over 4 months after which the participants were reassessed (Smith et al., 2009:3-4). The participants in the Smith et al., (2009:4) research never attained 85% accuracy, but did
improve after the intervention. The radiographers improved particularly in their ability to identify an abnormality and identify the type of abnormality. The area in which their accuracy did not improve was the open comment, which according to Smith et al. (2009, 6) demonstrated the difficulty radiographers have in using the correct vocabulary to communicate their findings. Overall Smith et al. (2009: 8) suggested that even short courses could have a positive outcome for radiographers in the interpretation of images in conjunction with post graduate training. They also stated that in Australia a difficulty that still needs to be overcome is the resistance of radiology staff to changes in the traditional role of health professionals and without collaboration between all staff members the future looks bleak.

In the USA advanced practice has taken a different form with the introduction of the radiology assistant (RA). However to become an RA, a radiographer requires further education. The role of a RA’s has been identified as an assistant to the radiologist. Their Scope of Practice includes administration of contrast media, patient management, fluoroscopy and evaluating images for image quality (Code of Practice, 2006: 4). The RA does not provide an interpretation of an image. The role of the assistant provides a service, which allows the radiologists to concentrate on aspects of their job such as image interpretation and specialised procedures. The American Society of Radiologic Technologists (ASRT) (2006) recognises the position of radiology assistant, however, due to the private healthcare system in the USA they do not receive recognition from the medical insurance funds. This means that there may be a lack of motivation to employ a RA and, therefore, no incentive for radiographers to further their education and advance their practice (Hardy et al., 2008:19).

2.14 LEGAL ISSUES CONCERNING IMAGE INTERPRETATION
The AIR had a membership of 5,500 radiographers in 2009 (http://www.air.asn.au). The AIR has provided a Malpractice and Negligence Policy for all employed members and students since 1974. A similar cover is provided by the Society of Radiographers (SOR) in the UK where indemnity cover is provided for all their members in all fields covered by their scope of practice (http://www.sor.org). The membership of the SOR constitutes 90% of radiographers employed in the UK.

When Forsyth and Robertson (2007:54) surveyed radiologists as to their concerns with radiographer reporting, their most common concern was the accountability of the radiographer and the medico-legal implications of radiographer reporting. Clinical governance has to be taken into account when role extension that is beyond the traditional scope of a profession is undertaken.

2.15 SUMMARY

In this chapter the initial establishment of a role for radiographers to identify abnormal images was investigated. The “red dot” system was placed in the context of its validity as RADS. The evolution of the role extension of radiographers in the field of image interpretation from a flagging system to providing a comment on an image was discussed. The type of training required to provide the radiographer with the skills for accurate image interpretation were considered in terms of pattern recognition, mentorship and length of study. The importance of assessing the competency of radiographers in musculoskeletal image interpretation was shown to be vital before implementing role extension in terms of image interpretation.

This researcher considered the available literature in respect of the ability of radiographers to interpret images. Although the literature is substantial questions still remained concerning the position of South African
radiographers that required investigation. The education, culture and clinical environment of radiographers in South Africa differ from that experienced in the UK where much of the research has been conducted. The Australian research appears more relevant to the South African situation. The resistance to change in the clinical environment exists in South Africa where radiologists are frequently resistant to changing the role of radiographers. Therefore it is important for radiographers to establish whether they can make a contribution to image interpretation, particularly in the A&E department in respect to musculoskeletal images. It needs to be established whether training is required in addition to that provided at diploma and undergraduate level and whether pattern recognition skills is the appropriate method of training to assist radiographers to fulfil the extended role.

The methodology implemented for radiographer training and the ability of radiographers to image interpret will be discussed in the next chapter.
CHAPTER THREE
RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

This chapter describes the research design and methodology used in the research to assess whether qualified diagnostic radiographers could, with training, interpret musculoskeletal radiographs to a standard that would provide an accurate initial comment.

Aim of the Research:

The aim of the study was to assess the ability of qualified diagnostic radiographers in two Gauteng Government hospitals to apply pattern recognition and interpret a radiograph after training in musculoskeletal pattern recognition.

The objectives of the study were:

- To train qualified diagnostic radiographers in musculoskeletal pattern recognition.
- To assess the ability of radiographers to accurately interpret musculoskeletal radiographs after undergoing training.

To achieve the objectives and to assess the ability of diagnostic radiographers to accurately interpret musculoskeletal radiographs an assessment prior to any training was done. Training in the form of an intervention was then carried out and another assessment was done after the intervention. The intervention took the form of training in musculoskeletal pattern recognition and image interpretation. Qualified diagnostic radiographers, the participants, in this research were trained in pattern recognition of the musculoskeletal system as pattern recognition
was recommended to be included in the curriculum for all disciplines of radiography in 1996 (Professional Board of Radiographers, 1996). According to the letter from Mr.B.Mokgonyana written on behalf of the Registrar of the South African Medical and Dental Council N.M.Prinsloo dated 23rd January 1997 to Miss.E.Durand the Faculty Officer Health and Biotechnology Technikon Witwatersrand the Executive Committee of the Professional Board recommended:

“…..that pattern recognition be recognised as a professional act of the profession of radiography, for this purpose pattern recognition was defined as the recognition of a variation of normal images, which simultaneously recognized the competency of radiographers to recognize normal images. This could, however under no circumstances be regarded as making a diagnosis.”

The Rules of Conduct pertaining specifically to the Profession of Radiography with regard to the performance of professional acts by a radiographer in terms of providing an interpretation of an image states:

“A radiographer shall not interpret radiographical investigations, report thereon or furnish information in regard to any work performed by him or her profession to any person other than a practitioner approved by the board at whose request such work was undertaken” (Health Professions Act 56, 1974).

Pattern recognition was chosen as a skill that radiographers could be taught, in order to enable them to provide a comment on images, which for the purpose of this study is an image interpretation. In addition according to Reeves (2004:213-215) pattern recognition was the foundation for providing a comment on an image. For the study the musculoskeletal system was chosen although pattern recognition can be used on all systems and for all modalities. Research has not established whether
diagnostic radiographers in South Africa can provide an accurate interpretation of a musculoskeletal image and therefore training in musculoskeletal pattern recognition was conducted and the diagnostic radiographer's ability to interpret radiographs of the musculoskeletal system before and after training was assessed.

3.2 RESEARCH DESIGN

A quantitative experimental research design was used. The use of quantitative research methods provides measurable results, which can be extrapolated to the larger population (Mouton, 2001:157). A positivist approach was used in this research. An intervention to test the aim experimentally was used. Positivism assumes that the objectives of the research would be based on a reality that can be measured and that theories can be proved experimentally (Bruce, Pope & Stanistreet, 2008:3). In a quantitative experimental design it is necessary for the researcher to be objective, remain emotionally detached and not distort the results due to personal bias (Bruce et al., 2008:3). Experimental research should be based only on factual knowledge.

The pre-test post-test model was used for measuring the effect of the intervention. According to Bonate (2000: 2) the pre-test post-test model is characterised by; a measurement taken prior to the intervention; followed by the implementation of an intervention and, thereafter, the same participants undergo a post-test measurement to assess the possible effect of the intervention. The use of an intervention necessitates a time period between the pre-test and post-test. The use of a pre-test post-test model implies the post-test results are dependent on the pre-test results (Bonate, 2000:3).

The researcher chose the pre-test post-test model because it has been used in similar research as outlined in 3.2.1.
3.2.1. Justification for Adopting the Pre-Test Post-Test Model

The pre-test post-test approach was used in previous research for example Hardy and Culpan (2007: 67) used the pre-test post-test approach when assessing the effect of a short course in musculoskeletal trauma on the ability of radiographers to interpret radiographs. Initially all the participants were offered the opportunity to undergo an assessment where their ability to correctly “red dot” a radiograph was assessed. The radiographer was required to identify the image as abnormal or normal and then if abnormal provides a comment on the abnormality. At the end of the short course (the intervention), the participants were again offered the opportunity to complete the same assessment they had undertaken in the pre-test. As previously stated in Chapter Two (cf 2.11.1:55-56) the model used by Hardy and Culpan (2007:67) accurately measured changes in the accuracy, sensitivity and specificity in the interpretation of images by the radiographers following their training. The pre and post-test comprised the same 20 images of which 9 images were normal and 11 images demonstrated radiographic abnormalities. The test was administered as a PowerPoint presentation and the participants had approximately 40 seconds to view each image and provide a comment on each image. The results were analysed using the SPSS statistical software (Hardy & Culpan: 2007, 67). The analysis in the post-test showed an improvement in the accuracy of identifying normal and abnormal images and in the ability of the participants to comment on the images. However in the post-test, the radiographers identified more normal images as abnormal, which Hardy and Culpan (2007:67) attributed to the training, resulting in overcall by the radiographers due to a heightened sensitivity towards pathology. The pre-test post-test model provided significant results.

Lanning, Best, Temple, Richards, Carey & McCauley (2006: 547-8) also used a pre-test post-test approach by providing training in radiographic interpretation (the intervention) between the tests. The first test, which was
the pre-test, comprised 25 PowerPoint images, which participants assessed for bone loss, with each image being viewed for 30 seconds. Training was then given to the participants followed by post-test 1, which was again conducted using 25 images. In the research two post-tests were implemented one immediately after the training and another three months thereafter. Lanning et al., (2006: 547) used the same images each time for all three tests although the order of the images was changed for each test. Furthermore, these authors discussed the results of the first post-test with the participants immediately upon completion of the test. With this additional knowledge the second post-test was completed three months after the training. The results of the first post-test demonstrated that the most significant improvement in assessing the radiographs occurred immediately following the training although accuracy continued to improve over the period between the training and the second post-test. The conclusion could be drawn from this pre-test post-test study that training had a positive result on image interpretation.

When considering the pre-test post-test research done by McConnell and Webster (2000), Hardy and Culpan (2007:67) and Piper and Paterson (2009:43-44), these researchers obtained results demonstrating the changes in the abilities of radiographers to perform image interpretation following an intervention and therefore this model has been shown to be valid previously for this type of study. The researcher on the basis of previous research done and as cited selected this research model as it demonstrated its validity as a tool to measure changes in the ability of diagnostic radiographers to interpret images before and after training. According to Knowles (2005: 82) the pre-test assesses the abilities of the participants before the intervention and the data collected should provide specific results relevant to the change that the research is hoping to demonstrate in the participants. The post-test assesses the same behaviour as the pre-test by demonstrating any change in the ability of participants with respect to image interpretation following the intervention.
In addition, according to McConnell and Webster's research (2000, 611) the two tests may be the same test. However, they did identify the same images being used as a limitation of their study. Other studies also used the same images in the pre-test and the post-test. The researchers in these studies supported their decision as the images were never used in the training and the number of false positives suggests that the students did not discuss the cases (Piper & Paterson, 2009:43, Hardy & Culpan, 2007:67, Coleman & Piper, 2009: 198).

3.3 POPULATION AND SAMPLING

Participants in the research were all qualified and registered diagnostic radiographers employed in the Gauteng Government Health Sector. The total number of qualified diagnostic radiographers employed in this sector is 560 (www.hst.org.za: 2010). To practice as a radiographer one must be registered with the Health Professionals Council of South Africa (HPCSA). In 2010, 6200 radiographers in total were registered with the HPCSA in the four radiography disciplines, namely; diagnostic, therapy, ultrasound and nuclear medicine (HPCSA, statistics: 2010).

The study drew participants from two of the Gauteng Government hospitals, namely Tambo Memorial Hospital and Chris Hani Baragwanath Hospital. Both hospitals gave permission (Annexure 1) for their radiographers to participate in the research and released them from their duties to attend the scheduled training.

Tambo Memorial Hospital has a complement of 24 radiographers when fully staffed. In 2009 they were severely understaffed. Therefore it was decided to include a second, hospital, Chris Hani Baragwanath Hospital in the research. Chris Hani Baragwanath Hospital has a complement of approximately 50 qualified radiographers. Random selection was not possible due to the radiographers' work commitments. Therefore all qualified radiographers at both hospitals were approached to participate in the research. Of the total number of ±approximately 74 diagnostic
radiographers from the two hospitals nine diagnostic radiographers participated in the entire study. The number of participants was dictated largely by the workload in the respective hospitals. The number of participants was agreed to after discussion with the heads of the respective departments, as their participation could not be permitted to impact on the functioning of the departments. The number of participants from each hospital allowed participants to attend the tutorials and fulfil the clinical application of the training (the research intervention) without impacting negatively on their departments.

Nine diagnostic radiographers were considered statistically valid as the participants interpreted 100 images in each test, which provided an interpretation of 900 images in the pre-test and 900 images in the post-test. In consultation with a statistician it was confirmed the number of images interpreted by the 9 radiographers would provide statistically relevant information when compared with other studies using a pre-test and a post-test. Similar numbers of images have been used previously. For example Piper and Paterson (2009:42) compared the abilities of 18 radiographers and 22 nurses in interpreting radiographs thus a total of 40 participants. The participants interpreted 20 images in each test. Therefore in the pre-test and post-test a total 800 of images were interpreted. Similarly McConnell and Webster (2000:609) had 22 diagnostic radiographers participating in a pre and post-test study with a short course as the intervention. The participants interpreted 42 images in each test, which resulted in 924 images being interpreted per test, a total of 1848.

Hardy and Culpan (2007:67) had 115 radiographers who interpreted 20 images per test, which provided 4600 responses in total, for all participants. Mackay (2006:469) had 133 radiographers who took part in a 2 day course and participated in a pre-test post-test study comprising of 30 images, which provided 3990 results for each of the tests with a total of 7980 results. One radiographer did not participate in the post test therefore there were 7950 results. It is acknowledged that the two studies
had many more participants and as such generated more results. It was, however, considered that nine participants and a total of 1800 results were statistically adequate for this study.

3.4 METHODS AND MATERIALS
The methods and materials used in the study are described and justified in the sections below. Potential limitations of the study are also highlighted.

3.4.1 Phases of the Research
The study used a four-phase approach:

- Phase One – Revision of the “red dot” system
- Phase Two – Pre-test
- Phase Three – Intervention
- Phase Four – Post-test

3.4.2 Phase One: Revision of the ““red dot”” System
The aim of the study was to train diagnostic radiographers and provide them with the skills to accurately interpret musculoskeletal radiographs and provide a written comment. The training or the research intervention comprised of pattern recognition tutorials and workshops on the musculoskeletal system to facilitate the achievement of this aim.

A precursor to the interpretation of radiographs using pattern recognition is the ““red dot”” system. The ““red dot”” system as previously discussed is when a ““red dot”” is placed on a radiograph indicated that diagnostic radiographer has identified this image as an abnormal image in accordance with the clinical history presented by the patient. The absence of a ““red dot”” indicates a normal radiograph. The diagnostic radiographer does not indicate the location, type or appearance of the abnormality when applying the ““red dot”,” as it is merely a flag to highlight a possible
abnormality requiring interpretation. The diagnostic radiographers in the pre-test were also asked to provide the interpretation and not merely the “red dot.” The “red dot” has been found to be ambiguous in previous studies. For this reason, Hardy and Culpan (2007:66) stated that a comment would be more accurate.

It was deemed necessary for the participants to revise the application of the “red dot” system prior to the pre-test for the following reasons:

- To provide an understanding of the “red dot” system to the participating diagnostic radiographers who qualified more than ten years ago when the “red dot” system was not part of the curriculum. All radiographers were eligible for the research as the number of years of qualification was not a criterion for exclusion.
- To provide a common understanding of the concept of the “red dot” system for all participants, independent of the tertiary institution at which they studied for their qualification.

The researcher provided a tutorial on the “red dot” system, which took place at the University of Johannesburg. Using a protocol adapted from Hargreaves and Mackay’s (2003: 285) study (Annexure 2) the participants were given a two-hour tutorial on the application of the “red dot”. The Hargreaves and Mackay (2003, 289) protocol required adaptation, as the emphasis of their research was to apply the “red dot” system specifically to trauma images, such as those demonstrating fractures, dislocations and the visualisation of foreign bodies. In the context of the present research a broader definition of abnormal musculoskeletal radiographs was applied including non-trauma related pathology.

During the revision of the “red dot” system the participants were shown both normal and abnormal images to provide them with the tools to identify
images requiring a “red dot” and those that did not. None of the images used in the revision tutorial were used in the pre-test. The understanding of the “red dot” system was discussed as a group allowing the participants to identify when they would use it. The images used were hard copies and displayed as for an Objective Structured Clinical Examination with self-testing and discussion of the correct responses.

3.4.3 Phase Two: Pre-Test

It was necessary to assess the participant’s ability to identify normal and abnormal radiographs and their ability to interpret the abnormality by providing a comment in support of their image interpretation before the intervention was administered. The images used in the pre-test required an initial interpretation by an expert to validate the findings of the participants. The radiologist provided the benchmark for the interpretation of these images. As a radiologist is considered the “gold standard” when interpreting radiographs and was therefore the reference standard for the research. A radiologist with forty years of experience was selected as the expert providing the reference standard. The radiologist viewed all the radiographs used in the pre-test and completed the same data sheet as the participants (Annexure 3 and 4). The radiologist classified the image as either normal or abnormal and when an image was considered abnormal provided a comment identifying the pathology in terms of the abnormal pattern and the location of the abnormality.

According to Brealey, Scally and Thomas (2002:.205) it is important to establish independence of interpretation. This was achieved in the study by ensuring the participants had no knowledge of the radiologist’s comment, which provided the reference standard for the correct and accurate response. Thus the reference standard was a single blind consultant radiological comment.
The pre-test used for the study comprised of a bank of 100 hard copies of musculoskeletal images labelled 1-100 for the participants to interpret. The hard copies were chosen as this form of viewing radiographs was the method of viewing most familiar to the participants. In addition, facilities were available for the use of viewing boxes to view the images and this was consistent for all participants.

The radiographs represented a 50:50 ratio that reflected positive to negative results. A positive image was abnormal and a negative image reflected a normal image. Thus radiographs viewed by the participants comprised of 50 normal images and 50 abnormal images. Participants were aware that some of the images were normal images. However, they were not aware of the ratio of normal to abnormal images. Normal images were included to be representative of the clinical situation. The radiographs reflected a higher proportion of abnormal images than would be seen in the clinical environment. In clinical practice, a higher percentage of images would be normal but for the purposes of the research it was essential for the participants to assess the interpretation of abnormal pathology. In Coleman and Piper’s research (2009:198) their test bank of 20 images comprised of 30% normal images and 70% abnormal images. Similarly Piper & Paterson (2009:42) used only five normal out of the 20. Hardy and Culpan (2007:67) also had a bank of 20 images of which 11 were abnormal images. Previous research thus supports the use of a high number of abnormal images proportional to normal images.

After considering previous pre-test post-test research some images included were subtle and difficult cases. Piper & Paterson (2009: 43) highlighted that these cases acted as discriminatory in demonstrating those radiographers with better interpretation skills than others. These types of images were consistent in both the pre-test and post-test and
therefore could accurately assess any change in the participant’s ability to identify these more complex conditions.

The participants were each provided with a data sheet (see Annexure 4) that reflected the image numbers 1-100. The data sheet was the same for all participants in the research as well as the radiologist. Identical instructions were reflected on the data sheets for both the participants and the radiologist as recommended by Neutens and Rubinson (2010: 77) in order to ensure consistency. The participants were then asked to identify normal or abnormal images by ticking the answer in the appropriate box. In addition the participants were requested to provide a comment on each of the images that they had identified as abnormal. The comment demonstrated the degree to which the participant could interpret images before the intervention. The results were analysed with regard to the correct interpretation of normal or abnormal images and if the image was correctly identified as abnormal the interpretation was assessed in accordance with how accurately the participant identified the pattern changes/ and/or pathology and the location of the abnormality.

The participants were given 150 minutes to complete the pre-test. The time for viewing was calculated in accordance with Piper and Paterson (2009: 43) who allowed 30 minutes for 20 images the equivalent of 90 seconds per image. However, Piper and Paterson (2009: 43) stated that they did not allocate specific viewing times per image but rather allowed the participants to use the allotted time as they felt necessary. They could spend less time on images that were easier to interpret and longer on those they assessed as more complicated. The researcher adopted Piper and Paterson’s (2009:43) approach where the time per image was not specified, and participants were allowed to view images according to their requirements and could return to images, if necessary. The participants viewed the images independently and the researcher invigilated the process.
The pre-test was conducted on two occasions due to the unavailability of all participants on one day. The researcher felt that due to the large number of images it would not be possible for the participants in the first session to communicate the type and nature of the images to their colleagues who were due to participate in the second session. In addition the participants did not receive feedback on their responses. Feedback was only provided after the post-test was completed.

In McConnell and Webster’s (2000:609) research they had 14 students participating in the pilot study and a further 8 students from subsequent courses totalling 22 students in all. Students from the pilot study completed the pre and post-tests before the students registered on the short course which was offered at a later date. The same 42 radiographs were used for all tests. In the research the test was conducted three times, namely once before the intervention, once immediately after the intervention and then six-ten weeks post training. The students did not have access to any of the 42 radiographs at any time and none of the images were used in the short course. McConnell and Webster (2000:611) reported an increase in false positives in their post-test immediately following the training. Therefore discussion of the images by the students did not appear to have influenced the outcome. Students would not be expected to incorrectly attribute an abnormality to an image that was normal if they had discussed the results. No feedback was provided in McConnell and Webster’s (2000:611) research until completion of the final assessment, which they felt validated, the significance of their results.

However in the present study the pre-test and post-test the tests were comparable, but not identical in order to prevent participants discussing the results of the pre-test and thereby affecting the post-test results.
3.4.4 Phase Three: Intervention – Training in Musculoskeletal Pattern Recognition

Once the pre-test was completed the participants took part in a series of tutorials on musculoskeletal pattern recognition. For the purpose of this study the tutorials on the musculoskeletal system included the appendicular and the axial skeleton, but excluded the skull. The musculoskeletal system or locomotor system was identified by McConnell and Webster (2000:609) as the area most commonly “red dotted” in the UK and, therefore, this system was the most commonly requested system for training in image interpretation, followed by the chest. The radiographs and information used in the tutorials was completely different to the images used in the pre-tests and the post-test.

Each musculoskeletal area, namely the – upper extremity, lower extremity, spine and pelvis were identified and five tutorials were offered and a feedback session on skeletal image interpretation using a checklist was given.

The following tutorials were provided to the participants:

- Introduction to pattern recognition
- Application of pattern recognition skills to the upper extremity.
- Application of pattern recognition skills to the lower extremity.
- Pattern recognition interpretation for the spine and pelvis.
- Check list to assist with pattern recognition and interpretation of plain films of the skeletal system.
- Feedback on plain film interpretation after utilising a checklist.

An outline of the content of the training is included as Annexure 7. The tutorials took place from October 2009 to May 2010. Each participant attended the tutorial and feedback session once and attendance registers
were kept. The tutorials were a combination of PowerPoint presentations and hands-on workshops where the participants used the skills and techniques of pattern recognition provided in the presentations to interpret hard copy images that demonstrated normal and abnormal patterns. PowerPoint presentations were used to demonstrate unusual and subtle cases, as it is not always possible to have hard copies of all the pathologies. The PowerPoint presentations also provided points of reference for the participants in the clinical environment. The participants had access to the PowerPoint presentations via e-mail and were able to print the tutorials for ease of reference whilst working. Hard copies of radiographs used in the tutorials could not be provided in this way to all participants individually.

The researcher and lecturers from the University of Johannesburg conducted the tutorials on pattern recognition. The lecturers offering the training were the same throughout the training as according to Neutens and Rubinson (2010: 77) it is important to keep variables constant. The tutorials were initially conducted on Saturday mornings at the University of Johannesburg, but due to work commitments and to enable all staff to attend every tutorial a venue was found at Chris Hani Baragwanath and tutorials were offered on a Friday morning when the department was quiet.

The tutorials were compulsory for all participants. Each tutorial was approximately two hours in duration. Five different tutorials that covered different areas were given. Some tutorials had to be repeated to enable all the participants to attend every tutorial once. The information provided was consistent as the workshops were presented as PowerPoint presentations, which were the same for the repeat tutorials. Due to the nature of the radiographers work commitments this is common practice as was the case in the study done by Hargreaves and Mackay (2003: 285) where the same tutorial was provided three times. Attendance registers were taken for each workshop to confirm that every participant attended every training opportunity. Furthermore, participants
were required to apply the pattern recognition and interpretation skills learnt in these tutorials in the clinical environment. In order to facilitate this, participants were each provided with a logbook (Annexure 1) to record the radiographs they used when applying pattern recognition and interpretation skills to musculoskeletal radiographs in their respective clinical environments. The participants were also required to complete image interpretation for four different areas of the musculoskeletal system and a minimum of five cases per area to monitor their ability to apply the training received to varied cases and areas. Some of the images they interpreted could be normal as it was essential to understand normal variants in conjunction with the abnormal patterns. The interpretation provided by the participants was verified by a radiologist in their department and signed by the radiologist who discussed the case with them. The participants were required to submit these at the same time as completing the post-test.

**3.4.5 Phase Four: Post-Test**

Once the intervention phase and clinical experience was completed a post-test was administered. The radiologist, the reference standard, again identified abnormal and normal images and provided a comment on the abnormal images using the same data sheet (Annexure 4). The radiologist remained the same for the pre-test and post-test. The test again comprised 100 radiographs labelled 1-100. The radiographs were not the same radiographs used in the pre-test. However, the images were comparable to the radiographs used in the first test. The ratio of normal to abnormal radiographs was the same as the pre-test, that is, a 50:50 ratio. The post-test was offered on two different dates to allow for the attendance of all the participants. The rationale applied was the same as for the pre-test. The images were not used in the pattern recognition training. Comparable images comprised of different images of the
anatomical areas with the same pathology or the same type of pathology in a different area. The post-test provided a means of measuring the change that occurred in the ability of radiographers to interpret radiographs after their training in musculoskeletal pattern recognition.

3.5 DATA COLLECTION TOOLS

Data sheets with numbers 1-100 (Annexure 4) were provided for the participants to complete the pre-test and post-test assessments. Peat (2002: 122) mentions that when using a questionnaire the tool should be clear, practical and easy to use. These same conditions apply to the design of a data sheet. The data sheet should be simple and easy to complete. The researcher allocated a number to each participant on his or her data sheet to ensure his or her anonymity. The data sheet for the radiologist who provided the reference standard for the post-test was identical to the one used by the participants.

3.6 DATA ANALYSIS

3.6.1 Test Bank Results

Brealey, Scally and Thomas (2002: 206) looked at studies that had conducted research into the image interpretation abilities of diagnostic radiographers. The researchers considered the methodology of these studies and identified the diagnostic accuracy study design, which according to Brealey, Scally and Thomas (2002: 206) is implemented when radiographers are required to interpret specifically selected normal and abnormal images under controlled conditions. The pre and post- tests in the present study were conducted as stated by Brealey, Scally and Thomas (2002, 206) and therefore, constitute a diagnostic accuracy study.

Sensitivity is the accurate diagnosis of positive cases, that is, identifying the abnormality and thus a true positive (TP). Specificity is the accurate
interpretation of normal cases and is termed a true negative (TN) (Coleman and Piper: 2009, 199).

Those cases, incorrectly interpreted, are classified as false positive (FP) when participants identify an abnormality whereas the reference standard identifies the image as normal. A false negative (FN) is where an abnormality is not identified and interpreted as a normal image. In summary the following:

- **True Positive (TP)** – Abnormal radiograph correctly identified
- **True Negative (TN)** – Normal radiograph correctly identified
- **False Positive (FP)** – Normal radiograph incorrectly identified as abnormal
- **False Negative (FN)** – abnormal radiograph incorrectly identified as normal

The researcher marked the responses on the data sheets. The answers on the data sheet were analysed to establish whether the participant had provided the correct response, either normal or abnormal according to the radiologist’s report. Once the normal or abnormal answer was assessed then the comment on the radiograph was considered. The comment was assessed in terms of the location of the pathology and the radiographic description of the abnormality. No marks were deducted for incorrect spelling or for the use of abbreviations when commenting on the images.

The accuracy, sensitivity and specificity data were analysed for normality using the Kolmogorov-Smirnov statistic. The data was considered to have a non-normal distribution. The data was considered non-parametric. Due to the pre- and post-test nature of the research it was necessary to compare the two sets of results. The non-parametric test used was the Wilcoxon Signed Ranks Test. The Wilcoxon Signed Ranks Test was chosen to compare paired samples where the same subjects are tested on two separate occasions as was the case in this study. A significance level
of 0.05 was considered for the analysis of the data. The p-value of 0.05 is generally a standard value in social science research (Somekh & Lewin, 2005: 227). Statistically significant results would be p-values of 0.05 or less. The use of box plots to reflect the results were used as previous research by Mackay (2006:470) and McConnell and Webster (2000:610) had demonstrated their results in this manner.

The researcher also felt that it was important to identify which images had been incorrectly interpreted by the participants. The FN images that were interpreted as being normal and were in fact abnormal were particularly important when considering the type of training needed in the future. Cases consistently misinterpreted by the participants highlighted a gap in their knowledge of specific types of pathology and their inability to interpret patterns seen on images, which could be rectified in future training programmes. FP images were also analysed as this could indicate a misunderstanding of normal variants, which again would require further training in the normal patterns seen on normal images when implementing an image interpretation course.

3.7 RELIABILITY AND VALIDITY

The different images used in the pre- and post-tests were used to prevent the testing effect (Neutens and Rubinson, 2010: 80). The testing effect is when performance in the post-test is improved due to a knowledge and experience of the previous test, which can also be called the practice effect (Altermatt, 2010:1). Using the same test for the pre-test and the post-test provides a knowledge of the images, therefore it becomes difficult to be sure that training has effected the change in the performance in the post-test. To eliminate the testing effect two different banks of images were used. The timing of the tests can affect recall of the pre-test therefore by having different tests six months apart eliminated the
likelihood of participants recalling images. A test bank of 100 images also makes it difficult to remember the images from one test to another. Using a radiologist as the reference standard for the image interpretation ensures the validity of the image interpretation. A radiologist considered the “gold standard” for image interpretation, underscores reliability and validity.

3.8 LIMITATIONS

The following possible limitations could have impacted on the study:

- The tutorials were repeated due to the work commitments of the participants. Whilst every precaution was taken to ensure that the tutorials were consistent by using the same lecturer, PowerPoint presentation and hard copy radiographs, the interaction between the lecturer and the participants could not be guaranteed to be exactly the same as this was unique to each particular tutorial.

- Participants in the study were provided with log books (Annexure 5). The skills taught during the intervention could be used and recorded in practice in the clinical environment. The participants then discussed the results with a radiologist in their department to confirm the accuracy of their interpretation. The interaction with the radiologist could have led to degrees of additional training unique to that particular participant.

- A single radiologist was used and it is acknowledged that a second radiologist would ensure validity of the comments provided for the images used in the tests.

Participants taking part in the study may have been more motivated to improve their image interpretation skills through additional study using books and the Internet, which could have affected their results.
3.9 ETHICAL CONSIDERATIONS

Ethical considerations were met by applying of the following:

- Letters requesting permission for the qualified diagnostic radiographers who were to be granted the opportunity of participating in the research were sent to the two institutions concerned (Annexure 1). Both hospitals, namely Tambo Memorial Hospital and Chris Hani Baragwanath Hospital gave permission for their diagnostic radiographers to take part in the study.

- Ethical approval was applied for and granted by the Academic Ethics Committee of the Faculty of Health Sciences, University of Johannesburg (Clearance reference number: 47/08).

- Letters requesting informed consent from the participants were given to each diagnostic radiographer volunteering to participate in the study (Annexure 6). The letters provided the participants with an outline of the research and the expectations of the researcher during the research process. In the letter the participants were reassured about issues pertaining to anonymity in the research process and informed that they could withdraw from the study at any point in the research process.

- Anonymity was ensured by allocating each participant with a unique number. Thus, the participant was never identified at any point during the research. Numbers were assigned to the data sheets by the researcher after the participants had completed the pre-test. The participants had no knowledge of the number assigned to them. They did not see their pre-test data sheets once completed. Therefore, the researcher was the only person who knew the number allocated to a participant. In this way, the privacy and confidentiality of the participant was assured.
• Issues surrounding anonymity were explained to the participants and the importance of the group results, as opposed individual results, was stressed (Neutens and Rubinson, 2010:60).

3.10 SUMMARY

In this chapter the pre-test and post-test model used to assess the ability of qualified diagnostic radiographers to use their pattern recognition skills to interpret images prior to and after training (the intervention) was described. The pre and post-test measured the effectiveness of the intervention.

The validity of the choice of musculoskeletal images for the pre and post-tests was discussed and shown to be representative of the clinical environment. The “gold standard” for image interpretation, was shown to be the radiologist who provided the reference standard, for every image used in the tests and who therefore, ensured the reliability of the results. The ethical considerations were discussed and the anonymity of the participants is shown to be maintained in the study.

The data was collected using data sheets that recorded the responses of the participants and the comments provided by the radiologist and then the data was analysed according to the comment provided by the radiologist. The results of the tests were recorded in spreadsheets and analysed by the researcher in accordance with the radiologist’s reports. The results of the analysis by the statistician are discussed in the next chapter.
CHAPTER FOUR

RESULTS OF STUDY

4.1 INTRODUCTION

The aim of the study was to assess the ability of qualified diagnostic radiographers in two Gauteng Government hospitals to apply pattern recognition and interpret a radiograph after training in musculoskeletal pattern recognition. In this chapter the results for the pre- and post-tests are discussed to establish whether the training in musculoskeletal pattern recognition had an effect on the ability of the participants to accurately provide an interpretation.

The sample population consisted of nine diagnostic radiographers (n=9). A 100 percent of the participants completed both the pre-test and the post-test and the intervention (the training) in musculoskeletal image interpretation. It is acknowledged that the sample size was small. However, 100 images were assessed in each test. Therefore the results in total for each test were 900 responses per test. At the proposal stage a minimum number of participants agreed to was eight, which was considered statistically valid because of the number of images in the pre- and post-testing phases. The requirement has been achieved in the study.

4.2 PRESENTATION OF THE DATA

The study population therefore comprised nine qualified diagnostic radiographers who participated in all the required elements of the study. See table 4.1.below:
4.3 ANALYSIS OF THE DATA

An analysis of the data is presented in the following sections.

4.3.1. Accuracy of Image Interpretation

The data regarding the accuracy of the image interpretations by the participants is analysed and presented in the following sections in regard to correct and incorrect responses.

4.3.1.1. Correct Responses

The accuracy of the image interpretation by the participants was analysed. The number of correct responses was compared with the number of incorrect responses. See Table 4.2 below:

<table>
<thead>
<tr>
<th>Cases</th>
<th>Valid</th>
<th>Missing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Percent</td>
<td>N</td>
</tr>
<tr>
<td>Completed the pre-test</td>
<td>9</td>
<td>100.0%</td>
<td>0</td>
</tr>
<tr>
<td>Completed the post-test</td>
<td>9</td>
<td>100.0%</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 4.2: Correct responses for the pre-test and post-test

<table>
<thead>
<tr>
<th></th>
<th>Statistic</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Correct responses pre-test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>70.1111</td>
<td>1.74359</td>
</tr>
<tr>
<td>95% Confidence Interval Lower Bound</td>
<td>66.0904</td>
<td></td>
</tr>
<tr>
<td>for Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Bound</td>
<td>74.1318</td>
<td></td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>70.0123</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>70.0000</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>27.361</td>
<td></td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>5.23078</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>61.00</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>81.00</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>3.50</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>0.573</td>
<td>0.717</td>
</tr>
<tr>
<td><strong>Correct responses post-test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>77.6667</td>
<td>1.84089</td>
</tr>
<tr>
<td>95% Confidence Interval Lower Bound</td>
<td>73.4216</td>
<td></td>
</tr>
<tr>
<td>for Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Bound</td>
<td>81.9118</td>
<td></td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>77.5185</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>79.0000</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>30.500</td>
<td></td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>5.52268</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>70.00</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>88.00</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>18.00</td>
<td></td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>8.00</td>
<td></td>
</tr>
</tbody>
</table>
The correct responses were all true negative and true positive responses. The mean for correct responses in the pre-test was 70.1% compared to the mean in the post-test which was 77.6% (see table 4.2). The significance of the results was calculated using the Wilcoxon Signed Ranks Test. The Wilcoxon signed ranks test was previously used by McConnell and Webster (2000:611) as they identified the test to be appropriate for a pair of non-normally distributed results. The Wilcoxon test is a non-parametric test, which is appropriate for these results as the results are taken before and after the intervention. The Wilcoxon Signed Ranks Test was chosen to compare paired samples where the same subjects are tested on two separate occasions as was the case in this study, having used the results of the pre and post-tests. See Table 4.3 below for the Wilcoxon Signed Ranks Test for correct responses.

<table>
<thead>
<tr>
<th>Accuracy</th>
<th>Correct post-test</th>
<th>Correct pre-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>2.666a</td>
<td>0.008b</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The significance value is p = 0.008 (see Table 4.3). The p-value of 0.05 is generally a standard value in social science research (Somekh & Lewin, 2005: 227). Statistically significant results are p-values of 0.05 or less, therefore the results for correct responses demonstrate significant change.

The improvement of the number of correct responses in the pre-test in comparison with the post-test can be attributed to the intervention that is the training in image interpretation.

Figure 4.1 below illustrates the box plot for the pre- and post-test correct responses.
Correct responses pre- and post-test

Figure 4.1: Box plot: Pre- and post-test correct responses

Boxplots are useful to compare two sets of scores as in this case the pre-test and the post-test number of correct responses are compared (SPSS:16). The boxes represent the distribution of the scores for the participants in the pre-test and the post-test. The median is represented by the bold line within each box. The lines extending from the boxes are whiskers which represent the lowest and highest results. Unless there are extreme results these would be represented as stars or circles and are outliers. The pre-test median is 70.0% and the post-test median is 79.0%. The median is the “middle number.” Therefore there was a 9% improvement in correct responses by the nine participants from the pre-test to the post-test, which may be a result of the intervention.

The box-plot Figure 4.1 has two outliers represented by stars for the pre-test correct results. Outliers are extreme results. These are results, which lie outside the interquartile range and...
deviate significantly from the rest of the sample. One participant had 81% correct responses, which is higher than the other participants and conversely there is one outlier showing correct responses 61% which is significantly lower than the other results.

The box plot demonstrates the quartile results with the lower whisker representing the lowest 25% of results. In this case, the end of the whisker on the pre-test box is not the minimum point due to the outliers and for the uppermost 25% the maximum point is not positioned at the end of the whisker due to the outlier. When considering the post-test results there are no outliers, therefore, the results for all nine participants are more uniform, which would suggest the intervention enabled all the participants to realise a similar level of ability compared to the extreme results of the pre-test.

Comparison between the post-test shows that the end of the whisker, which is the lowest point of the post-test results, is at 70.0%, whereas for the pre-test box, the median is 70%, which is the mid-point. Thus, the mid-point for the pre-test is the same as the minimum for the post-test. The pre-test distribution, ignoring the outliers, has a symmetrical appearance for each quartile, but, for the post-test results, the median is seen to be high in the 50\textsuperscript{th} quartile and the whisker of the 75\textsuperscript{th} percentile is very long. Thus, the results are not symmetrical and considered to be slightly skewed.

As the box plots for the correct responses are displayed in a parallel distribution, the box plot shows the difference in distribution of the initial correct responses in the pre-test. The range is very small and the participants all demonstrated very similar results with the exception of the outliers. Therefore, seven of the participants were of a very similar ability. However, post-test results demonstrate a much larger variability in the results and when comparing the boxes the post-test box was situated at a much higher centre. The comparison of the pre-test and post-test responses shows a significant increase in the number of correct responses in the post-test.

\textbf{4.3.1.2 Incorrect Responses}

The incorrect responses were analysed in line with the correct responses to assess the accuracy of the respondents as illustrated in Table 4.4 below.
The number of incorrect responses the false positive and false negative responses seen in Table 4.4 demonstrates that the mean number of incorrect responses pre-test is 28.0% compared with the post-test mean of 21.0%.

The results for the Wilcoxon Signed Ranks Test for the incorrect responses are shown in Table 4.5 below.
Table 4.5: Wilcoxon Signed Ranks Test for incorrect responses.

<table>
<thead>
<tr>
<th></th>
<th>Incorrect post-test</th>
<th>Incorrect pre-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>2.666&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.008&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. Based on positive ranks.

b. Wilcoxon Signed Ranks Test

The Wilcoxon Signed Ranks Test again (see Table 4.5) produced a p-value of 0.008 demonstrating a significant result.

Figure 4.2 below illustrates the box plot for pre-test and post-test incorrect responses.

![Box plot of incorrect responses pre and post-test](image)

Figure 4.2: Box plot pre-test and post-test incorrect responses
The median for the pre-test results (the bold line) is demonstrated in Figure 4.2 at the upper edge of the 50th percentile. The outliers are again demonstrated in the pre-test results. The outliers are shown as a star and a circle, a star is a more extreme result than a circle although both results are outside the lower and upper quartiles. The results reflect that participant number 2 (represented by the star) was the most accurate participant with 18% incorrect responses. The least accurate participant, namely number 7 (represented by the circle) had 34% incorrect responses.

The pre-test results have no lower whisker, which demonstrated that the majority of responses fell in a small range for the pre-test. The box for the interquartile range for the pre-test was shorter than the box for the post-test. The interquartile range for the pre-test is 3 compared with the interquartile range of the post-test which is 9 (see Table 4.4). There were no outliers for the post-test incorrect responses, therefore all the results fell within the quartiles and the study group has become more homogenous.

### 4.3.2 Image Interpretation - Sensitivity

Sensitivity is defined as the participants’ ability to correctly interpret abnormal images as abnormal (Hardy & Culpan, 2007: 67). Therefore, in order to consider the sensitivity of the participants, the researcher needs to consider the TP results, which are abnormal images correctly identified. The number of FN results must also be considered as these are the images that have been interpreted as normal when they were abnormal.

In order to calculate the total rate of sensitivity the formula used by Carter and Manning, (1999:72) in their case study was used where the sensitivity calculation equalled the TP results as a percentage of the total of abnormal images.

Sensitivity is the true-positive percentage, calculated by the following method:

\[
\text{Sensitivity} = \frac{TP}{TP+FN} \times 100
\]

- Total Pre-test Sensitivity:
Total TP pre-test = 363
Total FN pre-test = 66

\[
\frac{363 \times 100}{363 + 66} = \frac{36300}{429} = 84.6\%
\]

- Total Post-test Sensitivity:

Total TP post-test = 390
Total FN post-test = 46

\[
\frac{390 \times 100}{390 + 46} = \frac{39000}{436} = 89.44\%
\]

The difference in sensitivity identifying abnormal images was 4.84%, which showed an improvement post intervention.

The analysis of the results for correct interpretation of abnormal images and the corresponding incorrect identification of abnormal images as normal were considered in conjunction with the results for sensitivity. The results are shown in Table 4.6 below.
Table 4.6: True positive results equating to the correct identification of abnormal images.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Pre-test, number of true positive responses</th>
<th>Post-test, number of true positive responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>40.44</td>
<td>43.33</td>
</tr>
<tr>
<td>Std. Error</td>
<td>0.915</td>
<td>0.957</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Bound</td>
<td>38.34</td>
<td>41.13</td>
</tr>
<tr>
<td>Upper Bound</td>
<td>42.55</td>
<td>45.54</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>40.44</td>
<td>43.37</td>
</tr>
<tr>
<td>Median</td>
<td>40.00</td>
<td>43.00</td>
</tr>
<tr>
<td>Variance</td>
<td>7.528</td>
<td>8.250</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>2.744</td>
<td>2.872</td>
</tr>
<tr>
<td>Minimum</td>
<td>36</td>
<td>39</td>
</tr>
<tr>
<td>Maximum</td>
<td>45</td>
<td>47</td>
</tr>
<tr>
<td>Range</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.334</td>
<td>0.059</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As previously mentioned all participants (n=9) completed the pre and post-test image interpretation. As seen in Table 4.6, the mean for the correct identification of an abnormal image was 40.44% pre-test and 43.3% post-test, which is a difference of only 2.9%.

The Table 4.7 below shows the Wilcoxon Signed Ranks Test for correct responses.
Table 4.7 Wilcoxon Signed Ranks Test for correct responses identifying abnormal image

<table>
<thead>
<tr>
<th>Z</th>
<th>Asymp. Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.682^a</td>
<td>0.092^b</td>
</tr>
</tbody>
</table>

a. Based on negative ranks.
b. Wilcoxon Signed Ranks Test

The Wilcoxon Signed Ranks Test was performed to measure the significance of these results and the p-value is 0.092, which is greater than 0.05. Therefore these results are not considered significant. An improvement from the pre-test to the post-test, although small despite the small sample size, illustrates that training improved the ability of radiographers to interpret abnormal images.

Figure 4.3 below shows the distribution of TP results as a box plot.

Figure 4.3: Box plot of true positive (TP) accurate identification of abnormal images
The median for the pre-test is 40% and the post-test is 43%. When comparing the whiskers of the boxes, the whiskers are much longer in the pre-test results than in the post-test results and there is an outlier (represented as a circle labeled (1) in the pre-test results. Whereas for the post-test, all the results are within the quartiles and there are no extreme results, the pre-test results are symmetrical with equal lengths of whiskers and the median is in the centre of the 50th percentile. Thus, the results are not skewed. When observing the position and length of the post-test box plot, the improvement in the group as a whole is clearly illustrated.

The incorrect identification of abnormal images as normal or False Negative (FN) results were analysed and are presented in Table 4.8 below.
Table 4.8: Incorrect identification of abnormal images as normal equating to a False Negative (FN)

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Pre-test, number of responses false negative (incorrectly identified abnormal image as normal)</th>
<th>Post-test, number of responses false negative (incorrectly identified abnormal image as normal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>7.89</td>
<td>6.44</td>
</tr>
<tr>
<td>Std. Error</td>
<td>0.935</td>
<td>0.884</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Bound</td>
<td>5.73</td>
<td>4.41</td>
</tr>
<tr>
<td>Upper Bound</td>
<td>10.04</td>
<td>8.48</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>7.82</td>
<td>6.44</td>
</tr>
<tr>
<td>Median</td>
<td>8.00</td>
<td>7.00</td>
</tr>
<tr>
<td>Variance</td>
<td>7.861</td>
<td>7.028</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>2.804</td>
<td>2.651</td>
</tr>
<tr>
<td>Minimum</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Maximum</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>Range</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Skewness</td>
<td></td>
<td>-0.153</td>
</tr>
</tbody>
</table>

The Table 4.8 shows that for identification of FN images the mean result in the pre-test was 7.89 and the mean for the post-test is 6.44. Therefore there has been a small decrease in the number of images incorrectly identified as normal when in fact the image was abnormal.
The Wilcoxon Signed Ranks Test was used to compare the number of incorrect responses when identifying abnormal images see Table 4.9 below.

**Table 4.9: Wilcoxon Signed Ranks Test for incorrect responses identifying abnormal images as normal.**

<table>
<thead>
<tr>
<th></th>
<th>Post-test, number of responses false negative (incorrectly identified abnormal image as normal)</th>
<th>Pre-test number of responses false negative (incorrectly identified abnormal image as normal)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Z</strong></td>
<td>-0.891&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.373&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Asymp. Sig. (2-tailed)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Based on negative rank</td>
<td>b. Wilcoxon Signed Ranks Test</td>
</tr>
</tbody>
</table>

The significance of this result was analysed using the Wilcoxon test. The p-value is 0.373 and therefore, the result cannot be considered significant.

Figure 4.4 below illustrates the FN results where abnormal images were identified as normal.
Incorrect identification of abnormal images as normal

Figure 4.4: Box plot for False Negative (FN) results

A decrease in the number of false negatives, even a change as small as in this case, where the median is 8 for the pre-test and 7 for the post-test can be significant in terms of outcome of a patient’s condition if an image identified as normal when an abnormality should have been identified, treatment may be delayed. The size of the box plot post-test shows that the participants fell within the 50% quartile with the much shorter whiskers and there is no outlier demonstrating a more consistent group interpretation of abnormal images than in the pre-test. The training gave the participants the ability to identify an abnormality as a result of the pattern recognition skills they have acquired. Previously in the pre-test more of these images were identified incorrectly as normal.

The calculation of sensitivity considers all the abnormal images and the ability of the participants to identify abnormal images as a total of the abnormal images. The identification of true positive and false negative results is considered separately for each outcome. Both of these results are not significant. However, sensitivity has increased by 4.84% which could
impact on the overall identification of abnormal images and therefore, the correct treatment for the patient.

4.3.3 Image Interpretation Specificity

Specificity is defined as the ability of the diagnostic radiographers to identify normal images as normal, those being the TN results. The FP result or the images identified as abnormal when the image was normal were also calculated. In order to calculate the total rate of specificity the formula used by Carter and Manning, (1999:72) in their case study was used. Specificity is calculated using the TN results as a percentage of the total of normal images.

Specificity is the true negative percentage and is calculated by the following method:

\[ \text{Specificity} = \frac{\text{TN}}{\text{TN} + \text{FP}} \times 100 \]

- **Total Pre-test Specificity:**
  
  Total TN pre-test = 228
  
  Total FP pre-test = 179
  
  \[ = 228 \times 100 / 228+179 \]
  
  \[ = 22800 / 407 \]
  
  \[ = 56\% \]

- **Total Post-test Specificity:**
  
  Total TN post-test = 308
  
  Total FP post-test = 132
  
  \[ = 308 \times 100 / 308 +132 \]
  
  \[ = 70\% \]
These figures demonstrate that there has been a 14% increase in the images correctly identified as normal. One could conclude that the intervention has provided the participants with greater confidence in the identification of normal images.

Table 4.10 below shows the mean for correctly identifying an image as normal on the pre-test.

**Table 4.10: True negative results pre-test and post-test**

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Pre-test, number of responses true negative (correctly identified image as normal)</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>29.67</td>
<td>2.088</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td><strong>Lower Bound</strong> 24.85</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Upper Bound</strong> 34.48</td>
<td></td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>29.46</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>30.00</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>39.250</td>
<td></td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>6.265</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>34.33</td>
<td>1.993</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td><strong>Lower Bound</strong> 29.74</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Upper Bound</strong> 38.93</td>
<td></td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>34.59</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>38.00</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>35.750</td>
<td></td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>5.979</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.10 shows the mean for correctly identifying an image as normal on the pre-test which is 29.67 compared to 34.33 on the post-test. On the post-test normal images are being identified more accurately.
The Wilcoxon Signed Ranks Test was used to compare the number of correct responses when identifying normal images see Table 4.11 below.

**Table 4.11 Wilcoxon Signed Ranks Test for interpretation of normal**

<table>
<thead>
<tr>
<th>Z Asymp. Sig. (2-tailed)</th>
<th>Post-test, number of responses true negative (correctly identified image as normal) - Pre-test, number of responses true negative (correctly identified image as normal)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1.601&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>0.109&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

a. Based on negative rank  

b. Wilcoxon Signed Ranks Test

When the Wilcoxon signed ranks test (Table 4.11) was conducted on the TN results the results were not significant as the p-value is 0.109, which is greater than 0.05. Figure 4.5 below illustrates the box plot for false positive results pre- and post-tests.
When considering the median result for the pre-test for identifying true negative images (normal images), the median was 30% and that for the post-test was 38% (see the bold line on the box-plot graph Figure 4.5). The improvement of 8% could be due to the training. The pre-test has an outlier (o 2) showing that one participant was able to identify normal images very accurately during the pre-test. Table 4.12 below indicates the false positive results for the pre- and post-tests

Table 4.12: False positive results pre- and post-test.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Pre-test, number of responses false positive (incorrectly identified normal image as abnormal)</th>
<th>Std. Error</th>
<th>Post-test, number of responses false positive (incorrectly identified normal image as abnormal)</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>20.11</td>
<td>1.933</td>
<td>Mean</td>
<td>14.56</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound 15.65</td>
<td>Upper Bound 24.57</td>
<td>5% Trimmed Mean 20.40</td>
<td>Median 20.00</td>
</tr>
<tr>
<td>Variance</td>
<td>32.528</td>
<td>5.703</td>
<td>Minimum 8</td>
<td>8</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>5.798</td>
<td></td>
<td>Range 17</td>
<td>17</td>
</tr>
<tr>
<td>Range</td>
<td>19</td>
<td></td>
<td>Interquartile Range 8</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.964</td>
<td></td>
<td>Skewness 0.916</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.12 shows that the mean for FP was 20.11 on the pre-test and 14.56 on the post test. The change is 5.6, which is an improvement in the accurate identification of normal images by the participants. The training has given them the skills to prevent over calling normal images as abnormal.

The paired sample test below Table 4.13 considers the number of false positive results in the pre- and post-test to see the significance of the results.

Table 4.13: Paired Sample Test for False Positive responses

<table>
<thead>
<tr>
<th></th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pair 1</strong></td>
<td></td>
</tr>
<tr>
<td>Pre-test: number of responses false positive (incorrectly identified normal image as abnormal)</td>
<td>0.027</td>
</tr>
<tr>
<td>Post-test: number of responses false positive (incorrectly identified normal image as abnormal)</td>
<td></td>
</tr>
</tbody>
</table>

The Paired sample test (Table 4.13) had a t value of 0.027 which is below 0.05 and therefore is considered significant.

Figure 4.6 below demonstrates the improvement that took during pre- and post training.
Pre- and post-test incorrect identification normal images as abnormal

**Figure 4.6: Box plot for false positive results pre- and post-tests**

Figure 4.6 demonstrates the significant improvement that took place in the skills of the participants as indicated by a decrease in their False Positive responses from a median of 20 pre-test and a median of 8 post-test.

### 4.3.4 False Positive Results

The calculation of the False Positive rate is based on the formula used in the case study by Carter and Manning (1999:72):

\[
\text{False Positive Rate} = \frac{\text{FP}}{\text{Number of incorrect false positive responses}} \times 100 = \text{FP}\%
\]
The number of False Positives has decreased significantly.

4.4. PRE- AND POST-TEST ACCURACY OF THE COMMENT

Once participants established whether the image is normal or abnormal they were asked to provide a comment on abnormal images. The comments were then analysed to see how well their comments compared to the reference standard. It is important to note that all comments for both normal and abnormal images made by the participants were judged and marked as incorrect, partially incorrect or correct against the radiologist’s comments which were considered the gold standard in this study.

4.4.1 Incorrect comments

The study was to assess the ability of the participants to identify a normal or abnormal image. Once the image has been interpreted as abnormal the participants were then required to provide a comment on the abnormality seen on the image. The comments were ranked in three ways; incorrect comment, partially correct comment and correct comment of the image.

Table 4.14 below considers the incorrect comments on the images for the pre- and post-test.
Table 4.14: Incorrect comments on images for the pre-test and post-test.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Pre-test comment, number of incorrect image comments</th>
<th>Statistic</th>
<th>Post-test comment, number of incorrect image comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>24.11</td>
<td>Mean</td>
<td>17.78</td>
</tr>
<tr>
<td>Std. Error</td>
<td>2.850</td>
<td>Std. Error</td>
<td>2.722</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>17.54</td>
<td>95% Confidence Interval for Mean</td>
<td>11.50</td>
</tr>
<tr>
<td>Lower Bound</td>
<td></td>
<td>Lower Bound</td>
<td>24.06</td>
</tr>
<tr>
<td>Upper Bound</td>
<td></td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>24.07</td>
<td>5% Trimmed Mean</td>
<td>17.53</td>
</tr>
<tr>
<td>Median</td>
<td>22.00</td>
<td>Median</td>
<td>16.00</td>
</tr>
<tr>
<td>Variance</td>
<td>73.111</td>
<td>Variance</td>
<td>66.694</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>8.551</td>
<td>Std. Deviation</td>
<td>8.167</td>
</tr>
<tr>
<td>Minimum</td>
<td>14</td>
<td>Minimum</td>
<td>7</td>
</tr>
<tr>
<td>Maximum</td>
<td>35</td>
<td>Maximum</td>
<td>33</td>
</tr>
<tr>
<td>Range</td>
<td>21</td>
<td>Range</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.14 represents the pre- and post-test incorrect comments. The participants identified the images as abnormal images, true positive results, which is the correct interpretation. However, their comments were incorrect. Table 4.6 the mean was 24.11 for the pre-test and 17.78 for the post-test.

Table 4.15 demonstrates the Wilcoxon Signed Ranks Test for the incorrect comments on images in the pre- and post-tests.

Table 4.15: Wilcoxon Signed Ranks Test for incorrect comments on abnormal images.

<table>
<thead>
<tr>
<th></th>
<th>Post-test comment, number of incorrect comments - Pre-test comment, number of incorrect comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>-1.960&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>0.050&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

a. Based on positive ranks.
b. Wilcoxon Signed Ranks Test

When the Wilcoxon Signed Ranks Test (Table 4.15) was conducted these results have a p-value of 0.050 and therefore can be considered significant.

Figure 4.7 below demonstrates the box plot for the incorrect comments pre- and post-test.
Incorrect comments on images pre- and post-test

**Figure 4.7: Box plot of incorrect responses for abnormal images.**

The box plot Figure 4.7 illustrates a decrease in the number of incorrect comments. The movement of the box, representing the post-test, downward on the graph demonstrates a significant improvement in the post-test. In addition the median has decreased from 22 pre-test to 16 post-test. The improvement in the comments provided could be attributed to the training.

### 4.4.2 Incomplete comments for abnormal images

The comments on the images were compared with the reference standard and then judged to be either partially correct or completely correct. The following results illustrated in Table 4.16 are comments that were incomplete although they contained some of the correct response, in line with the reference standard.
Table 4.16: Incomplete comments for abnormal images.

<table>
<thead>
<tr>
<th></th>
<th>Statistic</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pre-test comment, number of correct but incomplete comments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>16.78</td>
<td>2.126</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>11.87</td>
<td></td>
</tr>
<tr>
<td>Upper Bound</td>
<td>21.68</td>
<td></td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>16.48</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>14.00</td>
<td></td>
</tr>
<tr>
<td>Variance</td>
<td>40.694</td>
<td></td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>6.379</td>
<td></td>
</tr>
<tr>
<td>Minimum</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Maximum</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Interquartile Range</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Skewness</td>
<td>1.069</td>
<td>0.717</td>
</tr>
</tbody>
</table>

| **Post-test comment, number of correct but incomplete comments** |           |            |
| Mean                                    | 21.78     | 2.272      |
| 95% Confidence Interval for Mean        | 16.54     |            |
| Upper Bound                             | 27.02     |            |
| 5% Trimmed Mean                         | 21.53     |            |
| Median                                  | 21.00     |            |
| Variance                                | 46.444    |            |
| Std. Deviation                          | 6.815     |            |
| Minimum                                 | 14        |            |
| Maximum                                 | 34        |            |
| Range                                   | 20        |            |
| Interquartile Range                     | 12        |            |
| Skewness                                | 0.600     | 0.717      |

For incomplete comments on the abnormal images Table 4.16: the pre-test mean was 16.78 and the post-test mean was 21.78 a 5 percent improvement indicating that the training has given the participants skills to write a comment albeit not entirely correct, a skill they did not possess initially.

The Wilcoxon Signed Ranks Test demonstrates the incomplete comments pre- and post-test see Table 4.17 below.
Table 4.17: Wilcoxon Signed Ranks Test for incomplete comments.

<table>
<thead>
<tr>
<th></th>
<th>Post-test comment, number of correct incomplete comments</th>
<th>Pre-test comment, number of correct but incomplete comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>-1.305&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>0.192&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> Based on negative ranks.

<sup>b</sup> Wilcoxon Signed Ranks Test

The p-value for the incomplete comments was 0.192 (Table 4.17) and therefore could not be considered significant.

Figure 4.8 demonstrates the box-plot for the incorrect comments on images pre- and post-test.

![Box plot incomplete interpretation of abnormal image](image)

Figure 4.8 Box plot incomplete interpretation of abnormal image
On the box plot the median for the post-test was in the centre of the 50\textsuperscript{th} quartile compared with the median for the pre-test, which was at the lowest point in the box. The median pre-test was 14 and the post-test median was 21, which although not statistically significant the graph demonstrates a change in the range of results and the placement of the median.

4.4.3 Correct comments on abnormal images

Table 4.18 considers the correct comments on the abnormal images pre- and post-test.
Table 4.18: Correct comments on abnormal images.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Statistic</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test comment, number of incorrect image comments</td>
<td>Mean</td>
<td>7.78</td>
</tr>
<tr>
<td></td>
<td>95%</td>
<td>1.816</td>
</tr>
<tr>
<td></td>
<td>Confidence</td>
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<tr>
<td></td>
<td>Interval</td>
<td></td>
</tr>
<tr>
<td></td>
<td>for Mean</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Bound</td>
<td>3.59</td>
</tr>
<tr>
<td></td>
<td>Upper Bound</td>
<td>11.97</td>
</tr>
<tr>
<td></td>
<td>5% Trimmed Mean</td>
<td>7.53</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>Variance</td>
<td>29.694</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
<td>5.449</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>16</td>
</tr>
<tr>
<td>Post-test comment, number of incorrect image comments</td>
<td>Mean</td>
<td>10.33</td>
</tr>
<tr>
<td></td>
<td>95%</td>
<td>3.308</td>
</tr>
<tr>
<td></td>
<td>Confidence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Interval</td>
<td></td>
</tr>
<tr>
<td></td>
<td>for Mean</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lower Bound</td>
<td>2.70</td>
</tr>
<tr>
<td></td>
<td>Upper Bound</td>
<td>17.96</td>
</tr>
<tr>
<td></td>
<td>5% Trimmed Mean</td>
<td>9.93</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>Variance</td>
<td>98.500</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
<td>9.925</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>Range</td>
<td>26</td>
</tr>
</tbody>
</table>

The correct accurate comments provided for the abnormal images had mean scores of 7.78 for the pre-test and 10.33 for the post-test, a 2.55% increase.
Table 4.19 below demonstrates the Wilcoxon Sign Ranks Test for the completely correct comments on the images in the pre- and post-test.

### Table 4.19: Wilcoxon Sign Ranks Test for complete responses.

<table>
<thead>
<tr>
<th></th>
<th>Post-test comments – number correct image interpretations in – line reference standard</th>
<th>Pre-test comments – number correct image interpretations in – line reference standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Z$</td>
<td>-0.563</td>
<td>0.574</td>
</tr>
<tr>
<td>Asymp. Sig (2-tailed)</td>
<td>0.574</td>
<td>0.574</td>
</tr>
</tbody>
</table>

a. Based on negative ranks.
b. Wilcoxon Signed Ranks Test

The results were considered not significant as the $p$-value is 0.574 (Table 4.19) greater than the 0.05 required to be significant.

Figure 4.9 demonstrates the box plot of the correct comments pre- and post-test.

![Figure 4.9: Box plot correct image interpretation pre and post-test](image)
The results (Figure 4.9) although not considered significant; do show some of the participants demonstrate a considerable improvement from the pre-test. When observing the parallel box plots for accurate comments the difference in distribution of the results can be seen. The pre-test results have a symmetrical appearance for the middle 50% of the responses demonstrating a very similar result for all participants. The post-test box was elongated and demonstrated skew results particularly as the median was in the lower portion demonstrating the difference in the participants abilities post-test.

4.5 INDIVIDUAL RESULTS PER IMAGE

4.5.1 PRE-TEST IMAGE RESULTS

The results to this point have identified the ability of the group of participants as a whole to interpret images accurately. From the group results for the comments when looking at the box plot Figure 4.9 it can be seen from the very long box for the post-test results the diversity of the ability of the participants to comment on the images is illustrated and therefore it would be important to consider the individual results. The individual image results for the pre-test were initially considered. The ratio of normal to abnormal images in both the pre-test and the post-test was 50:50.
Table 4.20 : Mean scores for each image in the pre-test for normal images.

<table>
<thead>
<tr>
<th></th>
<th>TN</th>
<th>FP</th>
<th></th>
<th>TN</th>
<th>FP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-85</td>
<td>0</td>
<td>100</td>
<td>Pre-36</td>
<td>66.6</td>
<td>33.3</td>
</tr>
<tr>
<td>Pre-1</td>
<td>11.1</td>
<td>88.8</td>
<td>Pre-44</td>
<td>66.6</td>
<td>33.3</td>
</tr>
<tr>
<td>Pre-8</td>
<td>22.2</td>
<td>77.7</td>
<td>Pre-51</td>
<td>66.6</td>
<td>33.3</td>
</tr>
<tr>
<td>Pre-32</td>
<td>22.2</td>
<td>77.7</td>
<td>Pre-63</td>
<td>66.6</td>
<td>33.3</td>
</tr>
<tr>
<td>Pre-3</td>
<td>33.3</td>
<td>66.6</td>
<td>Pre-18</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Pre-6</td>
<td>33.3</td>
<td>66.6</td>
<td>Pre-24</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Pre-26</td>
<td>33.3</td>
<td>66.6</td>
<td>Pre-43</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Pre-35</td>
<td>33.3</td>
<td>66.6</td>
<td>Pre-53</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Pre-60</td>
<td>33.3</td>
<td>66.6</td>
<td>Pre-66</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Pre-4</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-74</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Pre-10</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-93</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Pre-17</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-94</td>
<td>77.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Pre-21</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-34</td>
<td>88.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Pre-30</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-55</td>
<td>88.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Pre-31</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-86</td>
<td>88.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Pre-33</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-88</td>
<td>88.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Pre-44</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-91</td>
<td>88.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Pre-52</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-92</td>
<td>88.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Pre-54</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-98</td>
<td>88.8</td>
<td>11.1</td>
</tr>
<tr>
<td>Pre-11</td>
<td>55.5</td>
<td>44.4</td>
<td>Pre-67</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Pre-13</td>
<td>55.5</td>
<td>44.4</td>
<td>Pre-88</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Pre-16</td>
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<td>44.4</td>
<td></td>
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<tr>
<td>Pre-22</td>
<td>55.5</td>
<td>44.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-28</td>
<td>55.5</td>
<td>44.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-41</td>
<td>55.5</td>
<td>44.4</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Pre-42</td>
<td>55.5</td>
<td>44.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-46</td>
<td>55.5</td>
<td>44.4</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Pre-59</td>
<td>55.5</td>
<td>44.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-14</td>
<td>66.6</td>
<td>33.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.20 demonstrates the mean scores per image for the pre-test; for correctly identifying the normal image, that is, a true negative image. The Table 4.20 displays the images in order from the image that was the lowest score to the highest score. Image 85 was incorrectly identified as abnormal by all the participants. Therefore image 85 in the pre-test was the most inaccurately identified image. Image 1 was an image of a paediatric foot with epiphysis demonstrated on the image only, one participant identified this image as normal. The other participants all identified the epiphysis as a fracture of the foot. Only 2 images in the pre-test were correctly interpreted as normal by 100% of the participants. Certain images were consistently incorrectly interpreted by the majority of participants. Images 8 and 32 were also identified as false positive images by 77.7% of the participants.
<table>
<thead>
<tr>
<th>Image</th>
<th>TP</th>
<th>FN</th>
<th>Image</th>
<th>TP</th>
<th>FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-81</td>
<td>22.2</td>
<td>77.7</td>
<td>Pre-29</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Pre-79</td>
<td>33.3</td>
<td>66.6</td>
<td>Pre-38</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Pre-84</td>
<td>33.3</td>
<td>66.6</td>
<td>Pre-40</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Pre-49</td>
<td>44.4</td>
<td>55.5</td>
<td>Pre-47</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
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<td>55.5</td>
<td>Pre-48</td>
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</tr>
<tr>
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<td>Pre-87</td>
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<td></td>
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<td>11.1</td>
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<td>Pre-25</td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

When considering False Positive images pre-test results 22 abnormal images were correctly identified by all participants. From these numbers it would appear that participants had a problem identifying normal images and were better at identifying the abnormal images. Image 81 was the image identified by 7 participants as normal when the reference standard identified an acromioclavicular subluxation an abnormal interpretation. Image 79 was also inaccurately interpreted as normal when there was a subluxation of the humerus. Image 84 was interpreted as normal this was an image of a tibia and fibula, which demonstrated a deformity of the fibula due to an old fracture and osteophytes of the lateral malleolus. Image 49 was also an image demonstrating a subluxation of the acromioclavicular joint.
4.5.2 POST-TEST

The individual scores for images post-test for the normal and abnormal interpretations were considered.

Table 4.22: Mean scores per image for the post-test for normal images

<table>
<thead>
<tr>
<th></th>
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</tr>
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<td>Post-53</td>
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<td>Post-28</td>
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<td>11.1</td>
</tr>
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<td>Post-4</td>
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<td>Post-34</td>
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<td>Post-46</td>
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<td>Post-51</td>
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<td>Post-31</td>
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<td>Post-88</td>
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</tr>
<tr>
<td>Post-35</td>
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<td>33.3</td>
<td>Post-92</td>
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<td>11.1</td>
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<tr>
<td>Post-44</td>
<td>66.6</td>
<td>33.3</td>
<td>Post-14</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Post-52</td>
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<td>33.3</td>
<td>Post-24</td>
<td>100</td>
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</tr>
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<td>33.3</td>
<td>Post-55</td>
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</tr>
<tr>
<td>Post-98</td>
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<td>Post-67</td>
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</tr>
<tr>
<td>Post-11</td>
<td>77.7</td>
<td>22.2</td>
<td>Post-93</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>Post-16</td>
<td>77.7</td>
<td>22.2</td>
<td>Post-94</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

In the post-test 6 normal images were correctly identified as true negative by all the participants. Thus the participants went from 2 images out of 50 images in the pre-test to 6 images out of 50 images in the post-test correctly identified by 100% of the participants as normal. That is an improvement from 4% of the cases correctly interpreted by all participants to 12% of the cases being identified correctly by all participants.
The number of correctly identified abnormal images increased to 35 out of 50 abnormal images identified by all participants, that is, 70% of the abnormal images were identified by all the participants. The standard requirement for reporting radiographers with a post graduate qualification would be for sensitivity values between 90 and 95% of all images to be accurately identified as abnormal (Mackay, 2006:472). Post test the participants were able to identify more normal and abnormal images 100% correctly, however, the percentage was still not as high as prescribed by Mackay (2006:472).

The images 29, 62 and 97 were used in both the pre-test and post- test and contained specific abnormalities. The researcher considered it important to test the participants recognition of these specific patterns and to demonstrate
whether training had improved their interpretation skills. In the post-test, eight participants (88.8%) incorrectly identifying the image 62 as normal where there was an abnormality. Image 62 was used in both tests and the interpretation of the image was worse post intervention. Four participants had identified the image as abnormal pre-test and only five incorrectly interpreted the image compared with the eight post-test. Image 29 demonstrated soft tissue swelling and displacement of a fat pad at the distal humerus, 5 of the participants did not identify this in the post-test. Image 97 demonstrated a non-union of the scaphoid with avascular necrosis again 5 participants failed to identify the abnormality post-test.

When comparing the identification of normal and abnormal with the comment provided in the post-test some images, although correctly identified as abnormal were not well commented on. Image 2, an image of the tibia and fibula was correctly identified as abnormal, however, 7 participants provided only a partially correct comment. Image 5, a fracture of the scapula was well interpreted and 5 radiographers provided a comment in line with the reference standard. Image 38 was a paediatric patient and was difficult for the participants to interpret, 6 participants had an incorrect comment or no comment for this image. However a greenstick fracture also on a paediatric patient was accurately commented on by 6 of the radiographers. Six participants providing a partially correct comment on image 41 which was an image of an adult pelvis.

4.6 INDIVIDUAL RESULTS COMPARISON PRE- AND POST-TEST

4.6.1. Individual results for normal images

The individual results for the participants are to be considered in terms of their accuracy pre- and post-test.
Table 4.24: Individual changes in identification of normal images pre- and post-test

<table>
<thead>
<tr>
<th></th>
<th>TN% PRE</th>
<th>TN% POST</th>
<th>DIFF</th>
<th>FP% PRE</th>
<th>FP% POST</th>
<th>DIFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>58</td>
<td>12</td>
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<td>42</td>
<td>-12</td>
</tr>
<tr>
<td>2</td>
<td>84</td>
<td>80</td>
<td>-4</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>68</td>
<td>76</td>
<td>8</td>
<td>32</td>
<td>22</td>
<td>-10</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>76</td>
<td>16</td>
<td>40</td>
<td>22</td>
<td>-18</td>
</tr>
<tr>
<td>5</td>
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<td>46</td>
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</tr>
<tr>
<td>6</td>
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<td>70</td>
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</tr>
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<td>74</td>
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</tr>
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</tbody>
</table>

The participant most accurate in identifying normal images is participant 2 seen in Table 4.24. However, when considering change or improvement in a radiographer interpreting images, the participant showing the most improvement would be participant 7 who improved by 32%. The researcher knew the identity of the participant, however, the participants are not aware of their number in the research. Participant 5 also showed an improvement of 24%. In contrast, participants 8 and 9 showed very little improvement or no change in their ability from the pre-test to the post-test. Table 4.24 considers the results for individual participants in terms of true negative results and the false positive results in the pre- and post-test. Participant one, three, and six had similar improvements in interpreting images as normal. Participants four, five, and seven showed greater improvement. The training may have enabled participants to identify normal variants more accurately. Participant two and nine had no change or very little change in their ability to interpret normal images accurately. However, participant eight’s ability to identify normal images decreased and the number of false positive had increased identifying those images as having an abnormality where the reference standard had identified the image as normal.

4.6.2. Individual results for abnormal images

Participants individual results in accurately interpreting abnormal image pre- and post-test.
Table 4.25: Individual changes in identification of abnormal images pre- and post-test

<table>
<thead>
<tr>
<th></th>
<th>TP% PRE</th>
<th>TP% POST</th>
<th>DIFF</th>
<th>FN% PRE</th>
<th>FN%POST</th>
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<td>2</td>
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<td>94</td>
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</tr>
<tr>
<td>3</td>
<td>72</td>
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</tr>
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<td>8</td>
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<td>9</td>
<td>84</td>
<td>90</td>
<td>6</td>
<td>16</td>
<td>12</td>
<td>-4</td>
</tr>
</tbody>
</table>

Table 4.25: Individual changes in identification of abnormal images pre and post-

The results for the identification of abnormal images (Table 4.25) produces some interesting data. Again from the table participant 2 improved in interpreting abnormal images to the level where 94% of the abnormal images were correctly identified this would be in line for the requirement for a radiographer to accurately interpret images in practice. The other participant showing an improvement in accuracy of identifying abnormal images is participant 8, also with a 94% accuracy in identifying abnormal images. The result in interpretation of abnormal images contrasts with the results of interpreting normal images.

Table 4.25 looks at the individual results for the images that were considered abnormal and therefore would be accurately interpreted as true positive and compared them with the results where the participants incorrectly interpreted the image as normal. Only two participants declined in their ability to interpret abnormal images. However when considering participant one the accuracy results are high both in the pre-test and post-test at 96% and 80% respectively.

Participant four had no change for true positive results between the pre- and post-test.
Participant’s two, three, six and eight all improved their results by more than 10% between the pre- and post-test. Participants two, six and eight increased the percentage of accurate responses to identification of abnormal images to more than 90% accuracy.

Participants seven and nine had a minor change in their ability to identify abnormal images.

4.7. Viewing Time for Test Bank

The participants found it hard to view and interpret 100 images in 150 minutes and still maintain concentration levels. However when the accuracy of the last images viewed was considered, in comparison to the initial images the results do not appear more inaccurate. In the pre-test the results for images 1-10 and images 91-100 were as follows:

Table 4.26: Comparison of correct/ incorrect image interpretations for images 1-10 & 91-100 pre-test

<table>
<thead>
<tr>
<th></th>
<th>Correct-%</th>
<th>Incorrect-%</th>
<th></th>
<th>Correct-%</th>
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</tr>
</thead>
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<td>11.1</td>
</tr>
<tr>
<td>Pre-2</td>
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<td>Pre-92</td>
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<td>11.1</td>
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<td>Pre-93</td>
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<tr>
<td>Pre-7</td>
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<td>Pre-97</td>
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<td>Pre-100</td>
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<td>44.4</td>
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</table>

From the Table 4.26 the results demonstrate that the participants were actually more accurate for the last 10 images than for the initial 10 images.
Table 4.27: Comparison of correct/ incorrect image interpretations for images 1-10 & 91-100 post-test

<table>
<thead>
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</tr>
</thead>
<tbody>
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</tr>
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</tr>
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<td>Post-10</td>
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<table>
<thead>
<tr>
<th></th>
<th>Correct -</th>
<th>Incorrect -</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-91</td>
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<td>22.2</td>
</tr>
<tr>
<td>Post-92</td>
<td>88.8</td>
<td>11.1</td>
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<td>Post-93</td>
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<td>Post-94</td>
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<td></td>
</tr>
<tr>
<td>Post-96</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Post-97</td>
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</tr>
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<td>33.3</td>
</tr>
<tr>
<td>Post-99</td>
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<td>22.2</td>
</tr>
<tr>
<td>Post-100</td>
<td>33.3</td>
<td>66.6</td>
</tr>
</tbody>
</table>

The Table 4.27 again reflects the results and shows that the participants were more accurate for the last 10 images than for the first 10 images. Thus although the perception of the participants was that the test was extremely long their overall ability to provide an accurate image interpretation did not appear to be compromised.

4.8 SUMMARY

The participants showed an improvement in their accuracy to interpret musculoskeletal images from the pre-test to the post-test. The comments they provided on the images also improved from the initial test to the test after the intervention. The significance of these results in regard to the ability of radiographers to interpret musculoskeletal images and the training requirements of the diagnostic radiographers will be discussed in the next chapter.
CHAPTER FIVE
DISCUSSION

5.1 INTRODUCTION

In this chapter the findings of the study are summarised and discussed to reflect as to whether the participants could provide an interpretation of a musculoskeletal image. The type of training required to empower them with the ability to accurately image interpret in the clinical environment will be assessed using the findings of the study.

5.2 SAMPLE SIZE

The number of participants completing the study was small with only nine diagnostic radiographers completing the pre and post-test and the training. Initially the sample number was of concern and therefore a minimum number of eight participants was identified by the statistician as sufficient with the large number of images to be used for the pre- and post-tests. The research fulfilled this criterion by having nine participants. However, when statistically analysing the results some of the results could not be identified as significant. This could have been due to the sample size. With a small sample size, it is difficult to provide enough data to demonstrate whether a trend is significant or not.

Brealey and Scally (2008:e49-50) in their review article looking at the methodology to evaluate the ability of diagnostic radiographers to provide image interpretation, recognised that sample size was a research issue in the UK. They suggested that multi-centre research would provide a larger amount of evidence allowing the results to be attributed to the wider population. Multi-centre research was difficult to conduct, therefore Brealey and Scally (2008:
e50) felt that the results of various studies and audits could be pooled, to provide a larger sample size. In South Africa, however, there has not been enough research conducted to pool results at this time.

In Smith et al. (2009:7), the sample size was 16 radiographers who interpreted 25 images. The number of results was 400 image interpretations, which was considered to be small and difficult to extrapolate to the larger population. The results from Smith et al. (2009:7) were similar to the findings in the present study as well as being considered relevant in establishing the accuracy of radiographers in providing image interpretation. The results also demonstrated the value of continuous education in providing radiographers with the skills to interpret images accurately in spite of not being statistically significant.

Previous research in the UK done by McConnell and Webster (2000:609) had a sample size of 22 and the results reflected an improvement in accuracy and sensitivity after the training intervention, which suggested that the intervention was effective. Coleman and Piper (2009:199) in their comparative study of 18 radiographers, 7 casualty officers and 13 nurse practitioners who participated in the study, concluded that:

“radiographers have the ability to formally utilize their knowledge in image interpretation by providing the emergency department with a written comment.”

The radiographers were more accurate than the other professionals and were more accurate in assessing their own ability to interpret images in comparison with the casualty officers or the nurse practitioners. Coleman and Piper (2009:198) had not provided any training for the participants. The participants were all experienced in an A&E department where the nurses were interpreting images and the radiographers had been participating in a “red dot” scheme.

Thus, based on the evidence of previous studies it was acceptable to use the results of the present study to assess accuracy of the image interpretation
abilities of diagnostic radiographers and the impact of a training programme on their subsequent performance.

5.3 CONTROL GROUP

A control group is a different group of participants in a research project who only complete the pre-test and post-test without any intervention. Brealey and Scally (2008:e49) highlighted the fact that a control group should be identified to assess the impact of a learning effect over time. The learning effect would be the experience gained in image interpretation in the clinical environment over the same period of time that the research was conducted. The researcher, in the present study, did not have a control group. When previous research, that has been conducted in the UK by Mackay (2006:469) and in Australia by Smith et al. (2009:3), was considered, it was found that they did not have control groups, but were able to reach conclusions regarding the effectiveness of training. Mackay (2006:470-1) conducted a test six months after the training and the results were worse than in the pre-training test. Therefore, the learning effect of the clinical environment did not appear to improve the abilities of the participants. If the clinical environment provided teaching and learning experiences then the results could be expected to have improved. However they did not. Therefore, the lack of a control group in this study does not appear to have affected the validity of the results. The results of the changes in the ability of the diagnostic radiographers to interpret images could, therefore, be attributed to the intervention the training provided and not to the learning effect in the clinical environment. From Mackay’s (2006:471) study, the conclusion implies that diagnostic radiographers require ongoing training with possible mentorship within their clinical environment in order to maintain the accuracy achieved directly after training.
5.4 PARTICIPANTS ABILITY TO ACCURATELY IDENTIFY AND COMMENT ON IMAGES

The ability of radiographers to identify and comment on an image is critical to the extension of the role of diagnostic radiographers in image interpretation. The results provided by the research contribute to the realisation of the goal of radiographers for role extension in this field.

5.4.1 Accuracy of Assessing Normal and Abnormal Images

The participants in the study demonstrated a significant improvement in their ability to interpret an image after the intervention. The accuracy of the diagnostic radiographers is demonstrated in Figures 4.1 (see page 94), 4.2 (see page 98), 4.3 (see page 103) and 4.4 (see page 106). In the pre-test the median for accurate identification of normal and abnormal images was 70% and in the post-test 79%, which is an improvement of 9%. In Chapter 4 the accuracy was measured as the change in the number of correctly identified normal and abnormal images. The improvement in the accuracy could be attributed to the intervention between the pre and the post-test. The improvement in accuracy shown by the participants is in line with previous studies. Hargreaves and Mackay (2003:287) found accuracy improved from 89.9% before training to 93% after the training and McConnell and Webster (2000: 609) had a pre-test accuracy of 71.4% and an accuracy after the 6-10 weeks post-test of 80.0% . McConnell and Webster (2000:610) therefore found a change of 8.6% between the pre-test and the second post-test which is in-line with the present study. McConnell and Webster (2000:610), using their second post-test as their first post-test following the two day course had a large number of false positive results and, therefore, the result was skewed. As a result they felt that the second test was a true reflection of the effectiveness of the course.

The accuracy of identifying normal and abnormal images is, however, only the start of image interpretation and specific interpretation skills by the provision of a comment must be considered.
The sensitivity, when identifying an abnormality and specificity when applied to the identification of the normal images must also be considered.

5.4.2 Sensitivity

Findings relating to sensitivity, which is identifying abnormal images, are as follows:

- In this research sensitivity changed from 84.6% to 89.44% from the pre-test to the post-test.
- The results were similar to those of research conducted in the UK by Hargreaves and Mackay (2003:287) in which the sensitivity before training was 76.2% and after training 81.3%. In their conclusion, Hargreaves and Mackay felt that, although not statistically significant, conclusions could be drawn regarding the positive effect that training had on the participants’ identification of abnormal images.
- In Mackay’s study (2006:469), the results for sensitivity were 78.9% pre-test and 88.2% post-test respectively.
- Hardy and Culpan (2007:67) found that sensitivity for pre-training was 72.1% increasing to 88.5% post-training.

5.4.3 Specificity

Findings relating to specificity which is the identification of normal images, are as follows:

- The participants in this research demonstrated a specificity of 56% pre-training and 70% post-training.
- If the above results are compared with previous research done by Hargreaves and Mackay (2003:287) in which the mean specificity was 96.4% before training and 96.1% after training, a difference is observed.
- In Mackay (2006:469), the research specificity was 76.9% initially and 76.9% after training.
• In Hardy and Culpan (2007:67), it was 50.1% pre-training and 53.4% post-training.

The increase of 14% in the present research is in contrast to the research by Hargreaves and Mackay (2003:287) where they reported a 0.3% decrease in specificity, Mackay (2006:471) reported no change in specificity and Hardy and Culpan reported a 3.3% improvement in specificity. Hargreaves and Mackay (2003:287) suggested that radiographers are often confident in identifying the image as normal. However, initially the participants in the current research appeared unsure about identifying normal images, but after training their confidence appeared to be greatly improved.

In the study by Hargreaves and Mackay (2003:285) the radiographers had all been participating in the “red dot” system, although they had no pattern recognition training before the study, whereas the participants in the present study had no experience in the clinical situation of providing a “red dot” on an image or any image interpretation experience. The education in South Africa may place a different emphasis on pattern recognition and image interpretation. In addition the images used in the test bank of films could have been more difficult to categorise as normal due to the inclusion of all types of pathology. There were 50 normal cases out of 100 images in each test bank pre-test and post-test for the radiographers in the present research compared to that of Piper and Paterson (2009:43) which had 7 normal images out of 20 images in a test bank of films. More normal variants were tested in the present research, which could have affected the specificity of the participants in the pre-test but after training the specificity improved.

In the present study all pathologies were considered for image interpretation and not just fracture detection, which as previously mentioned could have also affected the identification of the normal image. Hargreave’s and Mackay (2003:285) only concentrated on fracture detection and fracture exclusion as they felt this was the most beneficial form of image interpretation to improve the outcome of the patient’s treatment in the A&E environment. In research conducted by Hardy and Culpan (2007:67) the images were musculoskeletal
trauma images and therefore the study concentrated on trauma pathology, although any abnormality seen on the image could be identified in the comment provided. When the radiographer is aware that fracture detection is the only criterion, this could make identification easier as they have a specific variant to look for rather than a wide variety of pathologies as was the case in the present study.

Sensitivity (identifying abnormalities) both pre-test and post-test was considerably higher than specificity (identifying normal images), which was also found by Hardy and Culpan(2007:67) who attributed this result to radiographers over calling normal images. As has already been mentioned, the results of Hardy and Culpan does not appear to be supported in this study because the radiographers improved in their identification of normal images and therefore did not over call normal images as abnormal.

5.4.4 Accuracy of the Comment Provided on Abnormal Images

The accuracy of the comments provided by the diagnostic radiographers once they correctly identified an abnormal image was significantly more accurate once the training had been undertaken. The results for accuracy of comment on abnormal images was illustrated in Figures 4.7 (see page 116), 4.8 (see page 118) and 4.9 (see page 121). The accuracy of the comment was identified in three categories, namely incorrect, partially correct and completely correct in-line with the reference standard. Initially, the mean for incorrect comments was 24.1% pre-test and after training the mean was 17.78%. The 6.3% improvement in commenting is considered statistically significant.

The partially correct responses were reported as 16.78% pre-test and 21.78% post-test. The correct comments had a mean of 7.78% pre-test and 10.33% post-test. Both results are not statistically significant. The participants’ post-training provided a partially complete or completely accurate comment on more images when compared with the reference standard. The training appeared to improve the radiographers’ clinical vocabulary following training.
as their comments were more accurate in describing the pathology and its location. However their interpretation was not as good as their ability to accurately identify abnormal and normal images.

In previous studies, Smith et al. (2009:6) found that with complex cases, after training, there was a significant change in participants’ general opinion and observations compared to pre-training results. According to Coleman and Piper (2009:202), radiographers could provide a written comment as an initial image interpretation in the A&E environment to assist with patient management. Coleman and Piper (2009:200) compared radiographers with nurses and casualty officers regarding their ability to identify normal and abnormal images, then identify the location and give a description of the abnormality. They found that the radiographers were more accurate when considering the results for specificity (normal images) and sensitivity (abnormal images). Sensitivity and specificity for radiographers was 67% and 80.5% respectively compared to nurses who obtained results of 49% for sensitivity and 54% for specificity and casualty officers with results of 51% and 57% for sensitivity and specificity respectively. Therefore, in their conclusion, Coleman and Piper (2009:202) identified radiographers as the correct choice for the interpretation of images rather than the nurses or casualty officers who normally provide this service in the A&E environment. Coleman and Piper's (2009:202) recommendation from the results of their research was that the radiographer should provide a comment on the image rather than a “red dot” as radiographers have more experience in viewing images. Therefore, if their role is expanded to include the initial image interpretation, their important role in the A&E department would be recognised and could provide the necessary motivation to continue developing skills and gaining knowledge in the field.

If the results of this research are compared with those of Coleman and Piper (2009:202), the participants demonstrated an improvement of 9% in the accuracy of their image interpretation after training and an improvement of 4.84% in sensitivity and 14% in specificity respectively, which is in line with their findings and demonstrates the ability of radiographers to provide an
accurate comment on an image. The researcher compared the commenting of the participants with the findings of Smith et al. (2009:6) and it appears that the results are comparable as well as showing an improvement in the ability of radiographers to provide an accurate comment.

5.4.5 Vocabulary of Image Interpretation

Radiographers do not learn the language required for commenting on images in their undergraduate qualification in South Africa. Therefore an important aspect of the training was to provide guidelines for writing an accurate comment. Ridley (2002:366) identified that a radiological report on an image needs to be concise, state the most important findings, suggest other procedures and provide a conclusion and recommendations. Radiographers need to incorporate similar qualities in their commenting. They often find it difficult to identify the important findings and communicate them in a clear and concise manner. When considering the comments on the post test, diagnostic radiographers were able to describe the pathology using more accurate medically accepted language, for example, mentioning soft tissue changes and more accurately identifying the location of the abnormality compared to their responses in the pre-test. As an example, participant 3 interpreted an image of the elbow correctly as abnormal in the pre-test, but no comment was provided. Post-test a similar image was correctly identified as abnormal and the comment was:

“There is soft tissue swelling on the left arm and a fat pad is seen displaced on the posterior aspect of the elbow."

The comment was in-line with the reference standard and provided information pertaining to location and soft tissue changes. Participant 3 was one of only two participants who submitted their log books after the study. The improvement in commenting could be a result of discussing the comments with the radiologist and writing in the log book. Participant 2 was the other
participant who submitted the log book and this participant demonstrated a high percentage of accuracy both pre and post-test.

Another post-test comment was on an image of a humerus where previously a partially correct comment was provided:

“Loss of soft tissue of the humerus. Increased bone density of the humerus. Loss of trabecular pattern of the bones and shoulder joint space is reduced.”

The comment matched the image interpretation of the reference standard. A further comment on an abnormal pre-test image of a “fracture distal radius” post-test, was:

“... radiolucent line is seen at the distal radius of the left wrist. Discontinuation of the cortical outline of the radius – Colles fracture.”

This comment is incomplete as the fracture of the ulna styloid process was not commented on, which demonstrated a “failure to search”, which is also recognised as a possible area for more training in previous studies.

Once an abnormality has been identified, the radiographer often stops looking for any further abnormalities. Piper & Paterson (2009:43) specifically included images in their test bank to identify the “failure to search” of their participants who were radiographers and nurses.

The training emphasised the importance of communicating all findings rather than “a fracture is seen”, which would have been the pre-training response. Therefore the need for training in the structure of the comment provided is important in order to provide the referral doctor with the most useful information for optimum diagnosis and treatment of the patient. The accuracy of commenting on images has improved by 6.32%, which is a significant result demonstrating that the training had given the radiographers the appropriate skills in image interpretation. The improvement in the vocabulary of the comments also reflects that the training helped radiographers understand the
construction of a comment, when communicating the image interpretation accurately to other medical staff.

5.5 BANK OF IMAGES

Diagnostic radiographers need to demonstrate that they are able to accurately interpret a wide range of images and their accuracy should be demonstrated in a timely manner. Therefore, the composition of the test bank is important to demonstrate accuracy over a number of images to comply with the clinical situation.

5.5.1 Number of Images in Test Bank

The number of images in both the pre- and post-test that were used for the participants to interpret was a 100. The criteria for the images selected were based on the following:

- Discriminatory images, which are difficult cases to interpret and identify the ability of radiographers to interpret subtle pathology
- Represent a ratio of normal to abnormal images of 50:50 in a large enough sample
- Wider variety of pathology beyond fracture detection
- Incorporate the appendicular and axial systems with the exclusion of the skull
- Incorporate normal variants to ensure recognition of normal patterns

Twenty images were chosen in previous studies conducted by Piper and Paterson (2007: 43), Coleman and Piper (2009: 197-8) and Hardy and Culpan (2007: 67). In the discussion by Coleman and Piper (2009:201), they mentioned that the sample size was small in their study as they were comparing the ability of non-medical health professionals to interpret images and, therefore, could justify the small number of images. However, the researcher felt that in order to assess the ability of radiographers to interpret images in the current study, a larger test bank of images was required to fully
test their ability and, due to the small number of participants in the study, to provide validity to the study.

The test bank needed to include those images previously identified in research by Piper and Paterson (2009:43) as difficult to interpret and discriminatory. In Piper and Paterson’s (2009:43) research they used the more difficult to interpret images with subtle pathology in order to identify differences in the ability of radiographers and nurses to recognise subtle changes on the images. In the present study as only radiographers participated in the study the recognition of subtle images would help to identify whether there were gaps in the training. Therefore the researcher decided on 100 images that would allow for a more varied bank of images. The bank of films would provide more images with a variety of pathologies, more anatomical areas and the opportunity to provide more images, with normal variants and epiphyseal lines. Included in the 100 images were images of the upper limb including the shoulder, the lower limb including the hip and the cervical, thoracic and lumbar spine and pelvis. The images included epiphyseal growth plates of the hand, wrist, forearm, elbow, foot, ankle, knee and hip, thereby testing the participants extensively on their ability to recognise the epiphyseal lines, which are important normal variants that a diagnostic radiographer should be able to recognise. In the present study, the participants were assessed not only on trauma images, but also on pathology such as a change in shape of bone and joint spaces and whether lytic and sclerotic areas were recognised. The range of images supported the use of 100 images in the test bank. These pattern recognition criteria were taught in the training and would by necessity need to be included in the tests.

Piper, Paterson and Godfrey (2005:29) assessed postgraduate students who had been trained in musculoskeletal image interpretation and at the completion of the programme, the Objective Structured Examination consisted of 200 images received from the A&E department and general practitioner referrals, which assessed their ability to identify trauma and non-trauma pathology and normal images. The pathology interpreted in the research done by Piper et al. (2005:29) was, therefore, similar to that used in the present study. Piper et al. (2005:29) also used the 50% ratio of normal to abnormal
images as a requirement to assess specificity and sensitivity. The 50% ratio allowed for the testing of normal variants and supports the test bank used in the present study.

5.5.2 Viewing Time for the Test Bank

The participants found it hard to view and interpret 100 images in 150 minutes and still maintain their concentration levels. When the accuracy of the last images viewed was considered in comparison to the initial images, the results as shown in Table 4.13 (see page 111) and Table 4.14 (see page 114) do not appear more inaccurate.

The time for viewing was based on Mackay’s study (2006:469) where the participants were allowed 90 seconds viewing time per image. Hardy & Culpan (2007:67) allowed only 40 seconds per PowerPoint image, which to the researcher, appears to be too short a time in which to provide a written comment on the image. However, the use of PowerPoint images may have affected the time allocation, considering the fact that the use of hard copies for viewing would require moving to view the images or placing images on viewing boxes. In a study by Smith, Traise and Cook (2009:3), the test bank comprised of 25 abnormal images and candidates appeared to have as long as they required per image, which for most, took less than 1.5 hours to complete the test. Therefore, the length of time necessary for diagnostic radiographers to differentiate between normal and abnormal images and provide a comment appears inconclusive. In Mackay’s (2006:469) study, 18 images were abnormal and 12 normal, Hardy and Culpan (2007:67) had 11 abnormal and 9 normal cases and, as was previously stated, Smith et al. (2009:3) had 25 abnormal cases. Thus, the difference in composition of the test bank could affect the time required to view the images.

Therefore although the participants in the pre-test verbally expressed the opinion that the number of images was too large and it was difficult to concentrate over such a long period of time, the viewing time was in line with
previous studies and does not appear to have affected accurate image interpretation.

5.6 TRAINING IN MUSCULOSKELETAL PATTERN RECOGNITION

The results of the study would appear to support that training in musculoskeletal pattern recognition has an effect on the ability of diagnostic radiographers to interpret musculoskeletal images. As previously stated the accuracy of image interpretation in the post-test results improved by 9%, which is statistically significant. The accuracy of the comments on the images also showed an improvement of 6.32% for the post-test. The correct comments were considered as either partially correct or correct and in-line with the reference standard. The number of partially correct comments increased from 16.48% to 21.78% and the correct comments increased from 7.78% to 10.33%. In the research conducted by Hardy and Culpan (2007:67) their results showed that radiographers were able to accurately identify normal and abnormal images. However, the accuracy of their comments was not always as successful because the training was a short course in musculoskeletal trauma imaging and they highlighted this as a limitation to their study. In addition it was stated that training needs to be more extensive in order to provide radiographers with the skills to provide an accurate comment on an image.

The training in the present study was more extensive and it would appear to have improved the ability of diagnostic radiographers to provide image interpretation. On assessing radiographers following a short course, McConnell and Webster (2000:612) felt that the results could be effective in providing information on the ability of a radiographer before progressing to a postgraduate qualification. As the training has been effective in improving the image interpretation abilities of the participants, the results could motivate radiographers to progress to postgraduate studies.
5.7 REFERENCE STANDARD

The reference standard for the study was a single radiologist. The radiologist has a great deal of experience and therefore was considered appropriate as the reference standard. Brealey (2001:344) suggested a minimum of one consultant radiologist is required as the reference standard and possibly a panel of radiologists would be the optimum reference standard. A radiologist was deemed necessary by Brealey (2001:344) rather than a reporting radiographer. There are no reporting radiographers in South Africa therefore a radiologist was the only appropriate reference standard.

5.8 COMMENTING VERSUS RADIOGRAPHIC OPINION FORM

Diagnostic radiographers appear to find difficulty in providing comments on images although they are capable of identifying abnormal images accurately. The participants in the study demonstrated an improvement in the ability to comment on an abnormal image, post training. However, the number of partially and completely correct image interpretations did not improve significantly. There was an improvement in both partially correct and correct comments, but this was not statistically significant, possibly because of the small number of participants in the study. A potential solution to the problem of partially complete comments on the image could be the use of a structured comment form. Smith et al, (2009:5) used a form in their research called the radiographer opinion form. Such a form could assist radiographers in providing guidance and provide a systematic method of commenting on an image.

5.9 IMPLEMENTATION OF RADIOGRAPHER IMAGE INTERPRETATION

Piper et al. (2005:33) concluded that radiographers specifically trained for reporting on musculoskeletal images can interpret all images accurately and therefore increase the scope of practice beyond trauma images alone.
The findings of the research in South Africa indicate that diagnostic radiographers require training at a postgraduate level to assist with immediate image interpretation and an initial comment on an image in Government hospitals. Certain images were consistently incorrectly interpreted by the participants and therefore further training is required to fill this gap. The images incorrectly interpreted were false positive images, where normal variants were often interpreted as abnormalities by the participants. Mackay (2006:469) had an increase in false positives post training and came to the conclusion that due to the nature of the training, which emphasised the abnormal pathology the radiographers were concentrating on identifying the abnormal and not the normal variants. In research conducted by McConnell an Webster (2000:611) they had an increase in false positives directly after the short course, but 6-10 weeks later the false positives decreased. Therefore the increase appears to be due to the training and with experience the number of false positive image interpretations falls.

Images that were difficult for the participants to interpret were normal variants such as the epiphyseal plates, which were incorrectly identified as fractures. Radiographers have had similar difficulties in other studies. Hardy and Culpan (2007:68-70) found that the epiphyseal line at the shoulder joint was consistently identified as a fracture. In conclusion Hardy and Culpan (2007:70) recommended that further training, over and above the short course the radiographers had attended during the research was required for radiographers to comment on images.

The participants in the present study also reported false negative images; for example the image incorrectly identified as normal in the pre and post-test was the subluxation of the acromioclavicular joints. This is again supported by Hardy and Culpan’s (2007:68-70) research where dislocation of the acromioclavicular joint was identified as normal. It would appear that subtle cases cause the most difficulty in providing comments on the abnormality. As a result, subtle cases have been identified as areas for training in the future.
5.10 CONCLUSION

The diagnostic radiographers in this study have demonstrated that they are able to accurately interpret normal and abnormal images after training. The sample size for the study was small although it has been shown that previous research also had small numbers. The study only included participants from two Government hospitals in the Gauteng area. Therefore with a small sample size and limited setting the results cannot be generalised to the larger population or nationally.

The results have shown that diagnostic radiographers are capable of identifying normal and abnormal images and after training the mean for accuracy being 79%, which is statistically significant. The improvement in accurate identification of normal and abnormal images took place after the intervention, thus proving that radiographers require training to enable them to provide accurate image interpretation.

The researcher wanted to establish whether radiographers could provide an accurate comment on the images in addition to identifying normal and abnormal images. There was an improvement in the commenting after the training. However, the comments were often incomplete and not consistent for all participants. Therefore, it would appear more training is required over an extended period of time to improve the level of accuracy of commenting on abnormal images. The images that were difficult to interpret have been identified.

In the next chapter, the training and the emphasis that should be placed on certain aspects of the training to provide radiographers with the optimum skills for image interpretation will be discussed.
CHAPTER SIX

RECOMMENDATIONS

6.1 INTRODUCTION

In this chapter the recommendations that could be implemented to enable diagnostic radiographers to provide initial image interpretations in the Government hospitals of Gauteng are presented. The type of training required to assist diagnostic radiographers in the accurate interpretation of images will be identified using the research results as a baseline.

6.2 SAMPLE SIZE

The present study had a sample size of nine participants, which was considered a statistically appropriate number to achieve the required amount of data taking into consideration the number of images viewed. If further research is carried out it is proposed that radiographers in other provinces in South Africa be included to increase the sample size and clinical environment. Expanding research to other provinces would be important, particularly as the population of diagnostic radiographers covers a large area and includes both rural and urban environments.

A study conducted in Australia by Smith et al. (2009:3) consisted of 16 rural radiographers who interpreted 25 abnormal images in the pre- and post-tests. As the diagnostic radiographers were widely dispersed throughout Australia the research used PowerPoint presentations and videoconferencing and suggested internet sites for the training. The Australian research could provide the direction for future South African research. Research conducted in this way in South Africa would assist in increasing the study sample size and include radiographers in more remote locations.
6.3 POST QUALIFICATION TRAINING MUSCULOSKELETAL PATTERN RECOGNITION

The research has established that post qualification training is required for role extension into image interpretation to take place. Therefore, it is important to consider the format of training for the best outcome for diagnostic radiographers to take on this role.

6.3.1 Post Qualification Training

The research has identified that radiographers, with training, can improve their levels of accuracy in image interpretation. The nine participants demonstrated a mean improvement from accuracy of 70.11% in the pre-test to 77.67% in the post-test which indicates that the training improved their skills in image interpretation. The ability to provide a comment on the images also improved after training. Fewer incorrect, inaccurate comments were identified from a 24.11% in the pre-test to 17.78% in the post-test. These results reflect the findings of previous research done in the UK by McConnell and Webster (2000:210) where accuracy also improved post training. The nine participants in the study were all qualified radiographers, therefore, the results indicate, the need for further post qualification training. Diagnostic radiographers are taught pattern recognition at diploma level. However, it is apparent from the results of the study that further education is required post qualification to enable accurate image interpretation. According to Hardy and Culpan (2007:70) and Brealey et al. (206:613), radiographers require training if they are to provide an initial image interpretation in the A&E department, which is the SCoR (2006:10) vision for role extension for radiographers in the UK. It is of the opinion that an undergraduate qualification does not provide the necessary skills for radiographers to interpret images accurately and that to maintain standards within the profession, further continued education is necessary. Hardy and Snaith (2009:103) supported these findings and questioned whether qualifying radiographers had the skills to provide image interpretation in terms of the RADS. Although Hardy and Snaith (2009:103) acknowledged that short course are offered as continuous professional
development, it is important to establish a postgraduate programme. This is an important consideration in the South African context as the development of a new curriculum for undergraduate and postgraduate education is currently taking place.

Hardy *et al.*, (2008:303) established that postgraduate radiographers with a reporting qualification failed to check images for adequacy believing that the radiographer who performed the examination had already performed the quality assurance checks. Therefore, training must place emphasis on the quality of the image that the radiographer is commenting on. The findings arising from the research endorses the UK findings and it is recommended that radiographers in South Africa receive additional training in assessing image quality, pattern recognition and image interpretation before this type of role extension can be implemented.

### 6.3.2 Length of Post Qualification Training

The researcher, based on the research findings, concurs with Mackay (2006:472) that the training period needs to be extended and should incorporate mentorship for radiographers in the clinical environment. The researcher recommends a post qualification training programme in pattern recognition of the musculoskeletal system, which would provide the skills for accurate image interpretation. The qualification needs to be a full year programme with provision for further continuous education opportunities. Certificate courses in image interpretation are offered in the UK by Universities. These are part-time courses over one year of attending a University, on a block basis. They incorporate a clinical component with the support of the clinical department (University of Bradford). In her reflection on radiographer reporting, Reeves (2004:215) identified the importance of a mentor for teaching purposes and to provide for the “gold standard” in the clinical environment. The need for mentorship within the clinical department should therefore be a prerequisite for participation in an image interpretation training programme.
The participants in the study could provide input in developing the training for the future programme drawn from their experience of participating in the research and the intervention. They could provide an insight into the areas, which should be emphasised in future, so as to assist with achieving accurate levels of commenting on images.

An assessment into whether a mentorship programme in image interpretation for diagnostic radiographers would be beneficial to complement the training could be an area for future research. Snaith and Lancaster (2008: 151) identified clinical competence as necessary for radiographers to interpret images accurately. The need for radiographers to be able to request other examinations and modalities and conduct clinical assessments of their patients was investigated (Snaith & Lancaster, 2008:152). These skills were identified as requiring support from the radiology staff as was experience in the clinical environment in order to achieve a complete role for the radiographer in a multi-disciplinary team.

Mentoring needs to be provided by radiologists and, therefore, they need to be willing to provide this service. Government hospitals would benefit from implementing such training and mentoring in the clinical environment and thereby provides a better service to the patients. Radiographers have a good understanding of the imaging procedures required to obtain optimum results for the patient and providing radiographers with the skills to request further procedures could be time saving in an overstretched health service. They could become an essential part of the multidisciplinary team.

6.3.3 Training in Recognition of Normal Variants

The limitations of the training in the present research is the length of time provided for the training. Due to these time constraints some normal variants were not extensively covered in the training. In the research training epiphyseal variants were taught, but the epiphyseal appearances and the age of growth plate appearances could not be covered in great detail. Some
subtle pathologies and epiphyses were not identified by the participants in the post-test. The subtle pathologies that were not identified in the study were subluxation of the acromio-clavicular joints, avulsion fractures and normal variants such as the epiphyseal lines of the metatarsals. The areas identified in the present study are very much in keeping with those identified by Hargreaves and Mackay (2003:288) who identified joint effusions, hand and lower limb fractures and epiphyses as difficult for radiographers to interpret accurately. The time frame needs to be extended to provide more extensive training in normal variants and the pattern recognition of subtle discriminating pathologies to improve the comments provided on the images.

When constructing a curriculum for pattern recognition of musculoskeletal images; normal variants should be taught with an emphasis on epiphyseal appearances and included as a dedicated module in future training programmes.

6.4 METHOD OF TESTING ACCURACY OF IMAGE INTERPRETATION AND COMMENTING

The researcher assessed the participants abilities by using an OSCE. This method has been used in previous research by Piper et al., (2005:29), Hardy and Culpan (2007:67) and Mackay (2006:468-9). The participants were provided with a test bank of a 100 images to interpret accurately images in an examination setting. On reflection, however, the number of images appear to be too many for one session. In retrospect the researcher would have chosen 50 images as a more realistic number, which would still have provided the variety of images needed to test the radiographers in all aspects of image interpretation. A different method of providing a large sample of images would be to adopt an approach similar to Piper et al., (2005:29) in which students were assessed on 25 images per bank with several banks being provided over time. The participants in Piper et al. (2005:29) were completing a postgraduate course and were assessed as competent by identifying images as normal or abnormal and providing a comment on the abnormal images.
They were assessed using eight banks of 25 images; a total of 200 images for interpretation.

The OSCE may not be the optimum method for assessing the ability of radiographers to interpret images as the situation is artificial and in a controlled environment. Brealey et al., (2006:611-2) reviewed studies regarding the ability of radiographers to provide image interpretation and stated that the OSCE was not representative of the clinical situation.

The gap in the provision of image interpretation is often in “hot” reporting in the A&E department. The need for an immediate comment on an image can have an impact on the treatment for the patient. Therefore, an assessment of radiographers in the clinical situation could be beneficial in providing immediate image interpretation by a radiographer as well as assessing whether environmental pressures affect their accuracy. This is of great importance as many images return to the A&E department in Government hospitals with an interpretation of the image.

“Hot” reporting in the A&E department is the gap that is envisioned radiographers should fill in the UK. Hardy and Snaith (2008:379) found that 77.5% of A&E departments operated “red dot” systems, 19% had “red dot” and commenting systems and 2.5% only had commenting systems operating. A possible method for assessment in the clinical environment and continuous training was demonstrated in a case study carried out by Carter and Manning (1999:72) where a radiographer, in order to complete a postgraduate module in image interpretation, was required to compile a report on a minimum of 300 image interpretations over a period of nine weeks and compare them with the radiologist’s reports. The image interpretations were “cold reports” on images returned to the department after the casualty officer had treated the patient. The radiographer then compiled his/her report. In the nine week period the radiographer sat in on radiologists’ reporting sessions in order to understand the language of reporting, discuss the image interpretations of the 300 cases with a radiologist who was a mentor, and use websites as a learning tool to assist with the interpretation of normal variants. This type of assessment
would add value to the training of radiographers and establish the accuracy of image interpretation in the clinical environment.

Therefore when considering the optimum method for assessing students following post qualification training in South Africa, a combination of an OSCE and clinical audit would be the best. The OSCE provides the opportunity to assess the student on a variety of images and the clinical assessment provides an assessment of the student’s ability under the pressures of the clinical environment. The log book used in the study facilitates the assessment of the radiographers in the clinical environment. Unfortunately, only two radiographers submitted the log books and therefore conclusions on the use of the log book are difficult to assess. However, the two participants (2, 3), appear to have developed a better understanding about constructing a comment than the other participants. Therefore, it is proposed that in future log books be used in the clinical situation to assist with the assessment of students and as a form of an audit.

6.5 TIME FOR VIEWING IMAGES IN A TEST BANK

The length of time required for optimum accurate image interpretation does not appear to have been established in previous research. Therefore the length of time allowed for interpreting the images was based on the research by Piper and Paterson (2009:43) which was 90 seconds per image. There were 100 images, which resulted in 150 minutes or 2½ hours for viewing. Other studies have used shorter time constraints such as 40 seconds per image (Hardy & Culpan, 2007:67) and or longer, namely 1½ hours for 25 images (Smith et al., 2009:3). Further research is required to establish the optimum period of time needed for accurate image interpretation taking into account the consideration of “hot” reporting.

Bryan, Weatherburn, Watkins, Roddie, Keen, Muris and Buxton (1998:1156) calculated the mean time taken for radiologists to report on conventional images as 145 seconds. The length of time taken to report on images in the Bryan et al. (1998:1155) study included the review of previous images and
multiple areas for reporting. Therefore 90 seconds would be appropriate for the commenting on a single musculoskeletal area.

6.6 ENVIRONMENT FOR IMAGE INTERPRETATION

Much has been made of the environment in which radiographers can optimally provide an image interpretation. When an OSCE is used to assess radiographer’s abilities to interpret images the environment is controlled with optimum viewing conditions. In this research the participants viewed hard copies on viewing boxes, which is considered the optimum viewing method as supported by Hardy and Culpan (2007:70) who used PowerPoint images for their research and identified this as a limitation to their study as the images cannot be considered to be equal in quality to hard copies.

Radiographers do not always have optimum conditions to interpret images. They are frequently asked for an opinion in the x-ray department or the A&E department where the viewing conditions may not be optimum and there could be time constraints for commenting due to the large number of patients to be seen. Hardy, Snaith and Spencer (2008:304) considered that “hot” reporting as immediate comments on an image in the processing area is not an optimum environment. However, the findings indicated that radiographers can still produce accurate interpretations and comments that are beneficial to the patient even under these circumstances.

In the case study by Carter and Manning (1999:78), they identified that the different viewing conditions in which radiographers work could impact on their ability to accurately interpret images. Carter and Manning (1999:78) agreed with Hardy et al. (2008:304) that radiographers who provide “hot reporting” may not have the optimum viewing conditions and limited time when compared with the time that is afforded to radiographers who report on images in reporting sessions similar to those of the radiologist who have optimum viewing conditions. Carter and Manning (1999:78) identified this as an area for further comparative studies to be done. The introduction of Picture Archiving and Communication Systems (PACS) in Government hospitals adds
another dimension in which the change in viewing conditions may be highlighted, and therefore, a need for a change in the training recognised. The clinical component of the training would require some changes to enable radiographers to optimally interpret images via the PACS system for the benefit of patient management.

6.7 CONTROL GROUP

Brealey and Scally (2008:e49) in the review of methodology in assessing the ability of radiographers to interpret images, considered that the lack of a control group affects the validity of these studies. According to Brealey and Scally (2008:e49), a control group may establish the role that time and the clinical environment plays in the ability of a diagnostic radiographer to accurately interpret images. However, the researcher is of the opinion that diagnostic radiographers in the control group who are aware of being involved in a study regarding the ability to interpret images could be motivated to use resources such as the internet to improve their knowledge and to ask the advice of radiologists on cases seen in the clinical environment. Therefore, learning could be taking place outside of a formal training programme. However, the participants in the training would also have these opportunities to access the internet and consult with colleagues. A control group could act as a measure of assessing the impact of the intervention (the training) as all the other factors are common to both groups.

6.8 DISTANCE LEARNING

In South Africa, it is difficult to conduct research of this nature in rural areas. However it appears to be a reality that radiographers are asked for their opinion particularly in remote areas without access to radiologists. Therefore, future research could use a similar method of training as implemented by Smith et al. (2009:4) where, due to the disparity of the geographical locations, all training was undertaken via computer. PowerPoint presentations were
used along with self-tests and then once a week the participants took part in a video conference discussion. Thereafter, specific internet sites were recommended and reading sources suggested to the participants. Further research is required in South Africa and with the advancements in technology, distance learning would appear to be the modality of choice in the future. Unfortunately South African Universities, which offer qualifications in radiography, are at present not designated to offer distance learning via the internet.

Hardy and Snaith (2009:104) felt distance learning had not been promoted as an education tool to deliver image interpretation courses. They felt that radiographic pathology could be learnt via on-line tuition together with the use of virtual learning environments. Hardy and Snaith (2009:104) in their discussion, suggested educators are unable to convert their content for use in the virtual environment as it would be time consuming and educators are not always competent in the use of technology. This may be the reason for the lack of on-line material. Distance learning is a form of learning that South Africa could possibly consider using in the future. For this to be successful, there would need to be a change in the mode of offering tuition by Universities in South Africa as, at present, the only University providing distance learning is the University of South Africa (UNISA) and they do not offer radiography. The future lies in using technology such as the internet, Skype and email. The method of offering further training in radiography in South African Universities needs to be reviewed.

6.9 THE RADIOGRAPHER OPINION FORM

Research has identified that radiographers are not as accurate with their comments as they are with the identification of normal and abnormal images (Hardy & Culpan, 2007:69). The researcher identified a similar result in this research, although the accuracy increased, the comments improved from no accurate comment to a partially accurate comment. However, if role extension into the field of image interpretation is to occur, the comments must improve. Smith et al. (2009:5) compiled a radiographer opinion form (ROF), which
could assist in providing an accurate comment. The ROF provides radiographers with a tick box to identify the image as abnormal or normal. Once the image had been identified as abnormal, radiographers are provided with a list of features of musculoskeletal pathology such as: fractures, dislocations, periosteal reaction, bone erosion, cortical destruction, changes in bone density, sclerotic or lytic changes and degenerative changes and are required to tick whichever they feel is appropriate to the image. Finally, they are asked to provide any further comments. A form in a similar format could be a useful tool to direct the novice radiographer undertaking image interpretation by providing a structured approach to the commenting format. The list highlights the pattern recognition criteria taught to radiographers via the on-line programme and provides a systematic approach for the interpretation of the image (Smith et al., 2009:4). This may prevent the problem of “failure to search” by providing structure. The radiographer is still required to identify the location of the pathology and give additional pertinent information.

6.10 CONCLUSION

In conclusion, the participants demonstrated a significant improvement in their ability to identify normal and abnormal images of the musculoskeletal system after the intervention. The accuracy of the participants improved following the intervention. There was also a significant improvement in their ability to provide a comment on the image compared to before the intervention, when no comment at all was provided. Therefore, the intervention, namely the training in pattern recognition of the musculoskeletal system to enable image interpretation of musculoskeletal images, would appear to have been partially successful for these participants, in the sense that some form of comment was provided, albeit the comments were not of a standard that could be compared with the reference standard as complete and comprehensive. The commenting ability of the participants was not the same for all participants although they all completed the same training. One of the participants improved and commented well. However, the others did not realise the
standard required for the clinical situation or the comments were not comprehensive enough to be used in the clinical environment.

Thus, in order to empower diagnostic radiographers in these hospitals with the skills required to provide image interpretation, a training programme needs to be developed for diagnostic radiographers with emphasis on the medical vocabulary and anatomy for accurate commenting. The programme needs to be offered in conjunction with the assistance of the radiologists in the clinical environment to provide mentorship for the radiographers wishing to participate in this form of role extension. The programme should be offered at a postgraduate level for a minimum of one year with follow up continuous professional development activities.

The research demonstrated that with the correct training the participants were able to go beyond the “red dot” system and fracture detection. The participants interpreted images and commented using pattern recognition to identify pathologies of all types. Further research is required as this was a small study in two hospitals. However, the ability of these radiographers to interpret images accurately improved with training and, therefore, training should be considered in the future, in preparation for role extension of radiographers in South Africa.

The research highlighted possible measures which could be implemented to contribute to diagnostic radiographers having the ability to comment on images accurately. The log books used could be a useful tool in assessing the ability of radiographers to interpret images in the clinical environment and give them the opportunity to discuss their comments with radiologists. Distance learning should be considered in the future, although changes need to be made in University policy to allow for distance learning, on- line internet teaching and learning.
REFERENCES


Modernisation of Tertiary Services - Diagnostic Radiology. Report from Diagnostic Radiology group meeting. 13 February 2003


Prinsloo, N.M. South African Medical and Dental Council, 23rd January 1997 Professional Board of Radiographers, 1996


Society of Radiographers available from:  


Statistics South Africa available from:  


Dear _______________________
Senior Clinical Manager Tambo Memorial Hospital,
My name is Lynne Hazell I am a postgraduate student at the University of Johannesburg studying for a Master’s degree in Diagnostic Radiography. I am interested in conducting a research study entitled: A Study to Assess the Ability of Radiographers to Apply Pattern Recognition Criteria and Interpret Radiographs

Therefore I could with your permission like to approach members of the qualified radiography staff to participate in my research. They would be provided with training by the University of Johannesburg in musculoskeletal pattern recognition at no cost implication to you. They would then be required to implement this training over a three month period. During this period they would keep a log book substantiated by the radiologists.

This would be beneficial to the X–ray department as it is anticipated that it would enable an interpretation of radiographs to be provided by these select radiographers during after hours work when radiologists may not be available. It could also release radiologists for specialised procedures.

I would be happy to discuss this proposal further with you or respond to any queries you may have.
Yours truly,

Lynne Hazell
Contact details: 072 225 8105, 011 559 6244.
**Consent to participate in the research project**

I, ________________________, have read and understood the information provided and hereby give my consent to the qualified radiographic staff at Tambo Memorial Hospital to participate in this research study subject to approval by the Ethics Committee at the University of Johannesburg.

Senior Clinical Manager, Tambo Memorial Hospital, Gauteng.

_____________________

Date

_____________________


UNIVERSITY OF JOHANNESBURG
Dr Billa,
Clinical Director,
Chris Hani Baragwanath Hospital.

My name is Lynne Hazell I am a postgraduate student at the University of Johannesburg studying for a Master’s degree in Diagnostic Radiography. I am interested in conducting a research study entitled: **A Study to Assess the Ability of Radiographers to Apply Pattern Recognition Criteria and Interpret Radiographs.**

Therefore I could with your permission like to approach members of the qualified radiography staff to participate in my research. They would be provided with training by the University of Johannesburg in musculoskeletal pattern recognition at no cost implication to you. They would then be required to implement this training over a three month period. During this period they would keep a log book substantiated by the radiologists.

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I would be happy to discuss this proposal further with you or respond to any queries you may have.

Yours truly,

Lynne Hazell

Contact details: 072 225 8105, 011 559 6244.
Consent to participate in the research project

I, _______________________, have read and understood the information provided and hereby give my consent to the qualified radiographic staff at Chris Hani Baragwanath Hospital to participate in this research study subject.

Chris Hani Baragwanath Hospital, Gauteng.

__________________________________________

Date

__________________________________________
ANNEXURE 2

The “red dot” protocol

• The “red dot” system is one whereby the radiographer appends a “red dot” to a radiograph that he/she believes shows an acute abnormality pertinent to the patient's clinical history.
• The system is to be used by all participating radiographers, to ensure validity of the application of the training.
• The presence (or absence) of a “red dot” is informal and has no legal significance. The presence of a “red dot” could indicate any one of the following abnormal appearances:
  • A recent fracture
  • A dislocation
  • A foreign body
  • Soft tissue signs:
    o elbow effusion
    o knee effusion
  • Pathology of non-traumatic nature:
    o Arthritis
    o Lesions benign or malignant of the bone
    o Bone density changes

The “red dot” protocol is taken from the Hargreaves and Mackay research where it is applicable to the musculoskeletal system (Hargreaves & Mackay, 2003:285).
## ANNEXURE 3

Participant Number:
Indicate normal/abnormal pathology with a X

<table>
<thead>
<tr>
<th>Normal Pathology</th>
<th>Abnormal Pathology</th>
<th>Application of the Pattern Recognition Criteria to the radiograph. Provide a description according to the pattern recognition criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiograph 1</td>
<td></td>
<td></td>
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<td>Radiograph 2</td>
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<td>Radiograph 6</td>
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<td>Radiograph 7</td>
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<td>Radiograph 8</td>
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</tbody>
</table>
ANNEXURE 4
Radiologist:
Indicate normal/abnormal pathology with a X

<table>
<thead>
<tr>
<th></th>
<th>Normal Pathology</th>
<th>Abnormal Pathology</th>
<th>Application of the Pattern Recognition Criteria to the radiograph. Provide a description according to the pattern recognition</th>
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<td>Radiograph 1</td>
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<td>Radiograph 8</td>
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</table>
ANNEXURE 5
LOG BOOK
Musculoskeletal Radiographs required to demonstrate pattern recognition and interpretation:
20 – Lower extremity (Foot, Ankle, Tibia and Fibula, Knee)
10 – Femur, Hip and Pelvis
20 – Upper Extremity (Hand, Wrist, Forearm & Elbow)
10- Humerus and Shoulder Girdle

<table>
<thead>
<tr>
<th>Examination Type</th>
<th>Normal</th>
<th>Abnormal</th>
<th>Pattern Recognition and interpretation seen on the radiograph</th>
<th>Radiologist Signature</th>
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Dear Participant,

I am a post graduate student at the University of Johannesburg studying for a Master’s degree in Diagnostic Radiography. You are invited to participate in a research study entitled: **A Study to Assess the Ability of Radiographers to Apply Pattern Recognition Criteria and Interpret Radiographs.**

The purpose of the study is to train participating radiographers in musculoskeletal pattern recognition and then assesses their ability to apply this training in providing a comment on this type of radiograph. The participants will all be qualified radiographers employed in a Provincial Hospital in Gauteng.

Permission has been provisionally granted by the Senior Clinical Manager of the Tambo Memorial Hospital subject to the approval of the Ethics committee.

The study will take the form of a quantitative study utilising pre and post test techniques. The pre test will be conducted after revision in the application of the “red dot” system. It will require interpretation of 100 radiographs on the normal and abnormal appearances. The training in musculoskeletal pattern recognition will then take place over a period of three months. It is anticipated that the training will be offered by the University of Johannesburg in the form
of tutorials, at no cost to the participants. The participants will be required to keep a logbook to demonstrate their application of the training in the clinical environment. The post test will then be conducted again with 100 radiographs and interpretation of abnormal and normal appearances will be required.

Your anonymity is guaranteed, as your name will not be mentioned. There is no responsibility incurred by you regarding any comment made by you during the three-month period of the study.

Your participation in the study is voluntary and you have the right to withdraw your participation at any stage. If you agree to take part in the study, please give your informed consent by signing the slip provided below.

Yours truly,
Lynne Hazell

_______________________
Researcher

Contact details:
072 225 8105/ 011 559 6244
lynneh@uj.ac.za

Mrs. J. Motto

_______________________
Supervisor
Consent to participate in the research project

I, ______________________, have read and understood the information provided and hereby give my consent to participate in this research study. Any questions raised by the participant have been answered by the researcher to my satisfaction.

Participant

________________________________

Date

________________________________
ANNEXURE 7

PATTERN RECOGNITION CRITERIA FOR THE MUSCULOSKELETAL SYSTEM

The following criteria would be applicable to the musculoskeletal radiographs

Signs of Bone Disease:
Change in Bone Density
Decreased or increased bone density

Periosteal Reaction:
Periosteal reaction occurs when excess bone is produced. The periosteum is not normally visualized on a radiograph

Cortical Changes:
Thickening of the cortical margin of the bone
Destruction of the cortical margin of the bone
Decrease in cortical margin of the bone
Changes in the alignment of the cortical margin

Changes in trabecular pattern
Decrease in the number of trabeculae visualized
Trabeculae seen in the compact bone
Prominence of the trabecular pattern

Change in the shape of the bone

Alteration in bone age
Epiphyseal centres indicate maturation of the bone

Changes in the soft tissue
Soft tissue swelling
Change in the joint space
Narrowing of the joint space

Abnormal calcification

(ARMSTRONG, P, WASTIE, M & ROCKALL, A, 2004: 301-353)

Fractures
Forces required for fracture to occur
Avulsion fractures
Pathological fractures
Stress fractures

Dislocation
Humeral head
Hip

Normal variants

Epiphyseal changes