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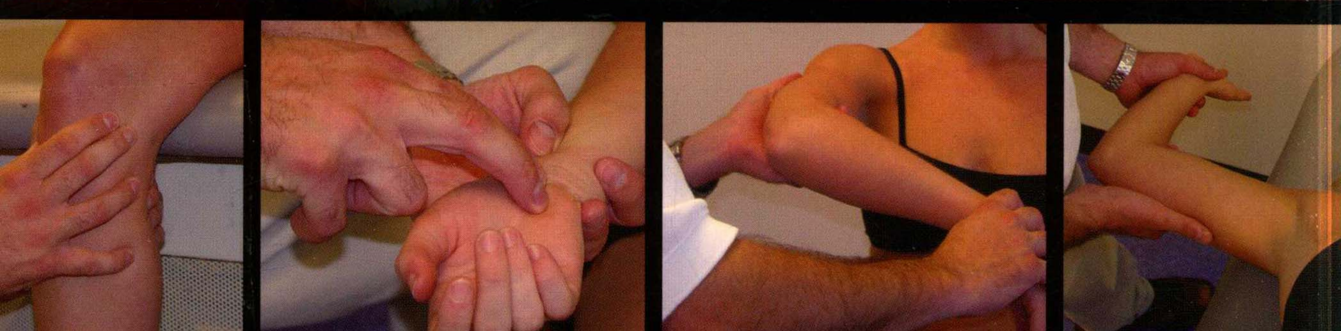
NETTER'S ORTHOPAEDIC CLINICAL EXAMINATION

An Evidence-Based Approach

3RD EDITION



Netter's Orthopaedic Clinical Examination

An Evidence-Based Approach

THIRD EDITION

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NETTER'S ORTHOPAEDIC CLINICAL EXAMINATION: AN EVIDENCE-BASED APPROACH, THIRD EDITION

ISBN: 978-0-323-34063-2

International Standard Book Number: 978-0-323-34063-2

Senior Content Strategist: Elyse O'Grady
Senior Content Development Specialist: Marybeth Thiel
Publishing Services Manager: Patricia Tannian
Senior Project Manager: John Casey
Senior Book Designer: Amy Buxton

Printed in China
Last digit is the print number: 9 8 7 6 5 4 3 2 1

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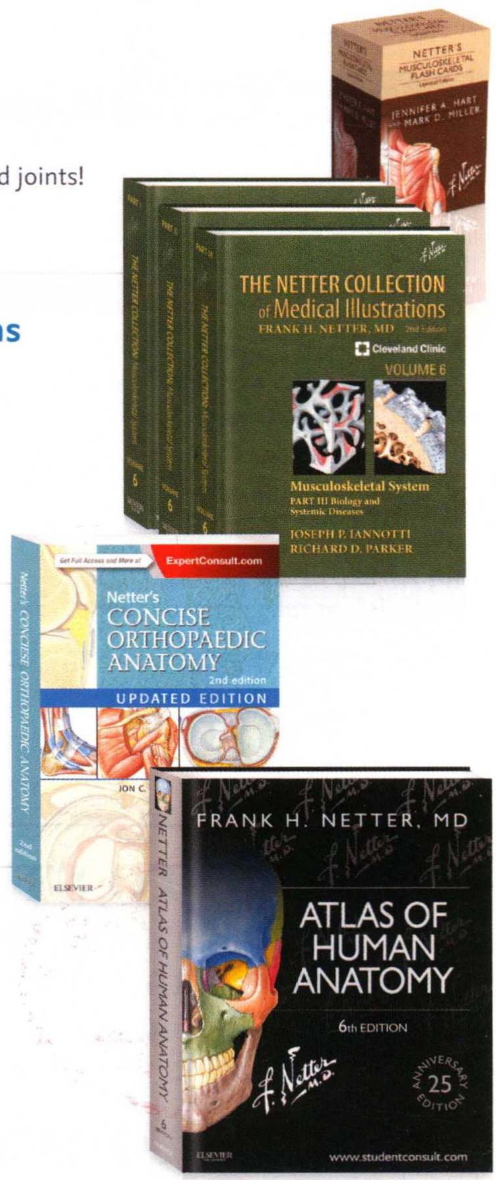

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To our incredible mentors and colleagues
who have fostered our passion for
evidence-based practice and orthopaedics.

To our photography models (Jessica Palmer, Nicole Koppenhaver,
and Farah Faize) and photographers (Sara Randall, Lindsey Browne,
Jeff Hebert, and Patrick Moon) for spending more hours
and retakes than we'd like to admit.

To Dr. Frank Netter and the Elsevier editorial staff
who turned our ideas into a fantastic literary guide.

And, most important, to our wonderful families,
whose sacrifices and support
made this considerable endeavor possible.

About the Authors

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Dr. Cleland earned a Master of Physical Therapy degree from Notre Dame College in 2000 and a Doctor of Physical Therapy degree from Creighton University in 2001. In February of 2006 he received a PhD from Nova Southeastern University. He received board certification from the American Physical Therapy Association as an Orthopaedic Clinical Specialist in 2002 and completed a fellowship in manual therapy through Regis University in Denver in 2005. Josh is presently a Professor in the Doctor of Physical Therapy Program at Franklin Pierce University. He practices clinically in outpatient orthopaedics at Rehabilitation Services of Concord Hospital, Concord, New Hampshire. Dr. Cleland is actively involved in numerous clinical research studies investigating the effectiveness of manual physical therapy and exercise in the management of spine and extremities disorders. He has published over 170 manuscripts in peer-reviewed journals and is an Editorial Review Board Member for the *Journal of Orthopaedic and Sports Physical Therapy.* He is currently an author/editor on 4 textbooks. Dr. Cleland is a well-known speaker both nationally and internationally. He is the recipient of the 2015 Rothstein Golden Pen Award for Scientific Writing, the 2011 Chattanooga Research Award, the 2009 Eugene Michels New Investigator Award, and the 2008 Jack Walker Award, all from the American Physical Therapy Association. In addition, he received the Rose Excellence in Research Award from the Orthopaedic Section of the American Physical Therapy Association in 2013, 2014, and 2015.

Shane Koppenhaver, PT, PhD

Dr. Koppenhaver received his Master of Physical Therapy degree from the U.S. Army–Baylor University Graduate Program in 1998 and a PhD in Exercise Physiology from the University of Utah in 2009. He became board certified in Orthopedic Physical Therapy in 2001 and completed a fellowship in manual therapy through Regis University in 2009. Dr. Koppenhaver is a Lieutenant Colonel in the U.S. Army and an Associate Professor and Research Director in the U.S. Army–Baylor University Doctoral Program in Physical Therapy. He has published numerous studies on low back pain, spinal manipulation, and the use of ultrasound imaging in the measurement of muscle function. His primary research interests concern mechanistic and clinical outcomes associated with manual therapy and dry needling, especially as they apply to clinical reasoning and management of patients with neuromusculoskeletal conditions.

Jonathan Su, PT, DPT, LMT

Dr. Su earned a Doctor of Physical Therapy degree from U.S. Army–Baylor University in 2013 and received board certification as a Sports Clinical Specialist from the American Physical Therapy Association in 2015. Dr. Su is a Captain in the U.S. Army embedded with the 2nd Stryker Brigade Combat Team, 25th Infantry Division, and serves as the unit's subject matter expert on human performance optimization, rehabilitation/reconditioning, and injury prevention. He operates a direct access sports/orthopaedic physical therapy clinic and advises key leaders on the design and implementation of physical training programs to maximize combat readiness for the unit's 4,400 soldiers. Dr. Su was inducted as an Honorary Member of the U.S. Army's 14th Infantry Regiment in 2015 for his contributions to soldier wellness and performance. His primary interest is in translating research into clinical practice to ensure the highest quality care.

About the Artists

Frank H. Netter, MD

Frank H. Netter was born in 1906 in New York City. He studied art at the Art Students League and the National Academy of Design before entering medical school at New York University, where he received his medical degree in 1931. During his student years, Dr. Netter's notebook sketches attracted the attention of the medical faculty and other physicians, allowing him to augment his income by illustrating articles and textbooks. He continued illustrating as a sideline after establishing a surgical practice in 1933, but he ultimately opted to give up his practice in favor of a full-time commitment to art. After service in the United States Army during World War II, Dr. Netter began his long collaboration with the CIBA Pharmaceutical Company (now Novartis Pharmaceuticals). This 45-year partnership resulted in the production of the extraordinary collection of medical art so familiar to physicians and other medical professionals worldwide.

In 2005, Elsevier, Inc. purchased the Netter Collection and all publications from Icon Learning Systems. More than 50 publications feature the art of Dr. Netter and are available through Elsevier, Inc. (in the US: www.us.elsevierhealth.com/Netter and outside the US: www.elsevierhealth.com).

Dr. Netter's works are among the finest examples of the use of illustration in the teaching of medical concepts. The 13-book *Netter Collection of Medical Illustrations*, which includes the greater part of the more than 20,000 paintings created by Dr. Netter, became and remains one of the most famous medical works ever published. The Netter *Atlas of Human Anatomy*, first published in 1989, presents the anatomical paintings from the Netter Collection. Now translated into 16 languages, it is the anatomy atlas of choice among medical and health professions students the world over.

The Netter illustrations are appreciated not only for their aesthetic qualities, but, more important, for their intellectual content. As Dr. Netter wrote in 1949, ". . . clarification of a subject is the aim and goal of illustration. No matter how beautifully painted, how delicately and subtly rendered a subject may be, it is of little value as a *medical illustration* if it does not serve to make clear some medical point." Dr. Netter's planning, conception, point of view, and approach are what inform his paintings and what makes them so intellectually valuable.

Frank H. Netter, MD, physician and artist, died in 1991.

Learn more about the physician-artist whose work has inspired the Netter Reference collection: http://www.netterimages.com/artist/netter.htm.

Carlos A. G. Machado, MD

Carlos Machado was chosen by Novartis to be Dr. Netter's successor. He continues to be the main artist who contributes to the Netter collection of medical illustrations.

Self-taught in medical illustration, cardiologist Carlos Machado has contributed meticulous updates to some of Dr. Netter's original plates and has created many paintings of his own in the style of Netter as an extension of the Netter collection. Dr. Machado's photorealistic expertise and his keen insight into the physician/patient relationship inform his vivid and unforgettable visual style. His dedication to researching each topic and subject he paints places him among the premier medical illustrators at work today.

Learn more about his background and see more of his art at: http://www.netterimages.com/artist/machado.htm.

Foreword

Appropriate treatment decisions depend on an in-depth understanding of anatomy and an accurate diagnosis. This book is unique in that it combines the extensive library of classic Netter anatomical drawings with high-quality photos and now even video in this edition demonstrating special tests. The authors should be applauded for including quality ratings for 269 studies investigating a test's reliability using the 11-item "Quality Appraisal of Diagnostic Reliability Checklist." This edition includes 84 new studies, 34 new photos, and 25 new videos demonstrating special tests. As a PT/ATC and director of a PT sports medicine doctoral program, I see great utility for this reference from the entry level student athletic trainer and physical therapist to ortho/sports residency and fellowship training PTs and MDs. The book is extremely user-friendly and well organized as it walks the reader through the anatomy, clinical exam, and then critically reviews all literature for given diagnostic tests. As we constantly strive for better evidence-based medicine, new and old clinicians would be well served by such a powerful book detailing the utility of diagnostic tests and even evaluating evidence for treatment modalities when available.

Thank you for this extremely helpful tool.

Don Goss, PT, PhD
Program Director
PT Sports Medicine Doctoral Program
U.S. Army–Baylor University

If we can make the correct diagnosis, the healing can begin.

—A. Weil

As an occupational therapist and certified hand therapist, I naturally gravitate toward the chapters on the upper limb. These chapters are exceptional! This is a must-have text for therapists at all levels of experience. The up-to-date tables that provide quality ratings on research facilitate evidence-based practice. The photos demonstrating special tests are invaluable for new learners, as are the supplemental videos included in this third edition. This book signifies a clear intent of the authors to provide a critical resource for therapists. It also shows commitment to education, a desire to translate research into advanced clinical practice, and a vision to advance rehabilitation science through accurate diagnostic evaluation. As I staff upper limb orthopedic cases of my students in training, this book is in my hands and on my clinic exam table as an open-book, go-to reference. It's an educator's dream to have all this valuable information in one text!

Kathleen Yancosek, PhD
LTC, SP, US Army
Program Director
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Preface

Over the past several years evidence-based practice has become the standard in the medical and healthcare professions. As described by Sackett and colleagues (*Evidence-Based Medicine: How to Practice and Teach EBM*, 2nd ed, London, 2000, Harcourt Publishers Limited), evidence-based practice is a combination of three elements: the best available evidence, clinical experience, and patient values. Sackett has further reported that "when these three elements are integrated, clinicians and patients form a diagnostic and therapeutic alliance which optimizes clinical outcomes and quality of life." Each element contributes significantly to the clinical reasoning process by helping to identify a diagnosis or prognosis or establish an effective and efficient plan of care. Unfortunately, the evidence-based approach confronts a number of barriers that may limit the clinician's ability to use the best available evidence to guide decisions about patient care, most significantly a lack of time and resources. Given the increasing prevalence of new clinical tests in the orthopaedic setting and the frequent omission from textbooks of information about their diagnostic utility, the need was clear for a quick reference guide for students and busy clinicians that would enhance their ability to incorporate evidence into clinical decision making.

The purpose of *Netter's Orthopaedic Clinical Examination: An Evidence-Based Approach* is twofold: to serve as a textbook for musculoskeletal evaluation courses in an academic setting and to provide a quick, user-friendly guide and reference for clinicians who want to locate the evidence related to the diagnostic utility of commonly utilized tests and measures.

The first chapter is intended to introduce the reader to the essential concepts underlying evidence-based practice, including the statistical methods it employs and the critical analysis of research articles. The remainder of the book consists of chapters devoted to individual body regions. Each chapter begins with a review of the relevant osteology, arthrology, myology, and neurology and is liberally illustrated with images by the well-known medical artist Frank H. Netter, MD. The second portion of each chapter provides information related to patient complaints and physical examination findings. Reliability and diagnostic utility estimates (sensitivity, specificity, and likelihood ratios) are presented for each patient complaint and physical examination finding and are accompanied by quick access interpretation guides. Test descriptions and definitions of positive test findings are included as reported by the original study authors, both to minimize any alteration of information and to provide readers insight into difference values reported by different studies. At the end of each chapter are tables listing information on commonly used outcome measures and quality ratings for all the studies investigating tests' diagnostic utility. For this new edition, we've also included quality ratings for all the studies investigating tests' reliability. Additionally, new video content demonstrating select tests from each body region can be accessed online.

We hope that clinicians will find *Netter's Orthopaedic Clinical Examination* a user-friendly clinical resource for determining the relevance of findings from the orthopaedic examination. We also hope that students and educators will find this a valuable guide to incorporate into courses related to musculoskeletal evaluation and treatment.

Joshua A. Cleland
Shane Koppenhaver
Jonathan Su

Contents

Diagnostic and Reliability Interpretation Keys

Diagnostic Interpretation Key

+ LR	Interpretation	–LR
≥10	Large	<.1
5.0-10.0	Moderate	.1-.2
2.0-5.0	Small	.2-.5
1.0-2.0	Rarely important	.5-1.0

Reliability Interpretation Key

ICC or κ	Interpretation
.81-1.0	Substantial agreement
.61-.80	Moderate agreement
.41-.60	Fair agreement
.11-.40	Slight agreement
.0-.10	No agreement

Video Contents

The Reliability and Diagnostic Utility of the Orthopaedic Clinical Examination

1

The health sciences and medical professions are undergoing a paradigm shift toward *evidence-based practice* defined as the integration of the best available research evidence and clinical expertise with the patient's values.[1,2] Evidence should be incorporated into all aspects of physical therapy patient and client management, including the examination, evaluation, diagnosis, prognosis, and intervention. Perhaps the most crucial component is a careful, succinct clinical examination that can lead to an accurate diagnosis, the selection of appropriate interventions, and the determination of a prognosis. Thus, it is of utmost importance to incorporate evidence of how well clinical tests and measures can distinguish between patients who present with specific musculoskeletal disorders and patients who do not.[1,2]

The diagnostic process entails obtaining a patient history, developing a working hypothesis, and selecting specific tests and measures to confirm or refute the formulated hypothesis. The clinician must determine the pretest (before the evaluation) probability that the patient has a particular disorder. Based on this information the clinician selects appropriate tests and measures that will help determine the posttest (after the evaluation) probability of the patient having the disorder, until a degree of certainty has been reached such that patient management can begin (the *treatment threshold*). The purpose of clinical tests is not to obtain diagnostic certainty but rather to reduce the level of uncertainty until the treatment threshold is reached.[2] The concepts of pretest and posttest probability and treatment threshold are elaborated later in this chapter.

As the number of reported clinical tests and measures continues to grow, it is essential to thoroughly evaluate a test's diagnostic properties before incorporating the test into clinical practice.[3] Integrating the best evidence available for the diagnostic utility of each clinical test is essential in determining an accurate diagnosis and implementing effective, efficient treatment. It seems only sensible for clinicians and students to be aware of the diagnostic properties of tests and measures and to know which have clinical utility. This text assists clinicians and students in selecting tests and measures to ensure the appropriate classification of patients and to allow for quick implementation of effective management strategies.

The assessment of diagnostic tests involves examining a number of properties, including reliability and diagnostic accuracy. A test is considered *reliable* if it produces precise and reproducible information. A test is considered to have *diagnostic accuracy* if it has the ability to discriminate between patients who have a specific disorder and patients who do not have it.[4] Scientific evaluation of the clinical utility of physical therapy tests and measures involves comparing the examination results with reference standards such as radiographic studies (which represent the closest measure of the truth). Using statistical methods from the field of epidemiology, the diagnostic accuracy of the test, that is, its ability to determine which patients have a disorder and which do not, is then calculated. This chapter focuses on the characteristics that define the reliability and diagnostic accuracy of specific tests and measures. The chapter concludes with a discussion of the quality assessment of studies investigating diagnostic utility.

Reliability

For a clinical test to provide information that can be used to guide clinical decision making, it must be reliable. *Reliability* is the degree of consistency with which an instrument or rater measures a particular attribute.[5] When we investigate the reliability of a measurement, we are determining the proportion of that measurement that is a true representation and the proportion that is the result of measurement error.[6]

When discussing the clinical examination process, it is important to consider two forms of reliability: intraexaminer and interexaminer reliability. *Intraexaminer reliability* is the ability of a single rater to obtain identical measurements during separate performances of the same test. *Interexaminer reliability* is a measure of the ability of two or more raters to obtain identical results with the same test.

The kappa coefficient (κ) is a measure of the proportion of potential agreement after chance is removed[1,5,7]; it is the reliability coefficient most often used for categorical data (positive or negative).[5] The correlation coefficient commonly used to determine the reliability of data that are continuous in nature (e.g., range-of-motion data) is the intra-class correlation coefficient (ICC).[7] Although interpretations of reliability vary, coefficients are often evaluated by the criteria described by Shrout,[8] with values less than 0.10 indicating no reliability, values between 0.11 and 0.40 indicating slight reliability, values between 0.41 and 0.60 indicating fair reliability, values between 0.61 and 0.80 indicating moderate reliability, and values greater than 0.81 indicating substantial reliability. "Acceptable reliability" must be decided by the clinician using the specific test or measure[9] and should be based on the variable being tested, the reason a particular test is important, and the patient on whom the test will be used.[6] For example, a 5% measurement error may be very acceptable when measuring joint range of motion but is not nearly as acceptable when measuring pediatric core body temperature.

Diagnostic Accuracy

Clinical tests and measures can never absolutely confirm or exclude the presence of a specific disease.[10] However, clinical tests can be used to alter the clinician's estimate of the probability that a patient has a specific musculoskeletal disorder. The accuracy of a test is determined by the measure of agreement between the clinical test and a reference standard.[11,12] A reference standard is the criterion considered the closest representation of the truth of a disorder being present.[1] The results obtained with the reference standard are compared with the results obtained with the test under investigation to determine the percentage of people correctly diagnosed, or the diagnostic accuracy.[13] Because the diagnostic utility statistics are completely dependent on both the reference standard used and the population studied, we have specifically listed these within this text to provide information to consider when selecting the tests and measures reported. Diagnostic accuracy is often expressed in terms of positive and negative predictive values (PPVs and NPVs), sensitivity and specificity, and likelihood ratios (LRs).[1,14]

2×2 Contingency Table

To determine the clinical utility of a test or measure, the results of the reference standard are compared with the results of the test under investigation in a 2×2 contingency table, which provides a direct comparison between the reference standard and the test under investigation.[15] It allows for the calculation of the values associated with diagnostic accuracy to assist with determining the utility of the clinical test under investigation (Table 1-1).

The 2×2 contingency table is divided into four cells (a, b, c, d) for the determination of the test's ability to correctly identify true positives (cell a) and rule out true negatives (cell d). Cell b represents the false-positive findings wherein the diagnostic test was found to be positive yet the reference standard obtained a negative result. Cell c represents the false-negative findings wherein the diagnostic test was found to be negative yet the reference standard obtained a positive result.

Once a study investigating the diagnostic utility of a clinical test has been completed and the comparison with the reference standard has been performed in the 2×2 contingency table, determination of the clinical utility in terms of overall accuracy, PPVs and NPVs, sensitivity and specificity, and LRs can be calculated. These statistics are useful in determining whether a diagnostic test is useful for either ruling in or ruling out a disorder.

Table 1-1 2×2 Contingency Table Used to Compare the Results of the Reference Standard with Those of the Test under Investigation

	Reference Standard Positive	**Reference Standard Negative**
Clinical Test Positive	True-positive results a	False-positive results b
Clinical Test Negative	False-negative results c	True-negative results d

Table 1-2 2×2 Contingency Table Showing the Calculation of Positive Predictive Values (PPVs) and Negative Predictive Values (NPVs) Horizontally and Sensitivity and Specificity Vertically

	Reference Standard Positive	Reference Standard Negative	
Clinical Test Positive	True positives a	False positives b	PPV = a/(a + b)
Clinical Test Negative	c False negatives	d True negatives	NPV = d/(c + d)
	Sensitivity = a/(a + c)	Specificity = d/(b + d)	

Overall Accuracy

The overall accuracy of a diagnostic test is determined by dividing the correct responses (true positives and true negatives) by the total number of patients.[16] Using the 2×2 contingency table, the overall accuracy is determined by the following equation:

$$\text{Overall accuracy} = 100\% \times (a+d)/(a+b+c+d) \quad (1\text{-}1)$$

A perfect test would exhibit an overall accuracy of 100%. This is most likely unobtainable in that no clinical test is perfect and each will always exhibit at least a small degree of uncertainty. The accuracy of a diagnostic test should not be used to determine the clinical utility of the test, because the overall accuracy can be a bit misleading. The accuracy of a test can be significantly influenced by the prevalence of a disease, or the total instances of the disease in the population at a given time.[5,6]

Positive and Negative Predictive Values

PPVs estimate the likelihood that a patient with a positive test actually has a disease.[5,6,17] PPVs are calculated horizontally in the 2×2 contingency table (Table 1-2) and indicate the percentage of patients accurately identified as having the disorder (true positive) divided by all the positive results of the test under investigation. A high PPV indicates that a positive result is a strong predictor that the patient has the disorder.[5,6] The formula for the PPV is:

$$\text{PPV} = 100\% \times a/(a+b) \quad (1\text{-}2)$$

NPVs estimate the likelihood that a patient with a negative test does not have the disorder.[5,6] NPVs are also calculated horizontally in the 2×2 contingency table (see Table 1-2) and indicate the percentage of patients accurately identified as not having the disorder (true negative) divided by all the negative results of the test under investigation.[11] The formula for the NPV is as follows:

$$\text{NPV} = 100\% \times d/(c+d) \quad (1\text{-}3)$$

The predictive values are significantly influenced by the prevalence of the condition.[11] Hence, we have not specifically reported these in this text.

Sensitivity

The *sensitivity* of a diagnostic test indicates the test's ability to detect those patients who actually have a disorder as indicated by the reference standard. This is also referred to as the *true-positive rate*.[1] Tests with high sensitivity are good for ruling out a particular disorder. The acronym *SnNout* can be used to remember that a test with high *Sen*sitivity and a *N*egative result is good for ruling *out* the disorder.[1]

Consider, for example, a clinical test that, compared with the reference standard, exhibits a high sensitivity for detecting lumbar spinal stenosis. Considering the rule above, if the test is negative it reliably rules out lumbar spinal stenosis. If the test is positive, it is likely to accurately identify a high percentage of patients presenting with stenosis. However, it also may identify as

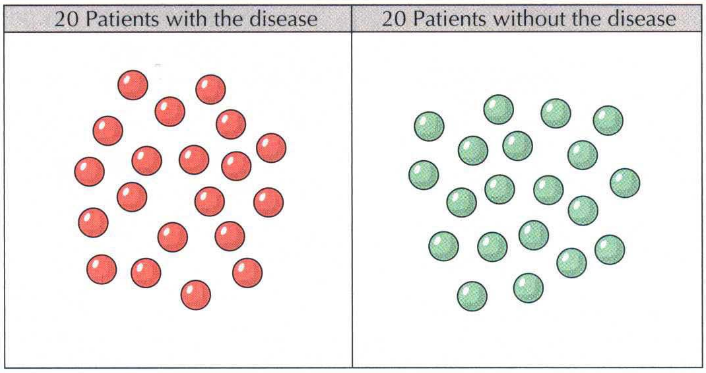

Figure 1-1
Sensitivity and specificity example. Twenty patients with and 20 patients without the disorder.

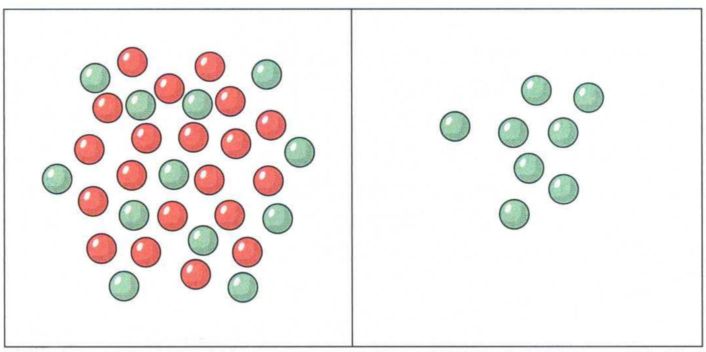

Figure 1-2
100% Sensitivity. One hundred percent sensitivity infers that if the test is positive, all those with the disease will be captured. However, although this test captured all those with the disease, it also captured many without it. Yet if the test result is negative, we are confident that the disorder can be ruled out (SnNout).

positive many of those without the disorder (false positives). Thus, although a negative result can be relied on, a positive test result does not allow us to draw any conclusions (Figs. 1-1 and 1-2).

The sensitivity of a test also can be calculated from the 2×2 contingency tables. However, it is calculated vertically (see Table 1-2). The formula for calculating a test's sensitivity is as follows:

$$\text{Sensitivity} = 100\% \times a/(a + c) \quad (1\text{-}4)$$

Specificity

The *specificity* of a diagnostic test simply indicates the test's ability to detect those patients who actually do not have the disorder as indicated by the reference standard. This is also referred to as the *true-negative rate*.[1] Tests with high specificity are good for ruling in a disorder. The acronym *SpPin* can be used to remember that a test with high *Sp*ecificity and a *P*ositive result is good for ruling *in* the disorder.[16,18,19]

Consider a test with high specificity. It would demonstrate a strong ability to accurately identify all patients who do not have a disorder. If a highly specific clinical test is negative, it is likely to identify a high percentage of those patients who do not have the disorder. However, it is also possible that the highly specific test with a negative result will identify a number of patients who actually have the disease as being negative (false negative). Therefore, we can be fairly confident that a highly specific test with a positive finding indicates that the disorder is present (Fig. 1-3).

The formula for calculating test specificity is as follows:

$$\text{Specificity} = 100\% \times d/(b + d) \quad (1\text{-}5)$$