BEME Systematic Review: *Predictive values of measurements obtained in medical schools and future performance in medical practice*

Topic Review Group (TRG)

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ABSTRACT

Background: Effectiveness of medical education programs is most meaningfully measured as performance of its graduates.

Objectives: To assess the value of measurements obtained in medical schools in predicting future performance in medical practice.

Methods:

- Search Strategy: We searched the English literature from 1955 to 2004 using MEDLINE, Embase, Cochrane's EPOC (Effective Practice and Organisation of Care Group), Controlled Trial databases, ERIC, British Education Index, Psych Info, Timelit, Web of Science and hand searching of medical education journals.

- Inclusion & Exclusions: Selected studies included students assessed or followed up to internship, residency and/or practice after postgraduate training. Assessment systems and instruments studied (Predictors) were the National Board Medical Examinations (NBME) I and II, pre-clinical and clerkship grade-point average, Observed Standardized Clinical Examination scores and Undergraduate Dean's rankings and honors society. Outcome measures were residency supervisor ratings, NBME III, residency in-training examinations, American Specialty Board examination scores, and on the job practice performance.

- Data Extraction: Data extraction by using a modification of the BEME data extraction form study objectives, design, sample variables, statistical analysis and results. All included studies are summarized in a tabular form.

- Data Analysis and Synthesis: Quantitative meta-analysis and qualitative approaches were used for data analysis and synthesis including the methodological quality of the included studies

Results: Of 569 studies retrieved with our search strategy, 175 full text studies were reviewed. A total of 38 studies met our inclusion criteria and 19 had sufficient data to be included in a meta-analysis of correlation coefficients. The highest correlation between

predictor and outcome was NBME Part II and NBME Part III, r = 0.72, 95% CI 0.30-0.49 and the lowest between NBME I and supervisor rating during residency, r=0.22, 95% CI 0.13-0.30. The approach to study the predictive value of assessment tools varied widely between studies and no consistent approach could be identified. Overall, undergraduate grades and rankings were moderately correlated with internship and residency performance. Performance on similar instruments was more closely correlated. Studies assessing practice performance beyond post-graduate training programs were few.

Conclusions: There is a need for a more consistent and systematic approach to studies of the effectiveness of undergraduate assessment systems and tools and their predictive value. Although, existing tools do appear to have low to moderate correlation with post-graduate training performance, little is known about their relationship to longer-term practice patterns and outcomes.

INTRODUCTION

Prediction is one of the major roles of assessment. Measurement of *outcomes* of medical education and the predictive value of these measurements in relation to on-the-job performance, i.e. postgraduate professional training and beyond, are fundamental issues in medical education that still requires further study. Studies of academic success at medical school and prediction of graduate's subsequent performance have resulted in equivocal conclusions (Pearson *et al*., 1998).

The multi-faceted and complex nature of being a doctor, combined with the diversity and multi-dimensionality of the working environment, increases the difficulty of defining and interpreting measurable and/or observable outcomes of medical education and training programmes. A recent publication on identifying priority topics for conducting systematic reviews in medical education listed as one of the first priority, "What are the *outcomes* we should use to evaluate medical education and to what extent do measures obtained before and in medical school predict these outcomes?" (Wolf, Shea & Albanese 2001).

Clinical competence, as outcomes of medical education, is increasingly being measured. However, as with other concepts, there is a lack of precision and clear definition. Kane (1992) defined clinical competency as "the degree to which an individual can use the knowledge, skills and judgment associated with the profession to perform effectively in the domain of possible encounters defining the scope of professional practice." Substantial effort has gone into defining measures of competencies in basic and higher medical education. Epstein and Hundert (2002) defined professional competence which should be the outcome of medical education programmes as "The habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values and reflection in daily practice for the benefit of the individual and community being served." This definition captures an important feature of professional competence which described it as a habit which will need time to be developed.

The categories recorded for assessment of clinical competency in many programmes have used general terms such as "knowledge base of basic and clinical sciences, history taking, preventive care skills and ethical/legal principles." These categories are too general to be measured precisely and be predictive of the candidate's future performance, which is a major

function of the examination. Some of the categories like skills assess the prerequisites of performance rather than the performance itself, which includes *processes* and *outputs* (Cox 2000).

When looking into the predictive value of assessment measures in medical schools, it is important to consider the time of measurement of outcomes along the continuum and time line of a physician's education, training and practice. Measurement can take place during or at the end of undergraduate educational programmes, immediately after graduation (internship or licensure examination), during and at the end of residency training and in practice.

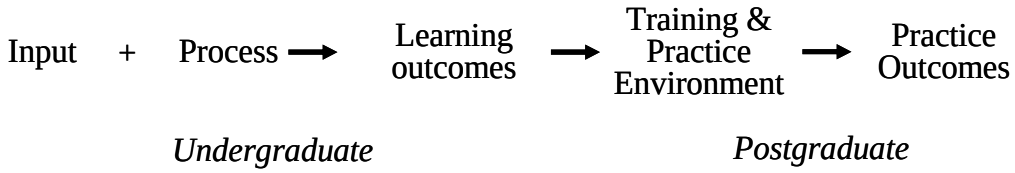
Ideally, an examination at the end of an undergraduate programme should predict whether a student is competent and is ready for further practice and training. Competence may *be perceived* in relation to a fixed reference point or, as a dynamic process in which measurements vary in relation to the expected level of competence and the amount of relevant experience. The measurement process should prevent false negative results, i.e. failing a student who is competent and, in particular, false positive ones, i.e passing a student who is incompetent, (van der Vleuten 2000).

Assessment of performance of medical school graduates during their first postgraduate year (internship) provides an indicator of the quality of the undergraduate curriculum and educational process, and serves as a quality assurance measure for those involved in undergraduate and early postgraduate training (Rolfe *et al*., 1995). Medical school grades are widely accepted measures of performance quality. It is assumed, without supportive evidence, that the grades provide a basis for predicting future performance in the workplace. The more we move away from the exiting point of the education programme, the more difficult becomes the measurement, the "noise" increases (Gonnella *et al*., 1993). Observation of performance for purposes of student appraisal in medical schools is done with the goal of extrapolating and generalizing competence that extends beyond the tasks observed.

Conceptual Framework of the Review

The prediction of performance in the real world of medical practice is now widely accepted as the goal of assessment at the different levels of medical professional education (Southgate *et al*., 2001). A simple linear model based on measurement of input, process and output of an undergraduate medical education programme cannot explain or address the complexity of measurement of its learning outcomes. The expected changes in learner behaviour and performance should not only be assessed at the end of the programme (learning outcomes), but more importantly in real life practice (practice outcomes).

'Learning outcome' measurements and 'practice outcome' measurements in medical education are different. Practice outcomes of an educational programme are the reflection of the programme; input, process, learning outcomes and postgraduate training and practice environment.



On this model, measurement of input, e.g. student characteristics, processes, e.g educational strategy and learning outcomes during and at the end of the programme may predict to a variable degree programme outcomes at different points of measurements after exiting the programme, i.e. internship, residency training and on-the-job performance (practice outcomes). Time since graduation, training and practice environments have a direct impact on the physician performance and practice outcomes.

Based on the relation between "learning outcomes" and "practice outcomes" model, it is proposed that measurements can take place at different levels on a hierarchical pyramid based on Miller's (1990) clinical competency pyramid and Kirkpatrick's (1967) levels of effectiveness (Fig 1). It is suggested that student's "learning outcomes" could be assessed at three levels (knows, knows how, shows how). The assessment of medical students has tended to focus on the pyramid base 'knows' and 'knows how'. This might be appropriate in early stages of medical curriculum (Wass *et al*., 2001), but at the end of the programme, higher levels should be assessed 'shows how' which should take place at the maximum possible level of simulation to actual practice. "Practice outcomes" need to be assessed as a

performance on-the-job ‘Does’. The impact of the performance could be considered as the highest level of practice outcomes (Ram 1998). This model represents a combination of assessment principles, the current development of theoretical views on medical expertise, and takes account of the difference between competence and performance (Schmidt, Norman & Boshuizen 1990; Rethans 1991).

The conceptual framework which guided the systematic review is looking primarily at the predictive validity of scores or assessment of student performance in medical schools generated by different assessment systems and instruments used in measuring learning outcomes, “Predictors”, and future performance of the graduates and its ultimate impact on health, “Practice Outcomes”

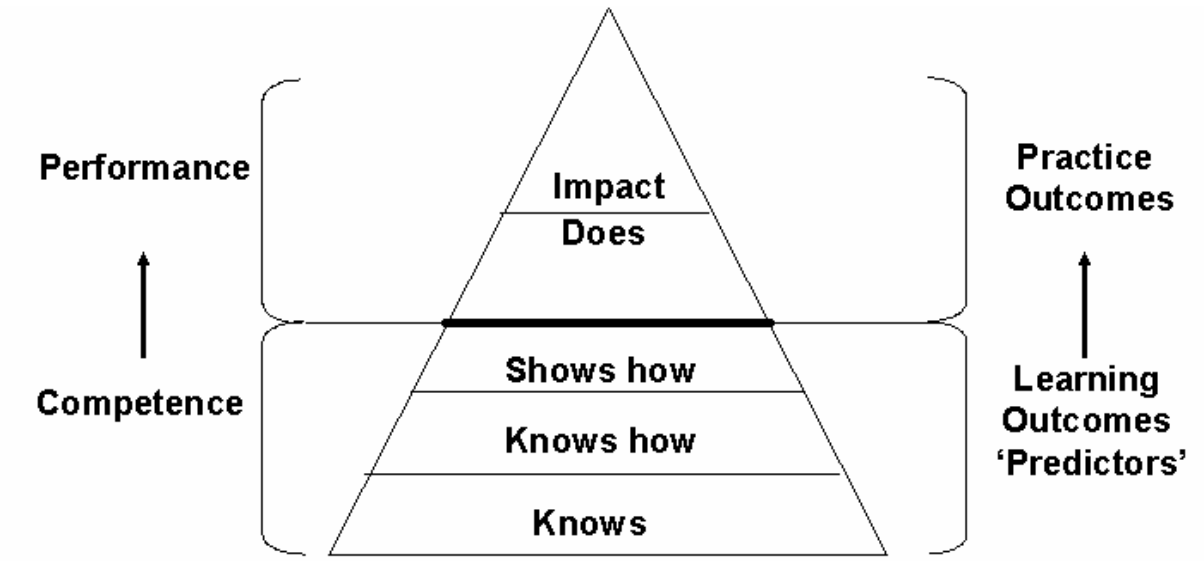


Fig 1: Conceptual relation between assessment in medical education of learning outcomes ‘predictors’ and “practice outcomes”.

Review Question

To what extent do measurements obtained in medical schools predict outcomes in clinical practice: performance during internship, residency programmes, on-the-job and its impact on health care?

Review Methodology

A) Inclusion Criteria

For studies to be eligible for inclusion in the systematic review, they must have all of the following:

(i) Study subjects: Medical students assessed or followed up to internship, residency and/or practice after postgraduate training

(ii) Predictors – Independent variables: 'Learning outcomes'

Student ratings/scores of assessments in medical schools, pre-clinical and clinical phases and evaluation of student clinical competencies

(iii) Outcome variables Dependent variables: 'Practice Outcomes'

a) Assessment scores of performance in residency or internship programmes
b) Scores of medical licensure examination or specialty board certification examination
c) Health outcomes in terms of quality of life of patients, mortality or patient satisfaction, costs of care

(iv) Study design:

Studies with the following designs will be selected:

a) prospective follow-up study of medical students up to internship/residency/ practice

b) retrospective analysis of correlation between predictors and outcome variables

B) Exclusion criteria: Studies meeting the inclusion criteria will be excluded from the review if they were only reviews, contained only interim analysis of some studies with final analysis included through subsequent publication and if they were duplicate publications.

C) Search Strategy and Sources: The search was conducted across a comprehensive range of sources in several stages.

In 2001, an initial broad scoping search was performed across the key medical and educational databases, ERIC, MEDLINE, Psych Info, Web of Science and Timelit. Significant relevant papers were identified prior to this search, and strategies were drawn up to ensure each of these papers would be retrieved by the scoping search. A series of filtering strategies were developed to remove false hits.

The full search included electronic and non-electronic sources. Multiple Medline searches were conducted and manageable results lists were reviewed. These searches utilised the most appropriate subject headings available, and employed limits to handle very large results sets. The Medline searches were enhanced by searches across other databases, including Embase, Cochrane's EPOC (Effective Practice and Organisation of Care Group) and Controlled Trial databases, and the British Education Index.

The non-electronic search was critical in identifying papers that the databases were unable to realistically produce in manageable quantities. In addition to recommendations from experts, we also conducted hand-searches across key medical education journals: *Medical Teacher*, *Academic Medicine*, *Medical Education* and *Teaching and Learning in Medicine.*

An updating search was conducted in May 2004 to retrieve new research published since the start of the group's work. This search was limited from 2001 to the latest citations and was run across Medline, Embase, Evidence Based Medicine Reviews (including Cochrane), SPORTdiscus, AMED, HMIC, ERIC and BEI. The search strategies used were sensitive, but were not designed for maximum sensitivity, given the impracticality of the massive number of irrelevant citations that would have resulted.

The Medline search strategy combined MeSH that described aspects of the study population, predictors and outcomes; exp Professional Competence/, exp Education, Medical, Undergraduate/, Internship and Residency, Schools, Medical/, Students, Medical/ Achievement/, Certification/, Educational Measurement/, Forecasting/, Longitudinal Studies/, Predictive Value of Tests/, Evaluation Studies/, Program Evaluation.

To reinforce the results of all searches, a separate cited reference search was conducted on the Web of Science. Each of the papers included for review from the first search results (as well as several from the updating search) was searched for papers that *cited it* and papers that *it cited*.

D) Selection methods: Selection of the studies was done by two independent reviewers applying the above criteria to papers obtained through the search strategy outlined above. Discrepancy in the list of included studies was resolved through discussion. Inter-observer consistency was measured using kappa statistics.

E) Assessment of Methodological Quality of Included Studies: The methodological quality of the included studies were appraised, guided by the questions developed by BEME for assessing the quality of a research-based educational study (Harden *et al.*, 1999), using the following criteria:

1. **Prospective or retrospective Cohort:** Prospective Cohort studies collect data for the purpose of correlating performance of students with their later performance as residents and practitioners. The data obtained can be complete and of high quality through the use of validated instruments and suitability for the purpose. Retrospective cohort studies have to depend on the extent and type of data collected in the past and cannot have control over their completeness or quality. Prospective studies therefore, were rated higher than the retrospective studies.

2. **Sample:** Selection of subjects was considered unbiased if an entire batch of students are included in a prospective follow-up study or all practitioners / residents or interns or a random sample of those working in a setting are included in a retrospective study.

3. Data Collection:

a. Similarity of correlated construct: The degree of correlation depends on the extent of similarity between the construct. For example, clinical competence shows stronger correlation with clinical knowledge examination scores (e.g. NBME II) than with basic science examination scores (NBME I). The studies correlating clinical measures were rated higher than those correlating basic science knowledge with the clinical measures after graduation.

b. Psychometric characteristics of measuring instruments*:* Reliability of the instruments measuring the predictor and criterion variables affect the degree of correlation between them. Generally, the correlation tends to be alternated because the instruments are practically never perfectly reliable. Accordingly, the studies reporting the reliability of the instruments were graded higher than those not reporting it. The report, even if indicating low reliability, allows estimation of the degree of attenuation and report disattenuated correlation. Similarly, the instruments need to have established validity. Invalid instruments affect the magnitude of the observed correlation.

4. Data Analysis:

a. Use of appropriate statistics: The choice of correlation statistics depends on the distribution of scores and nature of relationship between the predictor and criterion variables. For example, the Pearson product-moment correlation would be appropriate if the distribution of both the predictor and criterion variables are bivariate normal and if the relationship between the two are linear.

b. Attrition bias/Response Rate: Prospective studies may lose subjects during follow-up and retrospective studies are influenced by natural attrition of subjects due to summative evaluations at various stages after graduation. Thus the final set of data may represent the restricted range of eligible subjects. The degree of attrition bias/response rate may affect the magnitude of observed correlation.

c. Disattenuation of correlation co-efficient: Reporting disattenuation of correlation was considered a quality issue as it would adjust the correlation coefficient for lack of perfect reliability of the scores.

Data Management Techniques

A) Data Extraction

The data extraction form was developed, pre-tested and standardised to meet the requirement of the review (Appendix 2). Two reviewers independently extracted the data. The agreement between the two reviewers was assessed using Phi co-efficient because Kappa gave misleadingly low values in presence of low marginal figures. Both quantitative and qualitative data were extracted.

B) Data Analysis and Synthesis

1. Criteria for addressing the combinability of the studies

1.1. Similarity in timing of measurements: Studies to be combined were selected on the basis of similarity in the timing of measurement of predictor(s) and the outcome variables.

1.2. Similarity in assessment methods: The correlations between measures before and after graduation depended on the degree of similarity between the methods of assessment. For example, the knowledge in medical school assessed by objective examinations would correlate better with the knowledge assessed by objective examinations taken after graduation. Therefore, before combining the results of the independent studies, the extent of similarity of assessment methods was examined.

1.3. Inspection of point estimates and confidence intervals: The quantitative data were displayed graphically as forest plot using meta-analysis software (initially generated using Comprehensive Meta-Analysis version 1.0.23 (1998) and then transferred to SPSS for Windows version 12 to generate the actual graphs).

The correlation coefficient point estimates were inspected to determine closeness to each other. The overlap of their confidence intervals was examined to determine the extent of similarity between the results of the independent studies.

1.4. Test of homogeneity: Statistical tests of homogeneity "Q statistics" were performed to examine whether the observed parameters are similar between the independent studies. P-value of 0.1 or greater was accepted as indicating 'homogeneity'.

2. Estimating the Combined Correlation Coefficient Point Estimates

These were determined using random or fixed effects model depending on the results of the homogeneity test. If the P-value of the test was 0.1 or more, then fixed effects model was used, whereas if it was less than 0.1, then random effects model was used.

C) All included studies were summarized in a tabular format capturing main findings relevant to the review.

RESULTS

Search Results

Over 20,000 unique hits were returned. Their titles were visually scanned to eliminate obviously irrelevant results. Five hundred and sixty (2.8%) titles were considered potentially relevant for abstracts review. The specificity of the scoping search (percentage of the total that was relevant to the topic) was remarkably low. While this initial search did demonstrate that the topic would prove problematic, it also revealed that there was a suitable amount of evidence to assess for systematic review.

Selection of Studies

The reviewers scanned the titles and abstracts of the 569 papers retrieved by the search strategy. One hundred and seventy five papers were considered potentially relevant for further review. Full versions of the papers were obtained for evaluation. Two reviewers independently applied the eligibility criteria on these papers. The inter-observer agreement was substantial (kappa = 0.71; percent agreement 89%) All papers selected for inclusion or exclusion by either of the reviewers was discussed. Differences were resolved through discussion. The screening process eliminated 137 citations that did not meet the review inclusion criteria. Thirty-eight citations were identified eligible for the review (Appendix 3 & 6).

Overview of the Studies Included in the Review

Thirty-eight studies were included: One paper appeared in 1956, three in 1960's, two in 1970's, six in 1980's, 15 in 1990's and 11 in the year 2000's (up to 2004).

Thirty-two studies were from United States, three from Canada and one each from United Kingdom, Australia and New Zealand.

Assessment of methodological quality of the studies

Two reviewers independently applied the criteria for the assessment of methodological quality of the included studies. For each of the quality criteria, the papers were rated as 'met', 'not met' or 'unclear/not applicable'. One study met all the seven validity criteria

(Brailovsky *et al*, 2001), 16 studies met four criteria and 25 met two validity criteria. Twenty nine studies were retrospective cohort, five survey studies (Peterson *et al*, 1956, Clute 1963, Price, 1969, Fish *et al*, 2003 & Richards *et al*, 1962) and four prospective cohort studies (Probert, *et al*, 2003, Zu *et al*, 1998, Gonella *et al*, 2004 & Wilkinson *et al*, 2004). Only one study (Brailovsky *et al*., 2001) was prospective and reported the disattenuated correlation coefficients. Thirty-five studies had at least one construct similarity between predictor and outcome. The sample in all cohort studies consisted of an entire batch of students. All studies had a percentage of non-respondents. Only one study (Pearson *et al*, 1993) presented a comparison of the characteristics of respondents and non-respondents. However, we analyzed all the papers, qualitatively and quantitatively, so long as they met the inclusion criteria and had relevant data.

The inter observer agreement of the quality criteria were as follows: study design = 84%, sample selection = 32%, Phi = 0.15, similarity of construct = 100%, reliability of instruments = 79%, phi = 0.64, justification of statistics used = 21%, phi = -0.2, attrition/respondent bias = 21%, phi = -0.2, dissatentuation = 100%. For study design, similarity of construct and dissattentuation, phi coefficients were not estimable because one observer gave the same value to all the studies. The disagreements were due to different interpretation and unclear reporting in the studies of the quality criteria. However, all disagreements were resolved through discussion.

A wide variation was found in the methods, scales of measurements, analytical strategies and reporting styles. Psychometric characteristics of instruments were presented in a few studies. The reliability of the measures of predictor variables was given in three papers, while that for the outcome variables was given in five papers. The nature of the instruments was not described in detail. Only one paper reported reliability of both predictor and outcome variable. The most common outcome measure, “supervisor rating”, varied from study to study (e.g. scales used 25 to 33 items).

Tables in Appendix 5 present main characteristics, results and summary of conclusions in the 38 included studies.

There was a large variation in the method of analysis as well. Nineteen studies reported Pearson correlation coefficient and thirteen had regression analysis. The correlation

coefficients in the 19 studies formed the basis of our meta-analysis. They were organized around three outcome variables, Figs 2 – 11).

A. Supervisor rating during residency: was the outcome variable in eight studies, four had NBME I and NBME II as predictors, two had clerkship GPA as predictors and two had all the three predictors. Results for each predictor are presented below:

i) NBME I : The Pearson correlation coefficients of the nine data sets in eight studies are plotted in Figure 2. All the point-estimates indicate a positive correlation. The confidence intervals of the results overlap with each other. The test of heterogeneity is significant (Q value = 25.166, Df = 8, P = 0.0015) indicating lack of homogeneity of the results, but visual inspection of the point estimates and the confidence interval indicates an acceptable level of similarity in the results. The combined results (using random effects model) yielded low correlation (Pearson *r* = 0.22; 95%, CI 0.13 to 0.30).

ii) NBME II : Results from seven data sets in six studies are shown in Figure 3. All the point-estimates indicate a positive correlation. The confidence intervals of the five-studies (except Smith, 1993) overlap with each other. The test of heterogeneity is also significant (Q value = 26.539; Df = 6, P = 0.0002). The summary correlation coefficient using random effects model is 0.27 (95%, CI 0.16 to 0.38) indicating a low correlation.

iii) Clerkship GPA : The results from 11 data sets in ten studies are shown in Figure 4. All the point estimates indicate a positive correlation in all the studies with overlapping confidence intervals. The test of heterogeneity is also significant (Q value = 46.87, Df = 10, P = 0.0005) but, visual inspection of the point estimates and confidence intervals indicate an acceptable level of similarity in the results across the studies. The combined correlation coefficient using random effects model showed a low correlation (Pearson *r* = 0.28, 95%, CI 0.22 to 0.35).

iv) OSCE : Five studies had OSCE as the predictor variable as shown in Figure 5. The correlation coefficients were similar. Test of heterogeneity was non-significant (Q value = 1.0267, Df = 3, P = 0.7948). The combined correlation coefficient using fixed effects model was low (Pearson *r* = 0.37; 95%, CI 0.22 to 0.50).

v) Ranks based on Dean's letter: Three data sets from two studies lent themselves to meta-analysis for this predictor. The correlation coefficients were similar as shown in Figure 6. The test of heterogeneity was non-significant (Q value = 0.024, Df = 2, P = 0.988). The combined estimate of correlation coefficient using fixed effects model indicated low correlation (Pearson *r* = 0.22; 95%, CI 0.12 to 0.31).

vi) Pre-Clinical GPA : Only four studies, five data sets had this predictor with supervisor rating as the outcome. All the point estimates indicated positive correlation of similar magnitude as shown in Figure 7. The confidence intervals were overlapping. The test of heterogeneity was non-significant (Q value = 0.7399, Df = 4, P = 0.9463). The combined estimate, using fixed effects model, indicated low correlation (Pearson *r* = 0.25; 95%, CI 0.19 to 0.31).

The reliability of the measuring scale of the supervisor ratings were given in four studies (Markert 1993) 0.964, (Paolo *et al*., 2003) 0.98, (Fine *et al*., 1995) 0.8, (Hojat *et al*., 1986), 0.86.

B. NBME III: Two studies correlated NBME I & II with NBME III scores. Both had a large sample size: 628 for Markert *et al*., (1993) and 2368 for Hojat *et al*., (1993). Between NBME I and NBME III, the correlation coefficients, in the two studies, were similar as shown in Figure 8. Test of heterogeneity was statistically non-significant (Q value = 1.798, Df = 1, P = 0.18). The combined correlation coefficient using fixed effects model was 0.59 (95% CI 0.57 to 0.61). Between NBME II and NBME III, the correlations were similar as shown in Figure 9. Test of heterogeneity was statistically non-significant (Q value = 0.207, Df = 1, P = 0.649). The combined correlation coefficient based on fixed effects model was (Pearson *r* = 0.72; 95%, CI 0.70 to 0.73). These coefficients were substantially higher than the ones seen with the outcome supervisor rating. One study with six data sets correlated clerkship examination scores and NBME III (Rabinowitz, 1989). The correlation coefficient between different clerkship scores (predictor) and NBME III ranged between r=0.32 to 0.49.

C. American Board of Specialty Examinations: Three studies, five data sets correlated NBME I scores as predictor and American Board of Specialty Examination as outcomes lent themselves for meta-analysis. The point estimates were close to each other and confidence intervals were overlapping. The test of heterogeneity was non-significant (Q

value = 6.86, df = 3, P = 0.076). The combined correlation coefficient as shown in Figure 10, using fixed effects model, was moderately good (Pearson r = 0.58; 95%, CI 0.54 to 0.62).

One study, (Figure 11), with three data sets correlated NBME II scores as predictor and American Board of Medical Specialty examination scores. Point estimates were close to each other and confidence intervals overlapping. Test of heterogeneity was significant. The combined correlation coefficient using random effect model was moderately good (Pearson r = 0.61, 95%, CI 0.51 to 0.70).

The reviewed studies and the meta-analysis showed that the correlations between the predictor variables of assessment in undergraduate medical education and supervisor ratings were lower than with NBME I and II as predictors and NBME III and American Board of Medical Specialty Examinations as outcomes, although they were both statistically significant.

Some of the main findings in other studies with predictors and outcomes not included in the meta-analysis are summarized as follows:

The only study, (Brailovsky, 2001), giving disattentuated correlation coefficients showed moderate to high correlation between script concordance scores at the end of clerkship and clinical reasoning at the end of residency training.

Clerkship honor grades and honors society (Amos *et al*, 1996, Kron *et al*, 1985), student rank (Amos *et al*, 1996, Blacklow *et al*, 1993) and clerkship GPA (Arnold *et al*, 1993) predicted residency clinical performance and passing the written boards on the first attempt. Overall GPA in medical schools can predict performance in internship (average r=0.4), (Fincher, Lewis and Kuske, 1993).

The large study (6656 medical students) of Gonella, Erdmann and Hojat (2004) examined the predictive value of number of grades in medical schools and performance on USMLE III and supervisor rating during residency year one. They concluded that rating of clinical competence beyond medical schools are predictive by number grades in medical schools.

The only recent study (Tamblyn *et al*, 2002) on predicting process of care from final year MD examination scores showed statistically significant association (Table 33, Appendix 5).

DISCUSSION

This systematic review was conducted to determine to what extent measurements obtained in medical schools can predict outcomes in clinical practice; performance during internship, residency programmes, on-the-job and their potential impact on health. The effectiveness of medical education programmes is inseparable from the effectiveness of their products and the most meaningful measure of effectiveness is performance in practice.

The Search and Selection of Studies

Retrieving evidence for a systematic review in medical education is problematic, and the work done by the BEME Collaboration has highlighted the difficulties with systematic searching within the educational discipline (Haig & Dozier 2003). The sources of evidence that contain medical education research (primarily databases of peer reviewed literature) are either medical or educational, they rarely describe medical education content adequately – and frequently even lack the descriptors to do so. In this review the search strategies were made less sensitive (to reduce the number of false hits); some of the highly relevant papers identified were invariably missed.

Additional methods were therefore required to augment the search. The group used a variety of proven methods (hand-searches, experts in the field and cited reference searches) to improve the comprehensiveness of the retrieval. Achieving a measure of absolute saturation is rarely possible when systematically searching for evidence, but there are methods to realise when further searching is likely to be redundant. One such example is reaching the point where a cited reference search no longer produces unseen results from either the initial paper or any of its derivatives. Although the review topic proved challenging, these additional methods employed ensured that the outcome was systematic and most probably comprehensive.

This BEME review group highlighted these problems. A systematic review requires a comprehensive search of all relevant sources, yet without satisfactory descriptors, the searching proved difficult. Where adequate descriptors did exist (e.g. for the undergraduate population) they were applied sporadically while other key concepts had no satisfactory descriptor (e.g. predictive values/indicators of future performance). Given enough resources it would have been possible to sift through results lists numbering in the tens of thousands,

but this is unrealistic for a single review group. Indeed, even with a strategy designed for maximum sensitivity it is unlikely that all relevant citations for this topic would be retrieved. However, several problems were encountered. Out of the 175 potentially relevant reviewed studies, only 38 were found suitable for inclusion despite multiple strategies used to identify relevant studies. The inclusion criteria were identified in the light of the conceptual design of the study mainly looking at the relation between measurement of learning outcomes as predictors and practice outcomes including practice during residency training and beyond. This approach led to the exclusion of other predictors like psychosocial characteristics of students and other measures of outcomes, like board certification status, medical school faculty appointments, speed of career progression, research publications and stress burnout and satisfaction. All these have been reported in the literature as indicators of physician's professional success (Hojat *et al*, 1997, McManus, 2003, & West, 2001).

Assessment of the methodological quality of the studies

Lack of standard reporting style of the results and their statistical analysis made it difficult to rank the studies according to their quality criteria. A quality criterion may or may not be met based on the reporting style. The reporting is particularly limited in four elements of study quality: a) the psychometric characteristics of the measures of predictors and outcomes; (b) justification of statistics used; (c) comparison of characteristics of respondents and non-respondents; and (d) disattenuation. The question whether a study was of poor quality or the authors did not consider it important to report some of the above elements is difficult to resolve. Recent studies have begun to address the above limitation (Brailovsky *et al*, 2001). This review points to the need for regular reporting of the above elements of study quality in correlation studies. Strict application of a high quality threshold would have excluded a large number of the included studies. However, we have followed an inclusive approach as recommended by BEME.

The relation between predictors and outcomes

The results of the systematic review indicated that analysis of the performance after graduating from the medical school is complex and cannot be susceptible to one type of measurement. Clinical competence is not uni-dimensional. It is a multifaceted entity, and the strength of relationships with medical school performance measures varies depending upon conceptual relevance of the measures taken during and after medical school (e.g., the pre-clinical GPAs yields more overlap with physicians' medical knowledge than with physicians'

interpersonal skills). This expected pattern of relationship has been empirically confirmed. (Hojat *et al*, 1986, Hojat *et al*, 1993).

Medical education changes across the continuum of undergraduate medical education, postgraduate training and unsupervised practice performance. The latter is difficult to measure and predicting practice performance years after formal training is even more difficult. In the 1960's studies showed lack of relationship between medical school academic performances (GPA) and practice performance (Price 1969). Although lack of correlation was explained on the basis of restriction of range, Price *et al.*, (1964) argued that it was relatively unimportant.

In the 1970's, Price *et al*., (1973) and Wingard & Williamson (1973), published two evaluative literature reviews on grades as predictors of physicians' career performance. The main findings of these reviews indicated that, at that time, very little data on this subject existed with little or no correlation between the two factors. However, these studies were limited by the type of measures used to predict performance in practice.

In the 1980's, studies have used a broader range of assessment procedures, including clinically-based measures, to investigate the association between academic performance and competence during the early postgraduate years (Gonnella & Hojat 1983). These studies revealed weak relationships between medical school grades and performance in postgraduate training (Erlandson *et al*., 1982). Quattlebaum (1989) supported the view that attempts to predict performance during residency based largely on measures of cognitive ability have been unsuccessful.

In the 1990's Taylor & Albo (1993) studied physicians' performances and their relations to two predictors: performance of medical students in their academic years (one and two) and their clinical years (three and four). In this study correlation between 167 physicians' medical school grades and 61 composite performance scores ranged from -0.25 to 0.28. This poor correlation also applied to sub-groups based on the number of practice years and specialties. This position that performance during medical school does not differentiate applicants who will perform well during residency from those who will perform poorly was supported by Brown *et al.,* (1993) and Borowitz *et al,*. (2000). These studies indicated that the complex competencies needed for a physician to perform effectively are poorly measured by academic scores obtained through measurements which examine a narrow band of the

extremely complex total spectrum of skills, abilities and performances of practicing physicians.

There have been many explanations for the weak association between medical school and postgraduate performance and the inconsistent findings of previous research (Wingard & Williamson 1973; Gonnella *et al*., 1993). These include deficiencies in traditional grading systems or an inherent inability of grades to indicate the transformation of potential into the workplace, the effect of intervening experience between the time of academic training and subsequent career evaluation, and the failure of the selection processes of traditional medical schools to identify students with the characteristics which might be prerequisite for successful performance (changing mind sets: knowledge, skills, behaviors, and professionalism) in the work environment (Pearson *et al*., 1998).

The correlation between performance measures in medical school and in practice is always an under-estimated index of relationship, because of the exclusion of those in the lower tail of performance distribution in medical school due to attrition. Attrition always restricts the range of the grade distribution, leading to less overlap and shrinkage of correlations. This and other conceptual and methodological issues involved in predicting physician performance from measures of attainment in medical school have been reported (Gonella *et al*, 1993).

Other researchers have established a moderate relationship between academic performance at the medical school and practice performance, with higher correlations when an attribute is evaluated by a similar assessment method (Hojat *et al*., 1993; Makert 1993).

Predicting Performance during Post-Graduate Training

In this systematic review we were able to combine in a meta-analysis the correlation coefficients from only 19 out of the included 38 studies. This was due to:

1. Variability of the measured predictors in medical schools, 25 variables could be identified from the included studies. Some had objective measurements e.g. NBME / USMLE scores and other subjective measurements, e.g. ranking using Dean's letter or Honours Society 'AOA'.

2. Variability of the outcomes and how they were measured. Four outcome measures were identified in the included studies of the meta-analysis, NBME III, supervisor's

ratings during internship and different years of residency training, in-training examination of residents, and American Board of Medical Specialties Examination.

The meta-analysis demonstrated that summary correlations between NBME/USMLE I and supervisor rating during internship or first year residency, was low (0.22), though statistically significant and consistent with previous longitudinal study data of Hojat *et al*., (1993), Gonnella *et al*., (1993) and Bermer *et al*., (1993). However, correlation of NBME I and NBME II with NBME III and American Board of Specialty Examinations was moderately high (0.6 – 0.7) and statistically significant.

Although significant improvement is taking place in student assessment in the clinical years, the problem of measurement of clinical competence of physicians in training is a complex and daunting task. The complexity of professional competence necessitates the use of multiple assessment methods to evaluate performance. Despite the availability of several evaluation tools, how objective resident supervisors are about the evaluation of the clinical performance of their trainees remains unclear (Holmboe & Hawkins 1998).

It may be debatable whether specific assessment instruments like OSCE should be included in the systematic review. We believe that OSCE is an important instrument relatively recently incorporated in the assessment of medical students and its predictive validity should be assessed. In this systematic review, the correlation coefficient between OSCE and supervisor rating yielded a summary estimate of 0.30 (95%, CI 0.24 to 0.37) suggesting a low correlation. The weak correlations, although statistically significant, obtained from several studies looking into the predictive value of constructs assessed by OSCE as interpersonal skills, data collection and physical examination skills and residents supervisors rating could be explained on the basis that assessment of residents does not evaluate objectively the same constructs as assessed by the OSCE in the undergraduate programme. Another explanation could be the failure to correct for disattenuation.

The study by Rutala *et al*., (1992) showed that OSCE scale was best predictor of performance rated by the residency directors. The highest correlation was the one evaluating interpersonal skills, $r = .42$. Other OSCE domains had a lower positive correlation, differential diagnosis $r = .28$, decision making $r = .28$. The study by Probert *et al*., (2003) on 30 medical students demonstrated that OSCE showed consistent positive association with consultant ratings of their performance at the end of the pre-registration year. Other improved methods of

assessment of clinical competencies in medical schools, like the post-clerkship clinical examination PCX, has demonstrated that the correlation with the first year residency supervisors ratings ranged from .16 to .43, mean .32 (Vu *et al*., 1992).

Recent reports from the longitudinal study of the Jefferson Medical College showed that the number grades in medical schools can predict the performance on medical licensure exams and clinical competence ratings in the first postgraduate year (Gonnella *et al*., 2004).

Some studies explored how cognitive factors (data gathering and analysis skills, knowledge, first to fourth year GPA and NBME I and II) and non-cognitive factors (interpersonal skills and attitudes) assessed during medical student training predicted postgraduate clinical competence (Heneman 1983; Martin *et al.,* 1996). These studies showed that cognitive factors can account for up to 51% of the variance in NBME III grade (Markert 1993).

Our results indicated the importance of measurements of similar constructs in order to find out a positive and strong association. The correlation between clerkship GPA as predictor and supervisor rating during residency as outcome (r=0.3) was higher than other predictors in the preclinical phase (NBME I r=0.18). Studies in the 1960's and 1970's supported the view that grades and evaluations during clinical clerkships correlated well with performance during residency (Kegal-Flom 1975, Gough 1963, Richard 1962), particularly in the clerkship related to the field of residency chosen by the student (Keck *et al.*, 1979). Another predictor which was not included in our study is evaluation by peers, which was found to be a better predictor of future internship success than were estimated by preclinical and clinical faculty (Korman, 1971).

The study by Brailovsky *et al*., (2001) on Script Concordance between students and final year residents, demonstrated the importance of measurements of similar constructs at two different levels of expected performance (medical students and final year residents) along the continuum of medical education and practice. In this study, scores obtained by students at the end of clerkship using script concordance (SC) test predicted their clinical reasoning performance at the end of residency measured by OSCE, short answer management problems and simulated office orals. They reported generalisability coefficiencies for OSCE 0.717 (n=181), short answer management problems 0.816 (n=769), and simulated office orals 0.478 (n-769).

Predicting On-The-Job Practice Performance

The complex nature of measuring performance in practice should consider the conceptual difference between competence and performance of physicians. Competence "what a doctor is capable of doing" i.e. under test conditions, and performance as 'what he or she actually does in day-to-day practice' (Rethans 1991). This concept was further described by Epstein and Hundert (2002) when defining professional competence as the habitual application of knowledge, skills and attitudes in the care of patients. Competence and performance criteria are structural and procedural measures, thus representing moderate variables in the sense of surrogates for relevant and ultimate end points of measurement: the outcome criterion "improvement or maintenance of patient's health".

Assessing the quality of health care as a reflection of impact of physician performance is complicated. Donabedian (1998) argues that in measuring quality, we need to assess not only the performance of practitioners but the contributions of patients and family, the structural attribute of the health care setting, the process of care and its outcomes.

In this systematic review we were able to find few studies which looked into the relationship between medical school measurements and on-the-job performance beyond residency. Four studies fulfilled our inclusion criteria (Peterson *et al.*, 1956, Clute, 1963, Price, 1964 and Tamblyn *et al.*, 2002). Tamblyn *et al.*, (2002) investigated scores on Canadian licensure examinations taken immediately at the end of medical school and prediction of clinical behaviours 4-7 years later. This study was included in our systematic review as the Canadian licensure examination could be considered similar to a final year MD examination which measures students' learning outcomes at the point of exiting from the programme. The study showed that scores on the Canadian licensure examination were a significant predictor of practice performance. In this study indicators of practice performance were selected on the basis of unexplained practice variations, and/or their association with the outcomes or costs of care: e.g. 1) Mammography screening rate was used to assess preventive care; 2) Continuity of care because of its importance in prevention and chronic disease management; 3) The differences between disease-specific and symptom-relief prescribing rate and contraindicated prescribing rate; 4) Contraindicated prescribing, which accounts for 20% of drug related adverse events and 5) Consultation rate was used as an indicator of resource use because referral determines access to higher cost specialty care.

Assessing the relationship between examination scores and more objective measures of quality of care is difficult due to the complexity of evaluation of optimal and actual practice. Setting standards of practice and its measurement should not only consider quantitative data obtained from assessment scores commonly obtained from examinations which attempt to measure "competence", but should consider qualitative outcomes, like patient satisfaction, efficiency, outcome of consultation and impact of health education (Prideaux *et al.*, 2000, Tamblyn *et al*, 1994). The process of care could also be considered as reflection of performance, e.g. Screening and preventive services; diagnosis and management; prescribing; counseling and condition-specific processes of care (e.g. whether diabetics receive foot exams).

One of the main problems with studying postgraduate clinical performance is establishing a comparable scoring system for assessing competence in the different specialties. This is known as the "criterion problem" and confronts the predictions of success in all jobs, not only medicine (Ferguson *et al.* 2002). One solution to this problem has been to develop competency-based models of care and specific skills through detailed job analysis of individual medical specialties (Viswesvaran *et al*., 1996, Patterson *et al*., 2000).

Instruments used in measuring performance of residents and practicing physicians should have an acceptable degree of validity and reliability. Global rating which forms the primary basis for appraising clinical skills suffer from several sources of bias which involve cognitive, social and environmental factors which affect the rating, not only the instruments. Research showed that patterns of measuring instruments account for no more than 8% of the variance in performance ratings (Williams *et al.*, 2003).

Standards of practice should be developed in relation to a core of common health problems or presentations encountered in the specific domain of practice. Sampling performance in relation to a core of health problems and health indicators should allow generalisation of the results and avoid restricting the assessment to a small number of patients. Measurement of performance should not be limited to technical aspects and knowledge, but should also consider attitudes (Tamblyn 1994). An interesting study (Papadakis *et al.*, 2004) looked into the unprofessional behaviour of students in medical school and if it is associated with subsequent disciplinary action by a state medical board. It was found that the prevalence of problematic behaviour was 38% in the cases and 19% in the controls (odds ratio 2.15). These

findings indicated the importance of professionalism as an essential competency to be demonstrated by a student to graduate from medical school.

Personal and psychosocial attributes are important facets of the physician's clinical competence which few empirical studies have looked into. With regard to issues of psychosocial predictors of the academic and clinical performances of medical students, they found that selected psychosocial attributes could significantly increase the validity of predicting performances on objective examinations (Hojat *et al.*, 1988, Hojat *et al*, 1993, and Herman *et al*., 1983). Hojat, 1996 suggested that a significant link exists between selected psychosocial measures and physician clinical competence. Although assessing psychosocial attributes of the medical students was not part of the inclusion criteria in our systematic review, it is important to be considered and needs to be further studied.

The studies included in the systematic review provided evidence to support a relationship between measurements used in medical school and performance during residency. The magnitude of the correlation was higher when the predictors and outcomes measurements were based on objective written examination, e.g. NBME/USMLE I, II and III. On the other hand, Fine, *et al*, (1995) suggested that academic performance measures have been over emphasized as predictors of physicians performance in residency training.

Recent Developments in Outcome Measurements in Medical Education

During the late 1990's the issue of measurements of educational outcomes of undergraduate medical education and postgraduate residency training programmes, became an important international activity of several organisations responsible for medical education. This global activity is trying to look into three basic questions related to quality medical education: What to measure?; How best can we measure? and Is there a relation between what is measured and quality of practice.

In the US, the Accreditation Committee of Graduate Medical Educators (ACGME), the American Board of Medical Specialties (ABMS) and the American Association of Medical Colleges (AAMC), adopted six general competencies for evaluating residents and practicing physicians. The American Association of Medical Colleges (AAMC) and its accreditation committee (LCME) linked the medical school objectives to these competencies recognising them as learning outcomes, but at a lower level of expectation than that of the residency programmes (Stevens, 2000). In Canada, the Royal College of Surgeons (RCS) have

developed the CanMed 2000 which defines the expected competencies of residency programmes. In Europe the General Medical Council (GMC) in the UK and the Royal Colleges, have restructured their residency programmes. The World Federation for Medical Education (1998, 2003) developed global standards for basic medical education, postgraduate training and continuing professional development

In the Middle East the committee of Deans of Medical Colleges "Fourteen Colleges" in six Gulf States, United Arab Emirates, Saudi Arabia, Qatar, Oman, Kuwait, and Bahrain, developed accreditation standards and outcomes of undergraduate medical education (Guideline on Minimum Standards for Establishing and Accrediting Medical Schools in the Arabian Gulf Countries, 2001). The World Health Organization (WHO) Eastern Mediterranean office (EMRO) is leading a multinational project in the region to develop standards for accreditation of medical schools.

Defining global core of learning outcomes for undergraduate medical education, postgraduate residency training and continuing professional development should be organized around similar constructs. The six competencies of ACGME "Patient care, knowledge, ethics and professionalism, communication skills, practice-based learning and system-based practice" can be a model for such constructs which could be measured at different levels and phases of the professional life of a physician. The Dreyfus and Dreyfus (2001) taxonomy of levels of performance, which include novice, competent, proficient, expert, and master have the implication on progressive proficiency and can help in measuring performance at the end of medical school, residency training and beyond. The subjectivity of this taxonomy requires the identification of descriptors to improve its objectivity and valid, reliable instruments of measurements.

We hope that the conceptual model of this systematic review and its findings can provide the best available evidence on the predictive values of current assessment measurement in medical schools and future performance in medical practice which should be considered in the measurement of quality in medical education

Limitations of the Systematic Review

1. An important limitation of this review is the language bias. It is highly probable that there are publications on the topic elsewhere (Liu *et al*, 1990). Future cooperation with Colleagues can help in reviewing publications in French, Spanish and German in future updating of the review which we hope to do.

2. The results of this systematic review were based on studies mainly from the USA and the assessment systems reported are only used in the USA like NBME/USMLE, honours societies (AOA) and Dean's letters. This raises the issue of generalisability of the predictive validity of the assessment measurements. On the other hand, it is possible to find similarity which could be generalized when looking at the construct to be measured, eg. NBME I = Basic medical science knowledge; NBME II = application of knowledge in clinical sciences.

3. Meta-analysis of regression coefficients from various studies were not done because the reported regressions did not adjust for the same variables across different studies.

Future Direction

1. This systematic review emphasised the problems in retrieving evidence for medical education as a whole. The importance of employing additional methods to enhance the standard approach of searching a few core databases cannot be underestimated. While these methods will obviously require additional skills, time and resources, they are vital to ensuring that the systematic review is based on all available evidence. Not only are these additional methods more effective than trying to process massive lists of false hits, but they will almost certainly return relevant results that databases currently cannot.

   Although the coverage and description of medical education content has improved considerably in the last few years, there is substantial room for further improvement. By drawing attention to these challenges, and continuing to make efforts, currently underway, to overcome them (METRO Project 2004), the BEME Collaboration can make a significant contribution to improving accessibility to the available evidence in medical education.

2. The review identified some common measures of performance in practice beyond residency training which might be considered for future studies. These include patient outcomes and impact of the performance on health, like mortality and morbidity of common health problems in a given community, newer outcomes like patient satisfaction, functional status of patients, cost effectiveness of management or intermediate outcomes like better control of diabetes, HbA_{1c} and lipid levels of diabetics may give indirect indication of physician performance and its impact.

3. Similarity of the data collection methods and statistical analysis of the results will help in increasing the homogeneity between the research results and will allow for their combinability which will increase the strength of the evidence. It is recommended that studies should:
   a) report reliability of the data collection method 'measurement instrument';
   b) use similar statistical analysis, e.g. Pearson's Correlation with report of confidence interval;
   c) cognitive, social and environmental sources of bias in performance ratings should be considered in developing measurement instruments
   d) disattenuated correlation coefficients needs to be reported.
   e) whenever there are attrition and/or non-respondents in the studies, a comparison of characteristics of respondents and non-respondents need to be presented to allow assessment of attrition/respondents bias.
   e) report the justifications of statistics used. For example, while using Pearson's correlation, an indicator of whether the relationship between predictor and outcome is linear and their distribution is bivariate normal needs to be given.

4. Medical schools and residency training programmes need to conduct longitudinal studies on their graduates. The Jefferson study is a model for this type of research (Gonnella *et al.,* 2004).

CONCLUSION

1. The studies included in the review and meta-analysis provided statistically significant mild to moderate correlations between medical school assessment measurements and performance in the internship and residency. Basic science grades and clinical grades can predict residency performance.

2. Performances on similar instruments of measurements are better correlated such as:
    - NBME II scores with NBME III scores
    - Medical school clerkship grades and supervisor rating of residents
    - OSCE and supervisor rating of residents when similar constructs are assessed

3. No consistent statistical analysis was used in reporting the relationship between the predictors and outcome variables. Only a few studies reported reliability of the measurement instruments and disattenuation. The methodological shortcomings of past research in testing predictive validity needs to be addressed and sound models for assessing it needs to be further studied, e.g longitudinal profile development, cross validation and inspection of the adjusted R^2 (Renger R., *et al*, 1994).

4. Evidence on predictors of performance in practice beyond residency training is rare and weak. New measures of performance in practice, such as 'patient outcomes' and 'process of care' might be considered for future studies.

5. The difficulty in searching encountered in this systematic review indicated the importance that medical education journals should encourage the use of an agreed controlled vocabulary; Key words and MeSH words which describe instruments and variables used in student and physician assessment and in reporting outcomes of medical education.

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CONTRIBUTIONS

H. Hamdy and K. Prasad developed the systematic review protocol and worked on all aspects of the review from conceptualization to the writing of the final manuscript. M.B. Anderson contributed to the literature search and writing of the review. A. Scherpbier, R. Williams, R. Zwierstra conducted the hand search and advised on the methodology and writing of the review. H. Cuddihy contributed to the literature search and writing of the review.

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ABBREVIATIONS

AAMC	=	American Association of Medical Colleges
ABMS	=	American Board of Medical Specialties
ABS	=	American Board of Specialty
ACGME	=	Accreditation Committee of Graduate Medical Educators
AOA	=	Alpha Omega Association “Honors Society”
BEME	=	Best Evidence in Medical Education Collaboration
EMRO	=	Eastern Mediterranean Office
GMC	=	General Medical Council
NBME	=	National Board of Medical Examinations
RCS	=	Royal College of Surgeons
USMLE	=	US Medical Licensure Examinations
WFME	=	World Federation of Medical Education
WHO	=	World Health Organization

Appendix 1

Initial Medline Search Result

Terms used	Hits found
'Professional behavior' & 'Undergraduate Medical Education'	12
'Physician* Performance' & 'Clinical Performance' *(Limitation- 23/5/1996-23/5/2001, Review, Human)*	80
'Undergraduate Medical Education' & 'Clinical Performance'	549
'Physician* Performance' & 'Clinical Performance'	170
'Clinical Performance' & 'Undergraduate Medical Education'	3
'Physician* Performance' & 'Undergraduate Medical Education' (*Limits 23/5/2000 - 2001/05/23, Review, Human)*	12
'Clinician* Competence' & 'Undergraduate Medical Education'	21
'Professional Competence' & 'Undergraduate Medical Education'	1148
'Professional Competence' & 'Undergraduate Medical Education' (Limits: Review and Human)	23
'Process of Care' & 'Undergraduate Medical Education' (Limits: Review and Human)	5
'Clinical Practice' & 'Undergraduate Medical Education' (Limits: Review & Human)	30
'Clinical Behavior' & 'Undergraduate Medical Education' (Limits: Review & Human)	1
'Process of Care' & 'Undergraduate Medical Education'	131
'Clinical Behavior' & 'Undergraduate Medical Education'	41

Appendix 2

Systematic Review
Data Extraction Form

1. Study Number ☐

2. Citation: _____

3. Reference: Year: _____ Vol: _____ No: _____ Pages: _____

4. Timing of Assessment: Med School ☐ Internship ☐
   Residency ☐ Practice ☐

5. Research question(s)/hypotheses/objectives:

   _____

   _____

6. Study design: Prospective cohort ☐ Retrospective cohort ☐
   Case control ☐ Unclear ☐
   Others (please specify) _____

7. Sampling & Sample size: Random Sample ☐ Entire batch ☐ Unclear ☐

   Others (please specify) _____

   Sample Size: _____

8. Reliability of instruments : Given ☐ Not given ☐

	Instruments used:	**Reliability Coefficient:**
i)	_____	_____
ii)	_____	_____
iii)	_____	_____
iv)	_____	_____

Appendix 2

Correlation – Co-efficients

Predictor Variables	**Outcome/Criterion Variables**					
		P-value (C.I.)		P-value (C.I.)		P-value (C.I.)

Regression – Co-efficients

Predictor Variables	**Outcome/Criterion Variables**					
		P-value (C.I.)		P-value (C.I.)		P-value (C.I.)

Summary Statement: _____

_____

Other Comments: _____

_____

Appendix 2

Validity Appraisal of the Studies

	Yes	No	Unclear or N/A*
1) Prospective or Retrospective Cohort	❒	❒	❒
2) Sample			
Unbiased Selection of Subjects	❒	❒	❒
3) Data Collection			
a) Similarity of Correlated Construct *(at least one)*	❒	❒	❒
b) Psychometric Characteristics of measuring instruments	❒	❒	❒
4) Data Analysis			
a) Use of appropriate statistics	❒	❒	❒
b) Attrition bias/Response Rate	❒	❒	❒
c) Dissatenuation of correlation co-efficient	❒	❒	❒
Total No:	_____	_____	_____
	_____	_____	_____

**N/A = Not applicable or Not Available*

Appendix 3

List of 38 Included Studies - *(*) = studies included in Meta-Analysis*

(*) Alexander, G.L., Davis, W.K., Yan, A.C. & Fantone, J.C. 2000, 'Following Medical School Graduates into Practice: Residency Directors' Assessments after the First Year of Residency', *Academic Medicine*, vol. 75, no. 10, pp. S1517.

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Appendix 3

List of 38 Included Studies - *(*) = studies included in Meta-Analysis*

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List of 38 Included Studies - *(*) = studies included in Meta-Analysis*

165.
Price, P.B., Taylor, C.W., Richards, J.M. & Jacobsen, T.C. 1964, 'Measurement of Physician Performance', *J. Medical Education*, vol. 39, pp. 203-211.

Probert, C.S., Cahill, D.J., McCann, G.L. & Ben-Shlomo Y. 2003, 'Traditional finals and OSCEs in predicting consultant and self-reported clinical skills of PRHOs: a pilot study', *Medical Education*, vol. 37, pp. 597-602.

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(*) Wilkinson, T.J. & Frampton, C.M. 2004, 'Comprehensive undergraduate medical assessments improve prediction of clinical performance', *Medical Education*, vol. 38, pp.1111-16.

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(*) Yindra, K.J., Rosenfield, P.S. & Donnelly, M.B. 1998, 'Medical School achievements as predictors of residency performance', Journal *Medical Education,* vol. 63, pp. 356-363.

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Appendix 4

Predictors and Outcome Variables in the included Studies

Study References	Predictors Variables	Outcome Variables
Hojat *et al.*, 1993; Markert 1993	NBME I/USMLE I	NBME III
Hojat *et al.*, 1993; Markert 1993	NBME II/USMLE II	
Hojat *et al.*, 1993	Objective Clinical Exam	
Hojat *et al.*, 1993	Exam Grades in Basic Sciences	
Markert 1993	Preclinical GPA	
Markert 1993	Clerkship GPA (clinical performance/ scores)	
Rabinowitz & Hojat, 1989	3rd Year Clerkship Examination Scores Modified essay questions in family medicine clerkship	
Blacklow, Goepp & Hojat 1993; Kron *et al.*, 1985	Class Ranks	Supervisor Rating during internship and residency programme
Sosenko 1993 ; Borowitz 2000 ; Markert 1993; Loftus *et al.*, 1992; Smith 1993; Kahn *et al.*, 2001; Yindra, Rosenfield & Donnelly 1998; Kron *et al.*, 1985; Zu *et al.*, 1998	NBME I/USMLE I	
Fincher, Lewis & Kuske 1993	Cumulative GPA	
Markert 1993; Loftus *et al.*, 1992; Richards *et al.*, 1962 ; Zu *et al.*, 1998	Preclinical GPA	
Markert 1993, Loftus *et al.*, 1992; Kahn *et al.*, 2001; Callahan *et al.*, 2000, Rabinowitz *et al.*, 1989 ; Paolo *et al.*, 1992 ; Zu *et al.*, 1998	Clerkship GPA (clinical performance/ scores)	
Vu *et al.*, 1992 Vu *et al.*, 1993	Clinical Competence (post-clerkship score)	
Arnold & Willoughby 1993	Clerkship Rating	
Pearson, Rolfe & Henry 1998	Professional Skills	
Pearson, Rolfe & Henry 1998	Critical Reasoning	
Pearson, Rolfe & Henry 1998	Population Medicine	
Pearson, Rolfe & Henry 1998	Self-Directed Learning	
Arnold & Willoughby 1993	Final Year MD Exam Scores and Subscores	
Fincher, Lewis & Kuske 1993	Medical School GPA Ranking	
Fincher, Lewis & Kuske 1993	First Year Student Self Assessment (readiness for internship)	
Loftus *et al.*, 1992; Kahn *et al.*, 2001	First Year Student Ranking (using Dean's Letter)	
Loftus *et al.*, 1992	Ranking with Criterion Reference	
Loftus *et al.*, 1992	Ranking with Norm Reference	
Loftus *et al.*, 1992; Kahn *et al.*, 2001; Kron *et al.*, 1985	Honours Society	
Loftus *et al.*, 1992; Kahn *et al.*, 2001; Wilkinson & Frampton, 2004 ; Rutala *et al.*, 1992	OSCE	

Appendix 4

Loftus *et al.*, 1992	Intern's Selection Committee	Supervisor Rating during internship and residency programme
Loftus *et al.*, 1992	Number of Honours and Failing Grades in Preclinical, Clerkship and Clinical Electives	
Gunzburger *et al.*, 1987	NBME II Factor	
Gunzburger *et al.*, 1987	Clerkship Grade Factor	
Kahn *et al.*, 2001	Year 1 Average Scores of Courses	
Kahn *et al.*, 2001	Year 2 Average Scores of Courses	
Kron *et al*,, 1985	AOA, NBME, Class Rank	
Kahn *et al.*, 2001	Year 3 Average Scores of End of Clerkship Exam (Med, Obs/Gyn & Psychiatry)	
Fine & Hayward 1995	Clerkship GPA (Clinical performance/ scores	
Probert *et al.*, 2003	Traditional finals OSCE	
Boyse *et al.*, 2002; Sosenko *et al.*, 1993; Case & Swanson 1993	NBME I/USMLE I NBME II/USMLE II	Specialty Board Examination Scores (American Board) Ortho, Dermatology, Preventive Medicine), Internal Medicine
Fine & Hayward 1995 Brailovsky *et al.*, 2001 Ronai *et al.*, 1984	Clerkship GPA (Clinical performance/ scores Script concordance test NBME I & II	In-training examination of Residents: MCQ, OSCE, Short answer management problems, Simulated office orals
*Tamblyn *et al.*, 2002	Final Year MD Exam Scores and Subscores	Practice Outcomes
**Clute 1963	Academic scores in medical schools	
**Peterson *et al.*, 1956		
***Price *et al.*, 1964		

* Preventive care, continuity of care, resource use, consultation rate, acute and chronic disease management, disease specific prescription, contraindicated prescribing among elderly patients.

** Quality of practice: History taking, physical examination, investigation, therapy, preventive medicine, record keeping.

*** Measures of academic and practice performance of physicians, e.g. scientific publications, number of patients scheduled per hour, investigations and presentations.

SUMMARY OF INCLUDED STUDIES

(1)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Following Medial School Graduates Alexander, *et al*. *Acad Med* supp. 2000	1996-1998	To assess the contributions of academic assessments at various intervals during medical school to ratings of residency performance	Retrospective cohort	338	▪ USMLE I ▪ USMLE II ▪ GPA year 2 clerkship year 3 composite ▪ Cumulative composite score at graduation ▪ Ranking Top third Middle third Lower third	Performance in residency, by supervisor rating in: ▪ Primary care residency ▪ Surgery	▪ Cronbach's alpha of supervisor rating 0.94 ▪ Pearson correlations ▪ ANOVA to compare sub-groups means i.e. similarity in the subjective assessment by directors of residency programmes and attending ratings of students clinical performance	▪ USMLE I - r =0.2 ▪ USMLE II - r = 0.24 ▪ GPA year 2 - r = 0.2 ▪ GPA year 3 - r = 0.41 clerkship ▪ Composite cumulative - r = 0.32 ▪ All GPA P = < .000 ▪ Year 2 GPA and resident humanistic quality r = 0.07; P = 0.12 /not significant ▪ Conclusion: low magnitude correlations, but statistically significant except with humanistic quality ▪ Academic performance explained less than 20% of the variance in residency performance ▪ Strength of correlation between clerkship GPA and residency assessment may have been due to 'method effect' of the ratings.

SUMMARY OF INCLUDED STUDIES

(2)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Medical School Achievements as Predictors of Performance Amos, *et al.* *Acad Med* 1996	1959-1991	To determine the relationships between medical school achievements and clinical or academic performance of residents in physical medicine and rehabilitation, performance on board examination and entry into academic practice	Retrospective cohort	205 Residents	▪ Age, ▪ Sex ▪ Research experience ▪ Advanced degree ▪ Failed classes or clerkship ▪ Honors grades, class rank	▪ Annual evaluation scores of residents ▪ Publications ▪ GPA on masters degree ▪ Board scores ▪ Post-residency outcome variables: Fellowship, career selection (academic versus clinical)	▪ Chi-square analysis of variance, linear and logistic regression	▪ Clinical residency performance was predicted by clerkship honors grades (P = .0001) ▪ Probation was predicted by failing a basic science course (P=.0001) ▪ Written board performance was related to Alpha Omega Alpha status (P=.04) ▪ Failing written boards on the first attempt was predicted by failing a basic science course (P=.05) ▪ Entry into an academic PMR practice was predicted by an interest in the practice in personal statement of the residency application (P=.002) and writing a thesis in medical school (P=.03)

SUMMARY OF INCLUDED STUDIES

(3)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
The Empirical Association between student and Resident physician Performance. Arnold & Willoughby; *Acad Med* supp. 1993	• Medical School • (1980-1983) • Residency	Are categories of students performance levels associated with their standings on clinical performance ratings as residents? Is the association between performances in combined degree program residency stronger when measures are conceptually similar?	Retrospective cohort	298 (a combined degree program)	Clerkship GPA Clerkship rating Final Year MD exam scores and subscores	Supervisor rating for year one residency	Distribution free ▪ Statistics ▪ Chi-square ▪ Factors analysis	• 45% of subjects in same performance categories as students and residents • Agreement between high and low levels of student residency performance • Students clinical performance component was strongest correlate of residency clinical performance (Contextual variables-) $r = 0.3$ $P < .001$

SUMMARY OF INCLUDED STUDIES

(4)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Selection of obstetrics and gynecology residents Bell, *et al*. *Am J Obs Gyn* 2002	Medical School and Residency I Obstetrics & Gynecology 1995-1999	Whether USMLE scores predict residents in training examination scores	Retrospective cohort	24 Residents	▪ USMLE I ▪ USMLE II ▪ Number of hours in clinical rotations (five) ▪ Global assessment of applicant composite score of selection	▪ Supervisors ratings in PGY 1-4 four categories ▪ Clinical judgment ▪ Patient rapport ▪ Surgical ability ▪ Work ethics ▪ In-training examination PGYs 1-4 'GREOG' Council on Residents Education in Obstetrics and Gynecology	▪ Linear regression ▪ Spearman rank correlation to assess relationships among individual components and external measures 'Contents and Construct Validity'	▪ USMLE I significantly predicted performance on PGY 1-3 GREOG examination $P < 0.05$ ▪ USMLE II significantly predicted performance on GREOG examination in all 4 years $P < 0.05$ ▪ USMLE I did not correlate with PGY4 CREOG scores ▪ CREOG did not correlate with resident performance as measured by faculty evaluation ▪ No association between medical student composite scores and resident performance scores.

SUMMARY OF INCLUDED STUDIES

(5)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Further Psychometric Evaluations of a Class Ranking Model as a Predictor of Graduates' Clinical Competence in First Year of Residency. Blacklow, Goepp, Hojat *Acad Med* 1993	1991, 1992, 1986-19 • Medical school • Internship	To investigate the psychometrics of a class ranking model Is there a linear relationship between class ranks and ratings of postgraduate competence	Retrospective Cohort Faculty judged graduates' potential to become competent physicians. Student rankings compared to ratings received from faculty. Directors' rated data-gathering skills of graduates at end of internship.	Part I 215 graduates of Jefferson Part II 598 graduates	• Class Ranks • Basic science grades • Clerkship – clinical ratings in 3rd year	Supervisor rating at the end of the first year of residency	Concordance rates between faculty ratings and class ranking model	▪ The <u>means</u> of both measures of medical school performance increased significantly with increases in the levels of postgraduate clinical ratings, suggesting a linear relationship. ▪ Concordance rate 85% between ranks and ratings support validity of ranking model.

SUMMARY OF INCLUDED STUDIES

(6)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Information Collected During the Residency Match Process Does Not Predict Clinical Performance Borowitz, Saulsbury & Wilson. *Arch Pediatr Adolesc*, 2000	Pediatric residents over a 7 year period at the University of Virginia 1994 - 1997	To determine whether information collected during the national residency matching program predicts clinical performance during residency as evaluated by 10 faculty members	Retrospective Study	69 pediatric house officers	▪ Rank on matching list ▪ Score on NBME I ▪ Grade on pediatric and internal medicine clerkship ▪ AOA ▪ Scores of faculty interviews during interim application ▪ Pediatric in service examination ▪ Scores of American Board of Pediatrics	▪ Supervisors ratings of clinical performance	▪ Kappa for agreement between raters ▪ Linear regression ▪ T-test, analysis of variance	▪ Medical School Grades, Performance on NBME I, Interviews during the interim application process and match-list ranking are not predictors of clinical performance during residency.

SUMMARY OF INCLUDED STUDIES

(7)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Does Medical School Performance Predict Radiology Boyse, *et al*. *Acad Radiol* 2002	1991-2000	To determine the relationships between medical school achievements and clinical or academic performance of residents in physical medicine and rehabilitation, performance on board examination and entry into academic practice	Retrospective cohort	77 Radiology Residents	▪ Grades ▪ Dean's letter ▪ Letters of recommendation ▪ AOA ▪ NBME I & USMLE I	▪ Rotation evaluations supervisor rating ▪ Retrospective faculty recall scores ▪ American College of Radiology (ACR) ▪ American Board of Radiology (ABR) examination scores	▪ Student to test ▪ Analysis of variance ▪ Correlation coefficients	▪ Preclinical grades of honors or A ▪ Clinical grades of honors in medicine, surgery, high NBME/USMLE I predicted success on ABR written examination, but did not predict rotation performance ▪ Dean's letter, letter of recommendation AOA, high medical school prestige did not predict high examination scores or supervisor rotation performance.

SUMMARY OF INCLUDED STUDIES

(8)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Measurement of clinical reflective capacity early in training as a predictor of clinical reasoning performance at the end of residency: An experimental study on the script concordance test Brailovsky, *et al. Med Edu* 2001	1996	To verify whether scores obtained by students at the end of the clerkship predict their clinical reasoning performance at the end of residency	Cohort comparative study prospective of scores	24 students	Scores on SC end of clerkship	Scores on ▪ Short answer management problem (SAMP's) ▪ Simulated Office Orals (SOO) ▪ OSCE	Pearson correlation	▪ SC and SAMP correlation r = .451 P = 0.01 ▪ SC and SOOs r=0.447 P = 0.015 with OSCE r = 0.340

SUMMARY OF INCLUDED STUDIES

(9)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Validity of faculty ratings of students' clinical competence in core clerkship in relation to scores on licensing examinations and supervisors' ratings in residency Callahan, *et al*. *Acad Med* supp. 2000	1989 – 1998 Medical School Residency	Examine the validity of faculty rating of students clinical competencies in core clinical clerkship in relation to student subsequent performances on medical licensing examination and program directors' ratings.	Retrospective cohort	2158	Global ratings of student clinical competencies in six core clerkships	▪ USMLE II ▪ USMLE III ▪ Supervisors ratings of clinical performance in year 1 ▪ Residency "data gathering skills ▪ Interpersonal skills and attitudes ▪ Socioeconomic aspects of patient care	▪ Bivariate correlation ▪ Multiple regression analysis	▪ All correlations reported are statistically significant, but of low effect size ▪ Highest correlations 0.29 and 0.2 between internal medicine clerkship and steps 2 and 3 USMLE lowest correlations 0.17 psychiatry and 0.11 surgery clerkships ▪ Correlations with postgraduate clinical competence statistically significant, but low effect size ▪ Highest internal medicine clerkship and data gathering skills 0.27, lowest between surgery and psychiatry clerkship and postgraduate clinical competence 0.1 and 0.09

SUMMARY OF INCLUDED STUDIES

(10)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Validity of NBME part 1 and part II scores for selection of residents in orthopedic surgery, dermatology, preventive medicine. Case & Swanson, *Acad Med* supp. 1993	1991 • Medical school • Residency	How accurately do NBME scores predict criterion measures of success in residency training?	Retrospective cohort	Ortho= 656 Derm= 219 Prev.=169	NBME I, II	Specialty Board Exam Scores	Regression analyses correlations	▪ Patterns of high low scores on NBME Parts I and II generally related to skills required in the specialty areas. Is this a reflection of the examinee's preferred specialty or the programs selecting that person. ▪ NBME Parts I and II scores provided a good predictor of specialty board performance. Part II, generally better than part I. ▪ Part I or II scores below 400, examinee more likely to fail specialty boards. Predict BUT should not be sole criteria.

SUMMARY OF INCLUDED STUDIES

(11)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
The General Practitioner: A study of medical education and practice in Ontario and Nova Scotia Clute, Univ Toronto 1963	1961 – 1963 • Medical School • General Practice	To determine relationship between medical school academic marks and quality of practice in Ontario and Nova Scotia	Survey	85 Canadian GPs	Academic marks in clerkship	▪ Quality of practice	Pearson correlation	Relationship between academic and career performance – slight, positive, significant correlation of .56 in Ontario (N – 23), but also strong negative relationship between age and grades and quality of practice; in Nova Scotia (N = 39), positive, non-significant correlation of .24.

SUMMARY OF INCLUDED STUDIES

(12)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Relationships of intern's performance to their self-assessments of their preparedness for Internship and to their Academic Performances in Medical school Fincher, Lewis, Kuske *Acad Med* supp. 1993	• Medical School • (1990-1991) • Internship	Do medical students' cumulative GPA correlate with performance assessments? Do medical students' self assessments of preparedness for internship correlate with internship directors' assessments? Does med school academic performance predict performance in specific competencies as assessed by program directors?	Retrospective cohort	138/114 (1990) 145/104 (1991) 133 self-rating	• Cumulative GPA • Medial School GPA rank • Student self-assessment	Supervisor rating for year one residency	• Pearson Correlation Coefficients • Cross tabs • Chi-square • Multivariate • ANOVA	• GPAs of students who chose university based residencies significantly higher than those who chose community based - GPA predicts overall performance in specific competences in internship year. $r = 0.28–0.51$ • Ranking between med school internship year was different rather inconclusive. • Medical school academic performance relates significantly to performance in internship.

SUMMARY OF INCLUDED STUDIES

(13)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Do criteria predict resident performance Fine & Hayward, *Acad Med* supp. 1995	• Medical School • Residency	Factors considered by Res. Programs when selecting residents and whether factors predict resident performance	Retrospective cohort	123 Residents 308 appl.	Clerkship GPA	Overall rating (over several years)	Multivariate liner regression	• Significant independent relationship between medical school clerkship (International Medicine grade) and residency performance. • ISCs over emphasize of AOA, scores of medical school reputation. • Best predictor of overall residency performance were internal medicine clerkship honors and graduation from home institution.

SUMMARY OF INCLUDED STUDIES

(14)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Correlation of Standardized Testing Results Fish, *et al. Am J Phys Med Rehab* 2003	2001 (POE)	To determine the relationships between medical school achievements and clinical or academic performance of residents in physical medicine and rehabilitation, performance on board examination and entry into academic practice	Survey	86 Residents	▪ Self assessment examination (SAE) ▪ USMLE I ▪ USMLE II ▪ USMLE III ▪ Comprehensive Medical Licensing Exam (COMPLEX)	▪ POE scores and ranking	▪ Spearman rank correlation (rho) ▪ X^2	▪ 12 Residents (14%) thought SAE correlated with POE; 53.5% 'somewhat' 32% did not correlate well. 60.5% thought the SAE was easy; 8.1% more difficult and 31.4% same difficulty ▪ Participation in a board review courses did not correlate with quartile ranking on POE r_s = -0.2 ▪ All residents in the lowest quartile failed the POE ▪ Higher performance on standardized test USMLE I, II, III/ COMPLEX, SAE correlate with POE ▪ SAE r_s = 0.581 P < 0.001 ▪ Passing 1st attempt all USMLE 0.295 P < .007

SUMMARY OF INCLUDED STUDIES

(15)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
An empirical study of the predictive validity of number grades in medical school using 3 decades of longitudinal data: implications for a grading system Gonnella, Erdmann & Hojat, *Med Edu*, 2004	1970 – 1999 • Medical School • PG 1	To examine predictive validity of number grades in medical school	Prospective cohort study	6656 medical students	▪ GPA year 1 ▪ Number grades	▪ GPA year 2 ▪ GPA clerkship ▪ Medical school class rank ▪ USMLE 1, 2, 3 ▪ Supervisor rating PG 1	• Mean comparison ▪ X^2 ▪ ANOVA ▪ Effect size	Ratings of clinical competence beyond medical school are predicted by number grades in medical school

SUMMARY OF INCLUDED STUDIES

(16)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Premedical and Medical School Performance in Predicting First Yr Residency Performance. Gunzburger, *et al. J Med Edu* 1987	1982, 1984 (62) (123) • College • Medical School • Residency (Internship)	Relationships among measures of college and medical school performance and competence in 18 medical care tasks in PGY I.	Retrospective Cohort	185 Graduates of Loyola	• NBME II Scores • Clerkship grade • NBME I • GPA • MCAT	• Rating by supervisor for year one residency	• Factor analysis • Stepwise multiple regression • Rash model item analysis	• College and medical school academic achievement not best predictors of resident's competence. • High correlation found between: (1) NBME part II scores and residency competence ratings (i.e. test measures what it should – MBA) P = .005 (2) Clerkship grades.

SUMMARY OF INCLUDED STUDIES

(17)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Is the Glass Hall Full or Half Empty? A Reexamination of the Associations Between Assessment Measures during Medical School and Clinical Competence after Graduation Hojat, *et al.* *Acad Med* supp. 1993	• Medical School • Internship (1980 – 1990)	Investigate associations between performance during medical school and in the first year of residency. Hypotheses: 1) There is high correlation between medical school measures of performance and measures obtained at end of internship 2) Objective measures of medical knowledge attained during medical school and one year after graduation are highly correlated 3) Students' low or high academic standings in medical school are directly and significantly associated with their subsequent clinical competence ratings as residents The association between academic standings in medical school and status on clinical competence ratings as residents is stronger for measurements that are conceptually more similar than dissimilar.	Retrospective cohort	1,724 graduates Total = 2368	• NBME I, II • Objective Clinical Exam • Preclinical exam Grades	NBME III	• Factor analysis Distribution free statistical measures used • Chi-square • Pearson Product-moment correlations	▪ Associations exist between performance measures in medical school and those after graduation. ▪ Conceptually similar measures yield stronger associations than dissimilar ones. Need to refine assessment instruments. ▪ Associations among performance measures in medical school increase drastically when selected measures of personality are included in prediction models.

SUMMARY OF INCLUDED STUDIES

(18)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Residency Program Director Evaluations Do not Correlate With Performance on a Required 4th Year OSCE . Kahn, *et al. Teach & Learn in Med* 2001	• (4th Year) Medical School • Internship	Correlate performance on 4th year OSCE with residency program director assessment also class rank and USMLE scores	Retrospective Cohort 25 highest scoring 25 lowest scoring examinees. 5 point Likert Scale used by program directors	50 Graduates from Tulane	NBME I, II Objective Clinical Exam in Senior year Class ranking	Supervisor rating for year one residency History taking PE, interpersonal skills and overall medical knowledge.	▪ Mann-Whitney tests (ordinal data) ▪ Pearson's correlations ▪ Spearman's rho analysis	• Program directors scores did not correlate with class rank or USMLE scores, < .26 or TOSCE < .27, P <.08. • No individual score from prog. Director was significantly different between OSCEHI and OSCELO. • Strong correlations between USMLE scores and class rank. • Prog. Directors do poor job of assessing clinical comp.

SUMMARY OF INCLUDED STUDIES

(19)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Can Success in the Surgical Residency be Predicted from Pre-residency Evaluation? Kron, *et al.* *Ann. Surg* 1985	• 1973-1982 • Medical School • Residency	Compared level of a clinical performance and success of residents in one training program with information from initial application and interview. Can level of performance in residency be predicted from data in application? Can successful completion of residency program be predicted from objective and subjective data from medical school?	Retrospective Cohort	62	• Medical school application info • Election to AOA • NBME scores • Class rank (honors in basic science and clinical subjects, letters of recommendation, scientific publication during medical school, research experience) • Residency interview	• Rating by program director for year one residency level of clinical performance	Discriminant function analysis	▪ No correlation between any of the selection factors and resident's performance for the 42 who completed the program. ▪ Comparison of the 42 with 20 who were dismissed revealed AOA membership; high-class rank; clinical honors; and scientific publications during medical school predicted success with 89% accuracy. ▪ Personal interviews are not predictive of success, or performance.

SUMMARY OF INCLUDED STUDIES

(20)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
First-Year Residents' Performances Compared with Their Medical School Class Ranks. Loftus *et al*. *Acad Med* 1992	• Medical school • Residency	▪ Does student's class rank bear strong relationship to subsequent residency performance? ▪ What class rank system yields most sig. Correlation with postgraduate med. outcomes ▪ Is there a way to strengthen the relationship	Retrospective cohort	124 graduates with med school records 102 for internship records	• Preclinical GPA • Clerkship GPA • NBME I/NBME II • First year student ranking (Dean's letter category index) • Ranking with Criterion Ref. • Ranking with Norm Ref. • Honors Society Intern Selection Comm.	Rating by supervisor for year one residency 9 areas of clinical performance	Stepwise multiple regression Pearson's correlation	▪ Weighted combination of clinical performance measures bore strongest relationship to performance in residency. ▪ Low correlation of different ranking methods *r* (0.23–0.18) P < 0.05

SUMMARY OF INCLUDED STUDIES

(21)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
The relationship of academic measures in medical school to performance after graduation – Markert, *Acad Med* supp. 1993	• Medical School • Internship (1980 - 1991)	Study 3 hypotheses: Measures of medical school academic performance will correlate significantly with postgraduate outcome. Relationship will be strongest for conceptually similar measures; Students categorized as high or low will be categorized similarly on post grad. outcome measures.	Retrospective cohort	947 (628=NBME II scores) (481= physician. Supervisor ratings)	• NBME I, II • Preclinical GPA • Clerkship GPA	• NBME III • Supervisor Rating for year one residency	▪ Pearson correlation ▪ Stepwise regression ▪ Factor analysis ▪ Chi-square	▪ The medical school variables correlated significantly with NBME part III scores and physician supervisor ratings. First 2 hypotheses are supported. ▪ Medical School academic achievement significantly related to clinical competency in residency.

Appendix 5

SUMMARY OF INCLUDED STUDIES

(22)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Measuring Outcomes of Undergraduate Medical Education: Residency Directors' Ratings of First-year Residents Paolo & Bonaminio *Acad Med* 2003	1998-=2000 ▪ Medical School ▪ First-year Residents	To assess reliability and validity of a residency rating scale (Psychometric) and provide a method for gathering comparison data	Retrospective cohort	382	▪ Basic Science GPA ▪ Clinical GPA ▪ USMLE I ▪ USMLE II	▪ Supervisors ratings over 25 items based on the summative competency of the graduates using a Likert scale	▪ Structure of rating scale was assessed using principal components analysis with varimax rotation ▪ Correlation rating scale with undergraduate performance ▪ Analysis of variance for group difference ▪ Independent t-test	Five items: ▪ Interpersonal communication ▪ Clinical skills ▪ Population based health care ▪ Record keeping skills ▪ Critical appraisal skills Best explained the items and accounted for 86% of the variance Pearson correlations statistically significant ranging from 0.21 – 0.49 low to moderate relation between residency directors' ratings and UME performance measures of UME clinical GPA had the highest correlation with all five factors.

SUMMARY OF INCLUDED STUDIES

(23)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
The relationship between assessment measures of Newcastle Medical School (Australia) and performance ratings during internship. Pearson, Rolfe, & Henry *Med Edu* 1998	• Medical School • Internship 1991, 1992	Predictive value of academic performance in last 2 years of 5 year program for ratings during internship.	Retrospective Cohort	64 Graduates n=112 eligible	• Professional skills long case in each department • Critical reasoning • Population medicine • Self-directed learning • Identification prevention and management of illness.	Supervisor rating for year one residency 13 competencies	ANOVA Linear regression	• Significant positive correlations between mean ratings and examination scores from Domains 1,3,5. • Professional skills; identification, prevention management of illness; self-directed learning. • Best predictor of intern ratings was identified, prevention and management of illness $r = 0.28$ $P < 0.01$

SUMMARY OF INCLUDED STUDIES

(24)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
An analytical study of North Carolina General Practice Peterson *et al. Med Edu* 1956	1956 • Medical School • General Practice	To determine relationship between medical school academic marks and quality of practice in North Carolina	Survey	94 GPs	Academic marks in clerkship	▪ Quality of practice ▪ Career performance measures - Observation by internist of subject's clinical history, physical examination, use of laboratory aids, use of therapeutic measures, preventive medicine, and clinical records. Observer made composite ratings on a predetermined scale which gave preponderant weight to the quality of the subject's clinical history and physical examination.	Pearson correlation	Relationship between academic and career performance – slight, positive significance for younger doctors; no significance for older doctors.

SUMMARY OF INCLUDED STUDIES

(25)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Measurement of Physician Performance Price, *et al. Med Edu* 1964	1964 • Medical School • General Practice	To determine relationship between medical school GPA and academic and practice performance	Survey	215 GPs and 292 specialists	Medical school GPA's ▪ First two years ▪ Last two years	Career performance measures – About 80 measures obtained from interviews, records, and colleagues' opinions, for example, number of journals to which respondent's subscribed, peer nominations for outstanding performance, hospital recognition, and publications; composite performance clusters developed with factor analytic techniques.	▪ Pearson correlation ▪ Factor analysis	Performance – None; medical school grade point average (GPA), a factor almost completely independent of all factors having to do with professional performance

SUMMARY OF INCLUDED STUDIES

(26)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Traditional finals and OSCEs in Predicting Consultant and Self-reported Clinical Skills of PRHOs Probert, *et al. Med Edu* 2003	Medical School and PRHO 1999	To determine the relationships between medical school achievements and clinical or academic performance of residents in physical medicine and rehabilitation, performance on board examination and entry into academic practice.	Prospective cohort	20 PRHOs	▪ OSCE ▪ Long case examination	▪ Self assessment of clinical competencies ▪ Supervisor assessment of clinical competencies	▪ Z score ▪ Pearson Correlation ▪ Kendall's rank correlations ▪ Multiple variable logistic regression O.R. > 1 indicates better performance on examination; is associated with increase probability of being classified as better doctor	▪ No correlation between PRHOs self reported performance and consultant reported performance ▪ Traditional finals was inversely associated with consultant assessment. Better performing students were not rated as better doctors in surgery but not in medicine ▪ OSCE showed positive associations with consultant ratings

SUMMARY OF INCLUDED STUDIES

(27)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
A Comparison of the Modified Essay Question and Multiple Choice Question Formats: Their Relationship to Clinical Performance Rabinowitz & Hojat. *Fam Med*, 1989.	1976 – 1985, Jefferson Medical College	Determine the relation between (1) MCQ examination in third year clerkship (2) Modified essay question final examination in family medicine (3) clinical performance in post-graduate training	Retrospective Cohort Study	1458 graduates	▪ MCQ 3rd year clerkship. ▪ Modified essay examination in family medicine clerkship	▪ NBME I, II, III ▪ Supervisor ratings in residency	▪ Pearson correlation and ▪ regression analysis	▪ Grades on MCQ examination in internal medicine clerkship consistently yielded the higher correlation with NBME scores I, II, III (r=0.59, 0.64 and 0.49). Modified essay in family medicine had the lowest correlation with NBME I, II, III (r=0.37, 0.37, 0.38). ▪ Correlations of clerkship examination scores with post-graduate rating of competencies. ▪ Medical knowledge highest: internal medicine clerkship 0.23, lowest: pediatrics 0.12 ▪ Data gathering highest: family medicine 0.19, lowest: Ob/Gyn 0.15. ▪ Clinical judgment highest: family medicine 0.20, lowest: pediatrics 0.13 ▪ Professional attitudes, highest: 0.17, lowest: pediatric 11

SUMMARY OF INCLUDED STUDIES

(28)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
The prediction of Medical Intern Performance Richards, Taylor & Price *Appl Psychol* 1962	1955-1958 • Medical School • Internship	To determine the relationship between medical school and GPA internship performance	Survey	139 Interns	GPA Years 1, 2, 3	▪ Supervisor ratings of internship performance ▪ Career performance measures – Evaluation of internship performance by hospital official; judges applied a rating scale to the letters of evaluation. An adjusted rating was also obtained by modifying the above unadjusted rating by an index of hospital quality.	Pearson correlation coefficient	Relationship between academic and career performance – Slight, positive significant correlations of .21 and .24 between first- and second-year grades, respectively, and adjusted rating; positive, significant correlation of .33 and .45 between third-year grades and unadjusted and adjusted ratings, respectively.

SUMMARY OF INCLUDED STUDIES

(29)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Relationship between past academic performance and results of specialty in-training examinations Ronai, Golmon, Shanks, Schafer & Brunner. *J Med Educ, 1984*	• 1966 – 1981	What is the relationship between College grades, medical school performance and the results of specialty in-training examination of residents in Anesthesia & Orthopedics.	Retrospective Cohort Study	63 graduates of North Western Univ	▪ College Grade GPA ▪ MCAT Scores ▪ NBME I ▪ NBMEII	▪ Scores on the final assessment of their residency in-training examination in Anesthesia & Orthopedics	▪ T-test ▪ Pearson correlation ▪ Multiple linear regression for prediction	▪ No significant difference between the GPA, MCAT scores and NBME I & II between the two groups. ▪ Multiple linear regression analysis with stepwise forward inclusion. Best predictor of the anesthesia final in-training examination score was MCAT verbal ability 42%. For Orthopedic scores, ▪ GPA-non science inclusion of all variables accounted for 40% of the variance for both groups. GPA non-science negative correlation. ▪ NBME I and NBME II minimal effect in predicting in-training examination scores in anesthesia while significant information to the predictors of examination scores in orthopedics were found.

SUMMARY OF INCLUDED STUDIES

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Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Validity studies using standardized-patient examinations: standardized patient potpourri Rutala, *et al. Acad Med* supp. 1992	1989-1990 •	To assess whether OSCE with standardized patients could predict performance during residency	Retrospective	76 students	OSCE – Standardized Patients: ▪ Interpersonal skills ▪ Database development ▪ Decision making	▪ Residency directors questionnaire and rating	Pearson correlation coefficient	Correlation of OSCE with residency directors rating: ▪ Interpersonal skills - .42 ▪ Database development - .28 ▪ Decision making - .28 OSCE with SPs can measure what residency directors look for particularly in the domain of interpersonal skills.

SUMMARY OF INCLUDED STUDIES

(31)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Correlations between Graduates Performances as First Year Residents and Their Performances as Medical Students. Smith, *Acad Med* 1993	• Medical School • Internship 1989 - 1991	Examine relationship (correlation) between performance in internship and Med School performance, on a clinical skill exam	Retrospective Cohort	203 Graduates of Brown University	▪ Objective Clinical Exam in Senior Year (OSCE) ▪ Honors and Failing Grades in Preclinical Clerkship ▪ Clinical Electives	Supervisor Rating for year one residency	Pearson correlation coefficients	• Data collection score on the CSE correlated best with internship performance. r = 0.273 • Correlations for clinical net score, number of honors grades in clinical electives, and interpersonal skills score closely clustered behind data collection score. • Correlations for number of honor grades in preclinical courses and scores on NBME I and II was zero.

SUMMARY OF INCLUDED STUDIES

(32)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
NBME Examination Part I as Predictor of Clinical and ABIM Certifying Examination Performances Sosenko, Stekel, Soto & Gelbard. *J Gen Int Med*, 1993	1980 – 1988 Jackson Memorial Hospital	Whether scores from NBME I are predictive of competence in internal medicine as assessed by clinical performance ratings and American Boar d of Internal Medicine	Retrospective Cohort Study	117 internal medicine residents	▪ NBME I	▪ American Board of Internal Medicine Scores ▪ Supervisors rating of clinical competency during residency	▪ Pearson correlation	▪ High correlation between ABIME and NBME I (r = 0.57) ▪ Relation between clinical evaluations and the NBME I were considerably weaker (r=0.27)

SUMMARY OF INCLUDED STUDIES

(33)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	**Outcome**		
Association between licensure examination scores and practice in primary care. Tamblyn, *et al. J Am Med Assoc* 2002	1990-1993 - practice	To determine a sustained relationship between certification exam scores and practice performance. If licensing exams taken at end of medical school are predictive of future practice in primary care.	Retrospective cohort Cohort Outcome variables: 5 annual measures	912 FPs	▪ Final year MD Exam Scores and subscores • Licensing examinations	Practice Outcomes in Primary Care	▪ Poisson regression ▪ Multiple linear regression	• Relationships between certification exams were sustained through first 4-7 years of practice. • Exams taken in final year of medical school were significant predictors of practice performance.

Continued Tamblyn, *et al. J Am Med Assoc* 2002	**Outcomes**											
	Preventive Care Mammography Screening Rate		Coordination of Care Continuity of Care, % of visits		Resource Use Consultation Rate		Acute & Chronic Disease Management Symptom-relief Prescribing Rate Among Elderly Patients		Disease-specific Prescription Rate Minus Symptom-Relief Prescription Rate		Contraindicated Prescribing Among Elderly Patients	
Predictors	β (95% CI)	P Value	β (95% CI)	P Value	β (95% CI)	P Value	β (95% CI)	P Value	β (95% CI)	P Value	β (95% CI)	P Value
Overall score	16.81 (8.7 to 24.9)	< .001	0.2 (-0.4 to 0.8)	.52	4.93 (2.1 to 7.8	< .001	-7.15 (-15.0 to 1.0)	.08	4.83 (0.9 to 8.8)	.01	0.93 (0.82 to 1.05)	.21
Prevention subscore	8.10 (-1.0 to 17.2)	.08										
Clinical Assessment subscore	11.54 (5.5 to 17.6)	.002										
Management subscore			0.01 (-0.6 to 0.6)	.96			-7.0 (-14.0 to 2.2)	.15	3.0 (-1.0 to 6.9)	.15	0.91 (0.80 to 1.03)	.13
Diagnosis subscore							-5.1 (-12.0 to 2.3)	.18	3.80 (0.3 to 7.3)	.03	0.97 (0.86 to 1.10)	.67
Drug Knowledge subscore							-6.99 (-14.0 to 0.4)	.06	3.5 (0 to 7.1)	.05	0.88 (0.77 to 1.0)	.05

SUMMARY OF INCLUDED STUDIES

(34)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Clinical Performance - based test sensitivity and specificity in predicting first year residency performance. Vu, *et al. Acad Med* supp. 1993	• Medical School (1987, 88, 90) • Internship	To assess the utility of the post clerkship exam in predicting 1st year residency performance : 1) Students who would receive high 2) Students who would receive low.	Retrospective cohort	202 reduced to 133	Clinical Competence (Post-clerkship score	Supervisor rating for year one residency		• Supervisors are reluctant to give low ratings. • PCX = "Very sensitive"; Correctly identified 91% of students who received high ratings. • Much lower specificity for <u>low</u> ratings received.

SUMMARY OF INCLUDED STUDIES

(35)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Six years of comprehensive, clinical, performance-based assessment using standardized patients at the Southern Illinois University School of Medicine Vu, *et al. Acad Med* 1992	1986-1991 •	To determine the validity and reliability of a post-clerkship clinical performance examination	Retrospective	405 students	▪ scores on the PCX	▪ NBME I ▪ NBME II ▪ Clerkship scores First year resident supervisor rating	Pearson correlation coefficient	▪ Clerkship rating r = .36 to .62 ▪ First year residency supervisor r = .16 to .43, mean .32 ▪ NBME I r = .20 to .65, mean .42 ▪ NBME II r = 0.30 to .56, mean .40 All correlations were positive and significant, but they were relatively small, suggesting that the measures may assess different aspects of performance with small overlapping.

SUMMARY OF INCLUDED STUDIES

(36)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Comprehensive undergraduate medical assessments improve prediction of clinical performance Wilkinson & Frampton *Med Edu* 2004	2002 - 2003	▪ High correlation using the new assessment method during the intern year ▪ OSCE has a higher predictive validity ▪ Combining the results is better than relying on any single method	Prospective before and after cohort study	137 year 5 medical students followed into their trainee intern year	▪ Essay exam ▪ MCQ ▪ Modified essay ▪ OSCE	▪ Aggregated global ratings by senior directors, junior doctors and nurses evaluating global clinical skills, global humanistic skills and total global score and comprehensive structured assessment ▪ Comparison with the old written examination	▪ Pearson's correlation ▪ Multiple regression and partial correlation coefficient	Global total correlations: ▪ Old exam: written r = .17 ▪ New exam: written r = .54, OSCE r = .59 & combined r = .60

SUMMARY OF INCLUDED STUDIES

(37)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Medical School Achievements as Predictors of Residency Performance. Yindra, Rosenfeld & Donnelly *J Med Edu* 1998	1983 and 1984 ▪ Medical School ▪ Internship	Relationships between academic achievement in med school : performance in internship, evaluated by program directors	Retrospective Cohort	119, 158	▪ Medical school performance ▪ Average course grades years 1, 2, 3, 4 ▪ AOA ▪ Dean's Letter ranking ▪ NBME I ▪ NBME II	▪ Performance in first year residency	▪ Multiple regression ▪ Factor analysis ▪ t-tests ▪ ANOVA ▪ Pearson correlation	▪ Low correlation highest NBME Part II r = 0.37, but statistically significant relationships between measures of medical school performance and program directors' ratings. ▪ Confounding effects of specialty on resident's ratings.

SUMMARY OF INCLUDED STUDIES

(38)

Citation	Time of Measurement	Research Question/ Purpose of Study	Design	Sample Size	Variables		Statistical Analysis Used	Results/Findings
					Predictors	Outcome		
Board Certification: Associations with Physicians' Demographics and Performances during Medical School and Residency Xu, Veloski & Hojat. *Acad Med*, 1988	1976 - 1985 • Jefferson Medical School • Specialty Board Certification	Do physicians who are board certified have records of higher academic credentials during medical school and in residency. Can academic credentials during medical school and residency predict future board-certification status What is the effect of age, sex, ethnicity on both questions	Prospective, Longitudinal study	1186	▪ Grades of basic medical sciences (BMS). Year 1 & 2 ▪ Grades of clinical sciences – Year 3 ▪ GPAs, BMS and clinical sciences ▪ NBME I & II	▪ Supervisor ratings (Likert Scale) (PGY1) 33 statement 3 factors (data gathering and processing skills 60% of covariance). (interpersonal and attitudinal 5%), socioeconomic aspects of patient care (4%). Composite score of the three areas of postgraduate competence ▪ Self reported practice specialty in family medicine, internal medicine ▪ Board certification status	▪ Chi-Square tests for board certification and sex, age, race ▪ T-test, mean differences between board certified and those not certified ▪ Multiple linear regression models for correlation NBME and postgraduate clinical competence	▪ Data on 95% of graduates (1,186). 1068 were board certified 90% ▪ Rate of certification: 82% in surgery, 92% family practice, 94% internal medicine ($x2 = 37.96, P<.001$) ▪ Differences in Mean Scores of medical schools scores: GPA "BMS", GPA "CS", NBME I, NBME II among certified and not certified physicians. Certified had higher academic credentials. ▪ Similar certification rates for men and women ▪ Older graduates were less likely to be certified ▪ Much lower proportion of underrepresented physicians achieved certification ▪ NBME Score II better predictor than NBME I with ABM in medicine and surgery. In family medicine, neither NBME I or II was a significant predictor

Meta-Analysis of 19 Included Studies (Figs 2 – 11)

Study name	Sample size	Correlation(Random) 95% CI	Weight %	Correlation(Random) 95% CI
Markert 1993	481		14.95	0.20 [0.11 , 0.28]
Smith 1993	203		12.53	0.02 [-0.12 , 0.16]
Sosenko 1993	68		7.94	0.27 [0.03 , 0.48]
Kahn *et al*. 2001	50		6.57	0.08 [-0.20 , 0.35]
Yindra 1998 a	119		10.43	0.24 [0.06 , 0.40]
Yindra 1998 b	158		11.59	0.33 [0.18 , 0.46]
Alexander *et al*. 2000	338		14.11	0.20 [0.10 , 0.30]
Borowitz 2000	69		8.01	0.10 [-0.14 , 0.33]
Paolo *et al*. 2003	308		13.86	0.40 [0.30 , 0.49]
Total (95% CI)	1794		100.0	0.22 [0.13 , 0.30]
Test of heterogeneity: Q-value = 25.166, Df = 8, P-value = 0.0015				

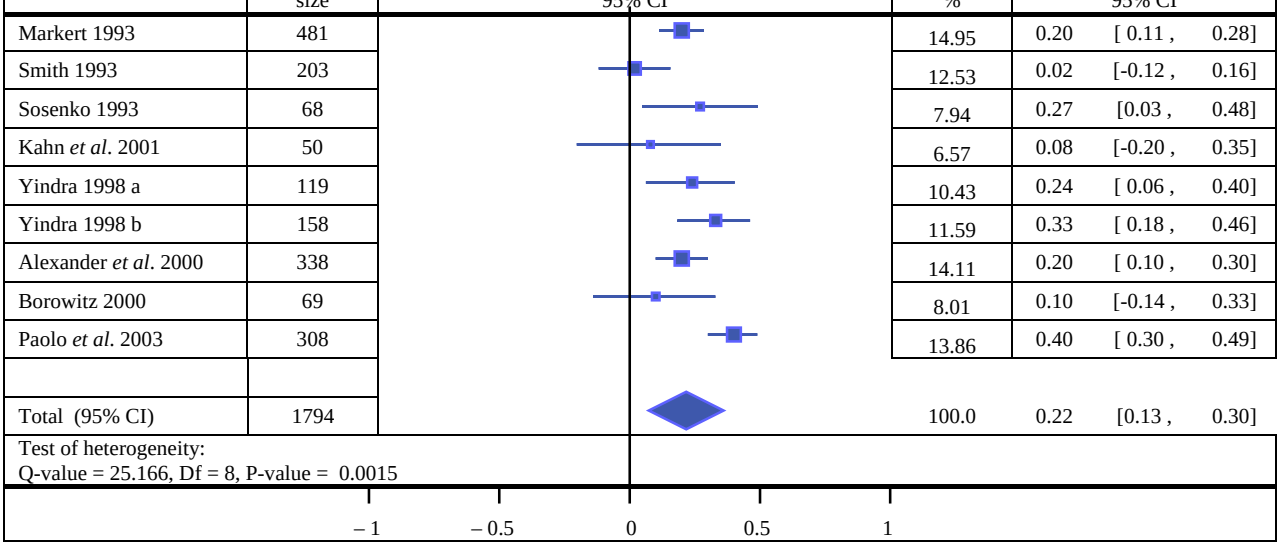


Fig 2: Correlation Coefficient between NBME I (predictor) and Supervisor rating (outcome)

Study name	Sample size	Correlation(Random) 95% CI	Weight %	Correlation(Random) 95% CI
Markert 1993	481		17.08	0.24 [0.15 , 0.32]
Smith 1993	203		14.9	0.02 [-0.12 , 0.16]
Kahn *et al*. 2001	50		8.69	0.22 [-0.06 , 0.47]
Yindra 1998 a	119		12.86	0.37 [0.20 , 0.52]
Yindra 1998 b	158		14.01	0.37 [0.23 , 0.50]
Alexander *et al*. 2000	338		16.35	0.24 [0.14 , 0.34]
Paolo *et al*. 2003	308		16.12	0.42 [0.32 , 0.51]
Total (95% CI)	1657		100.0	0.27 [0.16 , 0.38]
Test of heterogeneity: Q-value = 26.539, Df = 6, P-value = 0.0002				

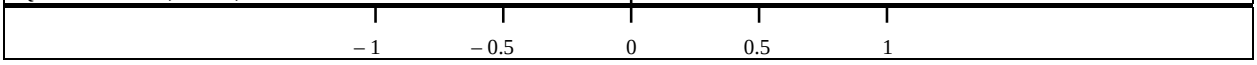


Fig 3: Correlation Coefficient between NBME II (predictor) and Supervisor rating (outcome)

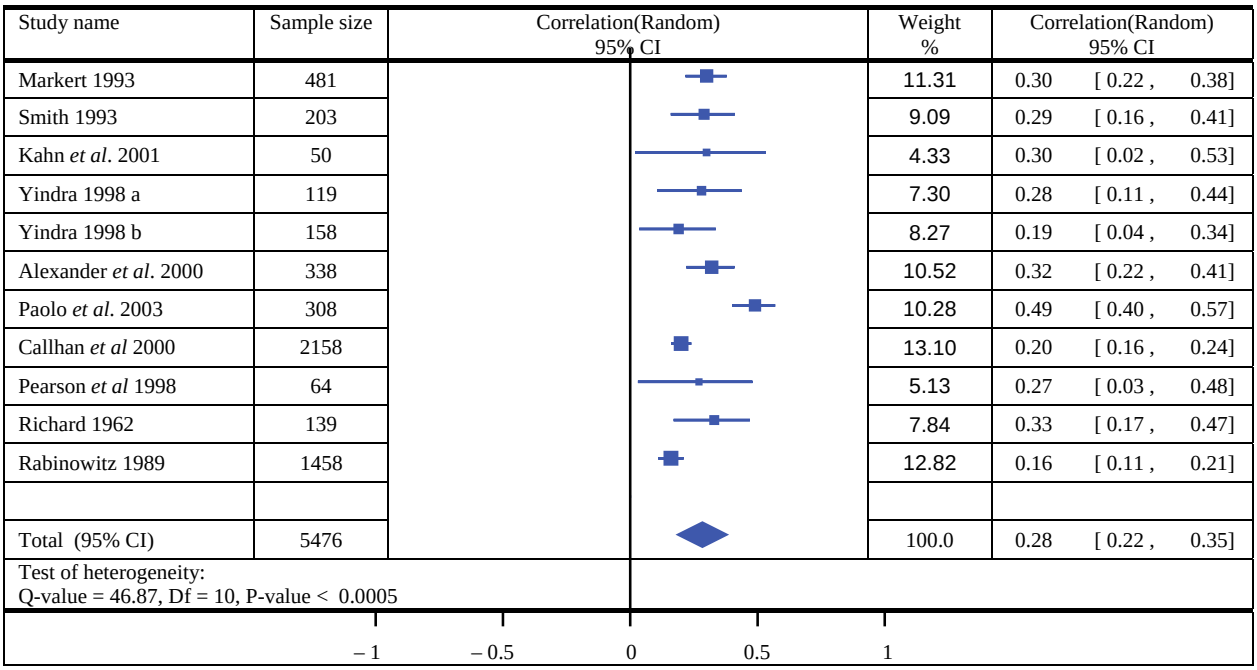


Fig 4: Correlation Coefficient between Clerkship GPA (predictor) and Supervisor rating (outcome)

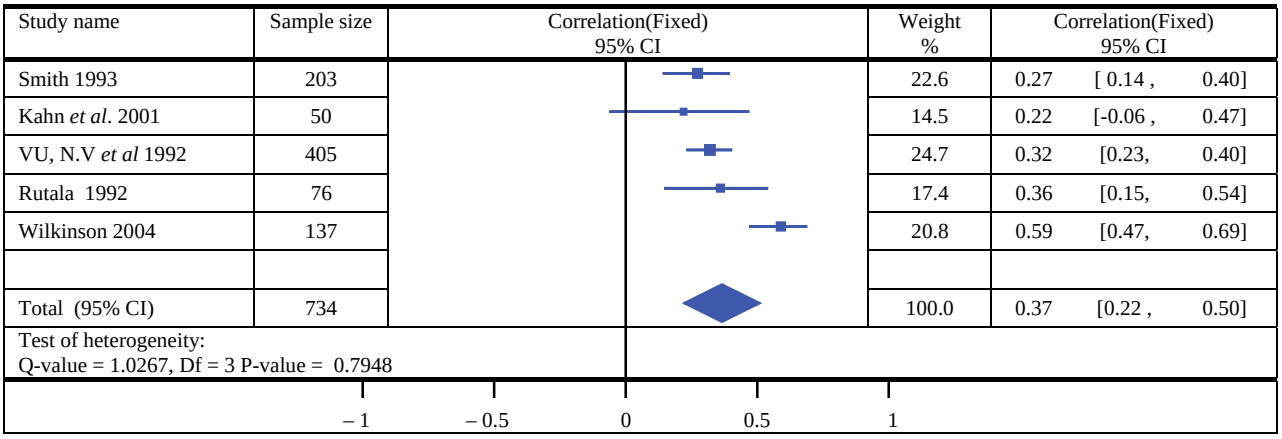


Fig 5: Correlation Coefficient between OSCE (predictor) and Supervisor rating (outcome)

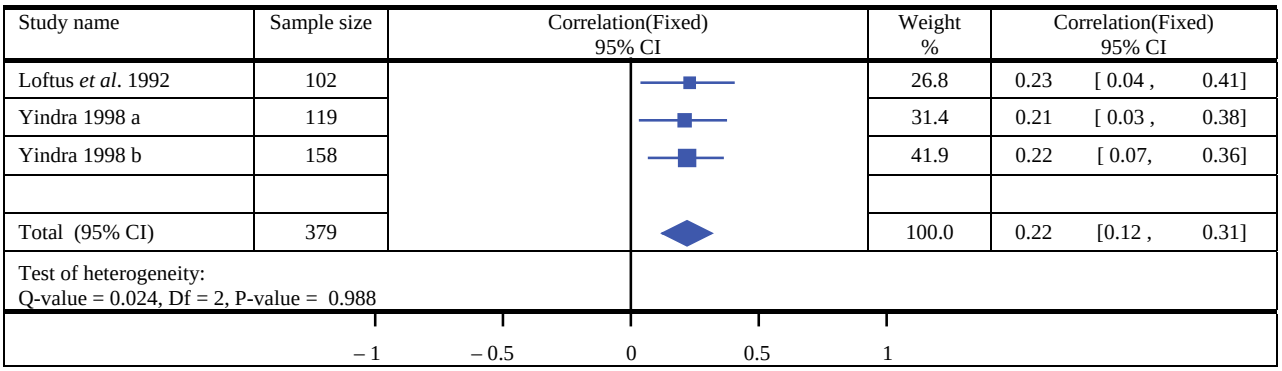


Fig 6: Correlation Coefficient between Ranking (Dean's letter) (predictor) and Supervisor rating (outcome)

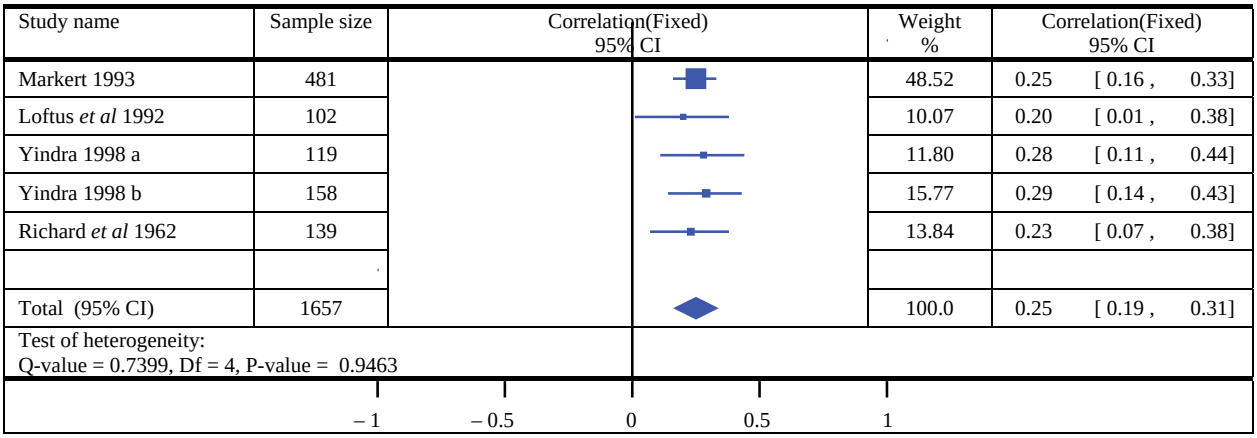


Fig 7: Correlation Coefficient between Pre-clinical GPA (predictor) and Supervisor rating (outcome)

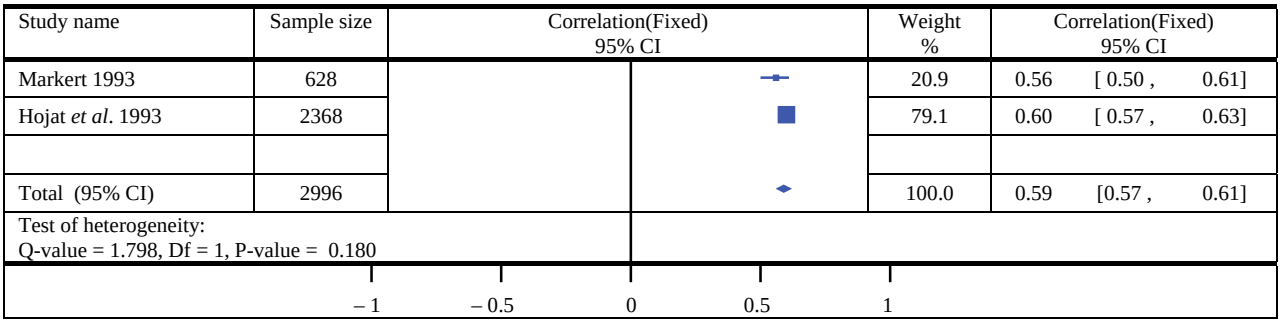


Fig 8: Correlation Coefficient between NBME I (predictor) and NBME III (outcome)

Study name	Sample size	Correlation(Fixed) 95% CI	Weight %	Correlation(Fixed) 95% CI
Markert 1993	628		20.9	0.71 [0.67 , 0.75]
Hojat *et al*. 1993	2368		79.1	0.72 [0.70 , 0.74]
Total (95% CI)	2996		100.0	0.72 [0.70 , 0.73]
Test of heterogeneity: Q-value = 0.207, Df = 1, P-value = 0.649				

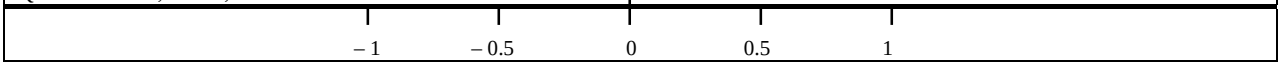
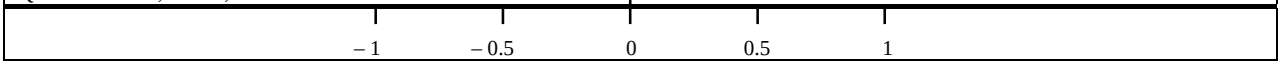


Fig 9: Correlation Coefficient between NBME II (predictor) and NBME III (outcome)

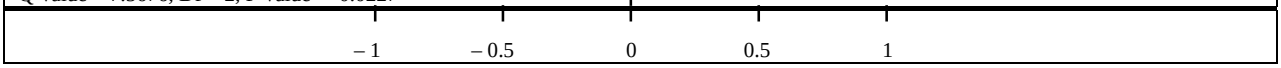
Study name	Sample size	Correlation(Fixed) 95% CI	Weight %	Correlation(Fixed) 95% CI
Case 1993 a *	621		34.02	0.59 [0.54 , 0.64]
Case 1993 b **	214		23.47	0.49 [0.38 , 0.59]
Case 1993 c ***	133		18.14	0.63 [0.52 , 0.72]
Boyse 2002 ****	42		7.62	0.73 [0.54 , 0.84]
Sosenko 1993	117		16.75	0.57 [0.43 , 0.68]
Total (95% CI)	1127		100.0	0.58 [0.54 , 0.62]
Test of heterogeneity: Q-value = 7.112, Df = 4, P-value = 0.130				



* American Board of Orthopedic Surgery; ** American Board of Dermatology; *** American Board of Preventive Medicine; **** American Board of Radiology

Fig 10: Correlation Coefficient between NBME I (predictor) and American Board of Specialty Examination Scores (outcome)

Study name	Sample size	Correlation(Random) 95% CI	Weight %	Correlation(Random) 95% CI
Case 1993 a *	623		38.62	0.64 [0.59 , 0.68]
Case 1993 b **	204		32.02	0.51 [0.40 , 0.60]
Case 1993 c ***	151		29.36	0.68 [0.58 , 0.76]
Total (95% CI)	978		100.0	0.61 [0.51 , 0.70]
Test of heterogeneity: Q-value = 7.5676, Df = 2, P-value = 0.0227				



* American Board of Orthopedic Surgery; ** American Board of Dermatology; *** American Board of Preventive Medicine

Fig 11: Correlation Coefficient between NBME II (predictor) and American Board of Specialty Examination