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The effectiveness of high fidelity simulation versus low fidelity simulation on practical/ clinical skills development in pre-registration physiotherapy students: a systematic review.

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Review title

The effectiveness of high fidelity simulation versus low fidelity simulation on practical/clinical skills development in pre-registration physiotherapy students: A systematic review

Abstract

Objective: To evaluate the effectiveness of high fidelity simulation versus low fidelity simulation on practical/clinical skills development in pre-registration physiotherapy students.

Introduction: Evidence suggests improved skill development in university can reduce anxiety in practice, improving performance of skills and overall learning on clinical placement for health professions students. Yet evidence indicates the clinical environment is most effective for learning. As a result there has been increased interest in the use of high fidelity simulation (HFS) where students can test knowledge and skills in an increasingly self-directed way. No previous reviews on the effectiveness of HFS on skill development in physiotherapy students were identified.

Inclusion criteria: Experimental and quasi-experimental studies comparing HFS (simulated person, manikin, virtual simulation, video case-studies) to low fidelity simulation (peer role-play, paper-based case-studies) in pre-registration physiotherapy education were included. Primary outcomes were objective measures of skills performance; secondary outcomes were students' perceptions of the impact of simulation on learning measured using quantitative outcomes.

Methods: A three-step search strategy was employed. Following initial searching of Medline and CINAHL and analysis of text words Medline, CINAHL, Eric, AMED, EThOS and Google Scholar were searched in November 2017. Reference lists of studies included at critical appraisal stage were hand-searched. Studies published in English from 1978 onwards were included. Title/abstract screening, critical appraisal, and data extraction were conducted by two independent reviewers; conflicts were resolved by discussion.

Results: Meta-analysis was not possible due to heterogeneity therefore results were presented in narrative form. Three randomized controlled trials and three quasi-experimental studies (310 participants) were included. They were conducted in the USA and Australia, and evaluated standardized patients (people who take on the role of a real patient), near-peers, computerized manikins, and virtual simulation in pre-registration Bachelor of Science (Honours), Master of Science, and Doctor of Physiotherapy students. One randomized controlled trial was considered high quality, with the remainder moderate quality. The main findings related to five main areas. (i[KC1]) In terms of motor skill performance an increased number of safety fails were found with HFS (HFS 13.5% safety fails, HFS +video feedback 15.4% safety fails, control (low fidelity simulation) 8.1% safety fails). (ii)

The Assessment of Physiotherapy Practice (APP) tool indicated no significant improvement in mean APP scores at week 6 of clinical placement (HFS 60.7(9.1), control 58.7 (8.4) p=0.35). (iii) Only one of two studies showed a statistically significant diference in clinical reasoning with HFS (p=0.001). This became non-signficant once students were on clinical placement (p=0.328). (iv) Students did not perceive a signficiant difference in their communication skills with HFS (Simulation 9 (+/- 1.27), control 8.75(+/-1.2) p=0.482) although students were significantly more positive about HFS for increasing awareness of; safety issues (p=0.002), patients' emotional status (p=0.002), handling skills (p<0.0001) and their ability to provide instructions to patients (p<0.0001).

Conclusions: Currently there is no high quality evidence that HFS improves motor skill performance in pre-registration physiotherapy students. There is a small amount of moderate quality evidence it may improve students' perceptions of their self-efficacy but no evidence that it improves communication skills. However, a lack of studies and variation in outcome measures used meant meta-analysis was not possible. At present no recommendations can be made regarding the use of HFS to improve skill performance in this population.

Keywords: High-fidelity simulation; Learning; Physical Therapy; Skill development; Students

51 # Summary of Findings

High fidelity simulation compared to low fidelity simulation in physiotherapy pre-registration education

Patient or population: Physiotherapy pre-registration students

Setting: University

Intervention: High fidelity simulation

Comparison: Low fidelity simulation

Outcomes	Impact	№ of participants (studies)	Certainty of the evidence (GRADE)
Motor Skill Performance (Motor)[28] Assessed with: Objective Structured Clinical Examination (OSCE)	One study indicated those who undertook HFS had a worse performance in clinical skill performance.	100 (1 RCT)	⨁⨁⨁◯ MODERATE [a,b,c]
Physiotherapy Performance (APP)[25] Assessed with: Assessment of Physiotherapy Performance	The addition of HFS prior to placement does not improve physiotherapy skills measured by clinical placement outcomes.	50 (1 RCT)	⨁⨁⨁⨁ HIGH
Clinical Reasoning (Reasoning)[24, 27] Assessed with: Various	Conflicting findings in relation to knowledge application between studies. HFS does not appear to influence knowledge development.	53 (2 RCTs) [d]	⨁◯◯◯ VERY LOW [b,c,d,e,f,g,h]
Self-efficacy (SE)[23,27] Assessed with: Various	Students reported improved self-efficacy after participating in HFS.	67 (2 RCTs)	⨁⨁◯◯ LOW [b,c,f,g,i,j]

High fidelity simulation compared to low fidelity simulation in physiotherapy pre-registration education

Patient or population: Physiotherapy pre-registration students

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Comparison: Low fidelity simulation

Outcomes	Impact	№ of participants (studies)	Certainty of the evidence (GRADE)
Perception of Communication Skills (Communication Skills)[26] Assessed with: Questionnaire	Students perceived an improvement in their communication skills through participating in HFS.	39 (1 RCT)	⊕⊕⊕◯ MODERATE b,c,i,j
Perception (Perception)[26] Assessed with: Questionnaire	Students held positive perceptions about participating in HFS.	39 (1 RCT)	⊕⊕⊕◯ MODERATE b,c,i,j

*__The risk in the intervention group__ (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).

CI: Confidence interval

GRADE Working Group grades of evidence

High certainty: We are very confident that the true effect lies close to that of the estimate of the effect

Moderate certainty: We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different

Low certainty: Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect

Very low certainty: We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Explanations

a. Potential facilitator bias influencing intervention

b. Potential confounding variables not controlled.

c. Small sample sizes with no power calculation

d. Lack of data about group sizes.

e. Lack of data about randomization.

f. Different interventions used.

g. Different outcome measures utilized.

h. Lack of demographic data.

i. Outcome measures not validated.

j. Lack of clarity relating to data collection.

Review question

The question of this review is: What is the effectiveness of high fidelity simulated learning methods versus low fidelity simulation on clinical/practical skill development in pre-registration physiotherapy students? The term 'skills' is interpreted broadly addressing practical skills in addition to higher order thinking skills and softer skills such as communication, clinical reasoning and team working.[18]

Introduction

The demands on graduate physiotherapists are increasing due to the changing environment in which the profession is practicing.[1,2] Drivers for safe, effective, but value for money care, mean those entering the profession must develop the core skills to assess and treat patients in an efficient and effective manner while developing the ability to think about how practice can be developed to provide the same quality of care with fewer resources.[3-5] Consequently, those responsible for physiotherapy education need to think differently about how we deliver core training to the physiotherapists of the future. To achieve this we need to develop a culture of creating, sharing and using new and different forms of knowledge.[6]

Transmitting knowledge to students and making them reliant on external sources for feedback is no longer sufficient. The World Conferation of Physical Therapy indicate that the entry level curricula

should equip students with the skills for life long learning and as such the need for self-evaluation is critical. Education is required to be more specific in focusing on affective learning; ensuring students have the engagement and motivation to learn for life. WCPT This motivation and engagement is essential for knowledge acquisition and understanding; the foundation for students to be able to perform in clinical practice to provide effective patient care.[7] Students' expertise is built in real work situations; learning and professional development progress through participation in real experiences.[8] Consequently, learning opportunities that engage and motivate students to learn need to be provided in an authentic environment with freedom to test knowledge and skills in an increasingly self-directed way.[9]

There is evidence that providing opportunities for students to practice skills as realistically as possible can help reduce anxiety in practice and improve performance of skills on clinical placement and overall learning.[9,10] Traditionally, physiotherapy education relies on students practicing skills on peers.[11] Peer practice and role play is considered the low fidelity end of the simulation continuum,[12] with simulation being defined as:

"An array of structured activities that represent actual or potential situations in education and practice. These activities allow participants to develop or enhance their knowledge, skills and attitudes or to analyse and respond to realistic situations in a simulated environment."[13(p32)]

Fidelity refers to "the degree of realism associated with a particular simulation activity" and "the ability of the simulation to reproduce the reactions, interactions and responses of the real world counterpart".[13 (p11,20)] Consequently role play and use of case studies are referred to as low fidelity simulation since the level of experienced reality is limited. This also applies to part task trainers[KC2] which enable students to focus on key elements of procedures but do not themselves provide any feedback.

Sabus and Macauley[14] report on the circumplex model of affect applied to simulation. This suggests that for learning to be most effective students need to be active: if simulation is causing a level of stress, tension and nerves, keeping students alert and excited they will be actively engaged in learning.[14] Traditional, low fidelity simulation methods of practicing on peers is unlikely to achieve this since students feel less threatened when working with each other and may not produce the same level of active engagement.[10] Anecdotally, it is suggested that students are easily distracted when practicing skills on each other, losing concentration and therefore not achieving the requirements for developing mastery of skills through deliberate practice (the need for planning, concentration, tolerance of repetition and reflection).[14]

To develop the necessary skills in a time efficient and effective way a different learning opportunity may be required. Use of high fidelity learning methods (standardized patients, high fidelity manikin use, simulated scenarios) is well established in medical and nursing education.[12] There is also a developing evidence base in physiotherapy. Two systematic reviews have investigated simulation in physiotherapy education. Pritchard et al[15] focused on the use of simulated patients while Mori et al[16] focused more broadly on the use of simulated learning experiences in physiotherapy entry-to-practice curricula. However, neither review focused on whether these higher fidelity methods of simulated learning were effective at improving skill performance in physiotherapy students. Furthermore, an initial search of databases CINAHL and Medline identified that there have been several studies published since the searches undertaken in both previous reviews.[Phillips, Murphy, Sword, Silberman, Black, Blackford] Although universities are being encouraged to maintain, if not improve the quality of the learning experience they are also experiencing pressure to reduce costs.[Grove] As a result it is critical that we can demonstrate effectiveness if we wish to implement what is an expensive method of learning.[Philips] Prior to undertaking this review a search of CINAHL, Medline, PROSPERO and The JBI Database of Systematic Reviews and Implementation Reports was conducted; no systematic reviews on this topic (published or underway) were identified[KC3].

A recent editorial in the Journal of Physical Therapy in Education indicates that it is time to refocus educational research in physiotherapy; that there is a need to understand the context of teaching, learning and evaluation of performance and outcomes.[17] This current systematic review, therefore, aimed to review the evidence of the effectiveness of high fidelity simulated learning in physiotherapy pre-registration curricula and establish whether this method of learning is beneficial to students.

The objective of this review was to identify if high fidelity simulated learning methods are effective at enhancing clinical/practical skills compared to usual, low fidelity simulated learning methods in pre-registration physiotherapy education.

Inclusion criteria

Participants

This review considered studies that included pre-registration physiotherapy students. Pre-registration courses may confer licensure or a Diploma, Honours, Masters (pre-registration) or doctoral degree. The level of qualification required for entry to the profession varies from country to country and consequently any studies that used pre-registration students during their entry level training were

considered. Published research investigating the learning achieved by physiotherapy students during interprofessional learning activities was included only where data specifically relating to physiotherapy students could be extracted.

Intervention

This review considered studies that evaluated high fidelity simulation. The definition of simulation used is that defined in the Healthcare Simulation Dictionary: "An array of structured activities that represent actual or potential situations in education and practice" that enable students to "enhance their knowledge, skills and attitudes or to analyze and respond to realistic situations in a simulated environment".[13 (pp31)]

With low fidelity simulation defined as "Not needing to be controlled or programmed externally for the learner to participate"[13(20)] and high fidelity simulation as:

"Simulation experiences that are extremely realistic and provide a high level of interactivity and realism for the learner; Can apply to any mode or method of simulation; for example: human, manikin, task trainer, or virtual reality."[13(p14)]

As this review aimed to be comprehensive, a range of simulated activities were included such as:

- Simulated person – "a person portraying a patient"[13 (pp32)]
- Manikin-based simulation – "the use of manikins to represent a patient"[13 (pp21)]
- Virtual simulation – "the recreation of reality depicted on a computer screen"[13(pp40)]

Simulated person encompasses standardized patients, volunteer patients and near-peer role play. These interventions may be supplemented by on-line study/skills packages, video demonstrations and by reflection on skills performance through video analysis. However, video only learning packages to help skill development were classified as computer aided learning and were consequently excluded.[19] Interventions included were classed as high fidelity but this was broad in interpretation to encompass anything beyond the traditional low fidelity simulation methods used in physiotherapy education (peer practice/role play and paper patients).[13] If a study used both low and high fidelity methods it was included only if the dominant component was high fidelity or if it was possible to separate information relating to the two methods.

Methods of portraying patients such as video clips can be incorporated into virtual learning resources. These can be developed to require students to apply clinical reasoning skills. Consequently such video case studies were included as they can be classified as high fidelity.[13(p14)] Additionally, simulations of

any frequency and/or intensity were included.

Comparator

This review considered studies that compared the high fidelity intervention to low fidelity simulation. Traditionally pre-registration physiotherapy education requires peers to take on the role of 'patient' in the form of role play and for skills to be practiced on peers wherever this is appropriate; activities which are classed as low fidelity simulation.[13(p20)] As a consequence peer practice and peer role play were the comparators in this systematic review. Paper patients/case studies were a further comparator.

Outcomes

Primary outcomes in this review included standardized objective measures of skills performance including peak force, force amplitude, oscillation frequency and the assessment of physiotherapy practice (as it relates to clinical placement). Measures of clinical reasoning, self-efficacy, confidence, communication skills and professional skills such as team working and prioritization were included. Any method of measuring these outcomes were included such as standardized measures (for example Student Perception of Effective Teaching in Clinical Simulation (SPETCS), Attitudes Towards Health Care Teams Survey, Readiness for Interprofessional Learning (RIPL), Arizona Clinical Interviewing Rating Scale and Assessment of Physiotherapy Practice tool (APP). Additionally measures developed by researchers specifically for their study were included.

Secondary outcomes were aspects such as perception of impact where the change was not actually measured but was reported by students in questionnaires using quantitative outcomes. Outcomes were measured pre and post intervention or only post intervention. This was influenced by the type of study.

Types of studies

This review considered both experimental and quasi-experimental study designs including randomized controlled trials and non-randomized controlled trials, and interrupted time-series studies. In addition, analytical observational studies including prospective and retrospective cohort studies, case-control studies and analytical cross-sectional studies were considered for inclusion.

Methods

This systematic review was conducted in accordance with the JBI methodology for systematic reviews of effectivness evidence.[20] This review was conducted in accordance with an *a priori* protocol.[21]

Search strategy

The search strategy aimed to find both published and unpublished studies. A three-step search strategy was utilized in this review. An initial limited search of Medline and CINAHLwas undertaken followed by analysis of the text words contained in the title and abstract and the index terms used to describe the articles. A second search using all identified keywords and index terms was undertaken on 8th November 2017 across the following databases[KC4]: CINAHL, Medline, Eric and AMED. The search for unpublished studies and gray literature included: EThOS Networked Digital Library of Theses and Dissertations and Google Scholar. Finally, the reference lists of all reports and articles selected for critical appraisal were searched for additional studies. Studies published in English and published from 1978, when physiotherapy first became an autonomous professions in the United KingdomCSP, were considered for inclusion in this review.

The full search strategy for CINAHL, Medline, Eric, AMED and gray literature is provided in Appendix I.

Study selection

Following the search, all identified citations were loaded into RefWorks (Proquest LLC) and duplicates removed. Titles and abstracts were screened by two independent reviewers for assessment against the inclusion criteria for the review. The full text of potentially eligible studies was retrieved and assessed in detail against the inclusion criteria by two independent reviewers. The details of studies that met the inclusion criteria were imported into the Joanna Briggs Institute's System for the Unified Management, Assessment and Review of Information (JBI SUMARI, The Joanna Briggs Institute, Adelaide, Australia). Full text studies that did not meet the inclusion criteria were excluded and reasons for their exclusion are provided in Appendix II. Any disagreements that arose between the reviewers were resolved through discussion.

Assessment of methodological quality

Eligibile studies were critically appraised by two independent reviewers at the study level using standardized critical appraisal instruments from the Joanna Briggs Institute for experimental and quasi-experimental studies[JBI]. Any disagreements that arose between the reviewers were resolved through discussion. In order to be comprehensive, a threshold score was not implemented. Consequently all studies that met the inclusion criteria were included but their methodological quality is reported and considered in relation to interpretation of the findings. Both reviewers determined, in discussion, what would consistute 'high', 'moderate' or 'low' quality scores. This resulted in RCT scores being determined as 'high' scores of nine or more, 'moderate' scores being seven or eight and anything below seven being 'low' quality. For quasi-experimental studies 'high' quality was determined as seven or eight out of eight, while five or six scored as 'moderate' quality and anything below five was 'low' quality.

Data extraction

Data was extracted from studies included in the review by two independent reviewers, using a modified version of the standardized JBI data extraction tool (appendix III). The data extracted included specific details about the interventions, populations, study methods and outcomes of significance to the review question and specific objectives. In particular the method of simulation utilized along with the frequency, duration and whether undertaken individually or in groups. Any disagreements that arose between the reviewers were resolved through discussion therefore a third reviewer was not required. Where relevant, authors of studies were contacted to request missing or additional data.

Data synthesis

Statistical pooling was not possible due to the variety of outcome measures used; no two studies used the same outcome measures. Additionally, there was often only one study that had investigated an aspect of skills performance. As a result the findings are presented in narrative form including tables and figures to aid in data presentation where appropriate.

Assessing certainty in the findings

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) approach for grading the certainty of evidence was followed [Guyatt] and a Summary of Findings (SoF) table was created using GRADEPro GDT 2018 (McMaster University, ON, Canada). The SoF table presents a ranking of the quality of the evidence based on the risk of bias, directness, heterogeneity, precision and risk of

publication bias of the review results. The outcomes reported in the SoF table include: Motor skill performance, Physiotherapy Performance, clinical reasoning, self efficacy, perception of communication skills, and students' perceptions.

Results

Study inclusion

Five thousand and sixty two articles were identified. This included 13 articles found by manually reviewing the reference lists of full text articles and the gray literature search. Once articles from all databases were collated 833 duplicate articles were removed leaving 4229 titles for screening. Of these, 4166 were excluded through title and abstract screening. Sixty three articles went forward for full text screening. Ten authors were contacted for further information; two full papers reporting on interdisciplinary activities and eight conference abstracts. Five authors responded but could not provide the additional data and these articles were consequently excluded. The remaining authors did not reply and these articles were also excluded. In total 57 articles were excluded at full text review. The reasons for exclusion can be seen in figure 1 and Appendix II (authors who were contacted for further information are identified in this appendix). The remaining 6 articles were progressed to quality appraisal and included in the review (appendix IV) and comprised 3 RCTs and 3 quasi-experimental studies.

<Insert fig 1 here>

Methodological quality

Methodological quality ranged from moderate to high (Tables 1 and 2). Two questions from the RCT tool were considered not applicable. Question 4: Blinding of participants, and question 5: Blinding of those delivering treatment (simulation), since neither would be possible for these educational studies. Hence the highest score possible for the RCTs was 11. Question 5; multiple measurements both pre- and post-intervention was similarly not applicable for the quasi-experimental studies, therefore the highest score possible was 8.

<Insert tables 1 & 2 here>

All 3 RCTs investigated different aspects of effectiveness but all used different validated outcome

measures that were applied in a reliable way hence reducing bias.[23-25] However, two of the RCTs were unclear about randomization methods, whether there was concealed allocation to treatment groups and whether outcome assessors were blind to group assignment hence introducing potential sampling and measurement bias.[23,24] Both these studies scored moderately in the quality appraisal (7/11) while the remaining study scored 11/11.[25]

One quasi-experimental study was moderate quality (6/8)[27] with the remaining two being high quality (7/8).[26,28] The outcomes being investigated (clinical performance, knowledge, student perceptions) could be influenced by many potentially confounding factors; however, by only measuring outcomes once post simulation the impact of confounding factors was limited. Measurement of outcomes was generally poorly reported however which introduces a potential threat to validity of any inferences drawn from these studies.[26,27] Despite their moderate to high quality scores, none of these studies used validated outcome measures. The measures used were developed in-house and their psychometric properties were not reported.[26-28]

Throughout the studies there are consistent issues relating to sample sizes. Sample sizes ranged from n=16 (8 participants/ group) to n=101 (approximately 37 participants/group).[23,28] Only one study utilized a power calculation to estimate an appropriate sample size required to detect statistical significance but failed to achieve the required sample size.[25]

Characteristics of included studies

Of the studies included, three were RCTs,[23-25] and three quasi-experimental studies [26-28] They were undertaken in the USA[23,24,26,27] and Australia.[25,28]

All the studies were undertaken within a university setting although one high quality RCT then assessed students in clinical practice as it aimed to investigate whether high fidelity simulation could enhance clinical performance and reduce clinical time required to attain competency.[25] Only one high quality quasi-experimental study investigated whether simulated learning improved skill performance.[28] Two moderate quality studies, one RCT and one quasi-experimental, focused on whether high fidelity simulation could improve physiotherapy students' knowledge,[24,27] and two reported on students' perceptions and self-reported behaviors with a strong focus on confidence. These were a moderate quality RCT[23] and a moderate quality quasi-experimental study.[26]

Across the six studies there were a total of 310 participants. One hundred and fifty one were

undertaking a BSc (Honours) degree,[25,28] 90 were MSc Pre-registration students[26, 27] and 69 were completing a doctorate in physiotherapy.[23,24] The male:female ratio of participants was reported in five of the studies and when data is pooled this results in 32% male and 68% female participants.[23-26,28] These same five studies reported mean ages ranging from 19 to 26.62 years. No further demographics could be reported due to different reporting scales and data collected over different time periods, for example Grade Point Average (GPA). Study characteristics are shown in Appendix IV.

Two high quasi-experiemental studies utilized standardized patients in their simulations,[26,28] the third used near peers to undertake the role of simulated patients.[27] Of the RCTs one high quality and one moderate quality study utilized computerised manikins,[23,25] and the remaining incorporated virtual simulation.[24] Details of the interventions are provided in table 3 which shows variation in the number and duration of simulations, whether they were undertaken individually or in groups and whether time-outs and debriefs were provided.

<Insert table 3 here>

Review findings

The findings are presented in relation to the primary and secondary outcomes of interest to this review.

Primary Outcomes

I: Standardized, objective measures of skills performance

Peak Force, Force Amplitude, Oscillation Frequency

None of the included studies measured these outcomes.

Assessement of Physiotherapy Performance

One high quality RCT, by Jones and Sheppard, was found that used this outcome measure.[25] They aimed to investigate if simulation can replace clinical time by providing simulated learning prior to clinical practice, the comparison was 'traditional training' which comprised of didactic lectures and practical classes. They recruited 62 students, 31 per group and used the Assessment of Physiotherapy Practice tool (APP). The APP measures students' skills in subjective assessment, objective assessment, interpretation from assessment findings (clinical reasoning), and communication in addition to evaluation of effectiveness of treatment. Their results suggest that HFS made no difference to clinical

performance, that is skill performance, as measured on the APP at the end of placement (Sim 60.9(9.1), control 58.7(8.4) p= 0.35).

Despite using a valid and reliable outcome measure[29] the study was underpowered gaining APP measurements for only 21 students in the simulation group when a power calculation indicated a sample size of 30 was required.

Motor Skill Performance

The high quality study by Phillips et al used a quasi-experiemantal study design to investigate if high fidelity simulation using simulated patients would produce a difference in students' motor skills performance and failure rates as assessed by an observed structured clinical examination (OSCE).[28] They recruited 103 students who were allocated to one of the practical groups in a non-randomized way: One group undertook skills practice using normal practice of role play with peers (n=37); one group practiced on simulated patients who provided feedback (n=28); the final group also used simulated patients who provided feedback but also had the option of viewing a video of their performance for feedback (n=38). Groups were similar in age but the proportion of males and level of academic achievement as measured by grade point average (GPA) varied (Table 4).

Results are shown in table 4 and indicate that those who practiced with simulated patients and had the video feedback opportunity had the lowest performance scores but analysis to show whether this was statistically significant was not undertaken. The results also show that the HFS alone and HFS and video feedback groups, who practiced with simulated patients, which included practice of a safety issue, had the highest number of safety fails (defined as a breach of safe or professional practice).

<insert table 4 here>

II: Measures of clinical reasoning, self-efficacy, confidence, communication skills and professional skills

Clinical Reasoning

Two studies, an RCT by Huhn et al[24] and a quasi-experimental study by Boissonault et al[27] investigated the impact of high fidelity simulation on students' knowledge. The RCT compared traditional lectures

with a single, 20-minute near peer simulated patient activity followed by students discussing and presenting back their findings with 53 students.[24] They used the Health Science Reasoning Test (HSRT), a standardized and validated test of knowledge and clinical reasoning in addition to an observed structured clinical examination (OSCE) to assess transfer of knowledge. The quasi-experimental study investigated the effectiveness of a virtual patient simulation programme compared to a tutor-facilitated discussion for promoting clinical reasoning and knowledge acquisition in 67 students.[27] A written examination, was used to assess student knowledge. Neither study performed a power calculation but used convenience samples.

The moderate quality RCT by Huhn et al found no statistically significant difference in mean scores in knowledge acquisition or knowledge transfer between their control and simulation groups (knowledge acquisition - HSRT: control 74.07 (SD 8.47) HFS 77.65 (SD 7.95) p=0.59) (knowledge transfer - OSCE: control 88.79(SD 24.23) simulation 89.67 (SD 8.91) p= 0.214).[24] In contrast, the quasi-experimental study found a statistically significant difference in performance between groups in overall examination scores (control mean score 50%, HFS mean score 59% p = 0.01). Boissonnault et al further analysed for any difference between knowledge and knowledge application. [27] They found no statistically significant difference between groups in knowledge questions (HFS 36% (SD 0.16) vs control 45% (SD 0.18) p=0.05) but they did find a significant difference for knowledge application questions (59% (SD 0.24) vs 74% (SD 0.24) p=0.01).

Self-efficacy and confidence

Students' beliefs in their ability to produce specified levels of performance was investigated by two studies; one RCT by Silberman et al,[23] who had a sample of 16 DPT students and one quasi-experimental by Boissonnalt et al who utilized a sample of 67 MSc students.[27]

Silberman et al's moderate quality RCT included aspects of patient assessment and treatment application and therefore self-efficacy in skill performance.[23] This was the only study to utlise a valid and reliable outcome measure in the Acute Care Confidence Survey (ACCS). The control, who received the standard curriculum (nor further detail provided) and HFS groups both completed the survey at 3 time points: before the simulation (T1), after the simulation but just prior to clinical placement (T2) and midway through clinical placement (T3). Those who participated in the high fidelity simulation, using a high-fidelity manikin, showed a statistically significant improvement in self-efficacy at each completion of the ACCS (T1-T2 and T2-T3, p = 0.012) compared to the control group who only showed an improvement once on placement (T-T2 p=0.735, T2-T3 p=0.017). The difference was statistically significant between groups after the simulation period (T1-T2, p = 0.001) although this difference

became non-significant during placement (T2-T3, p=0.328).

Boissonault et al's moderate quality quasi-experimental study compared a high fidelity simulation group, who practiced skills with standardized patients, with a control group who received normal low fidelity simulation methods. Students were asked to mark their confidence in medical screening and patient referral abilities on a visual analogue scale pre and post simulation. They found a statistically significant difference in favour of simulation (simulation 53mm +/- 0.17, control 45mm +/-0.17 p<0.05).[27]

Communication skills

No studies were located that objectively measured the impact of high fidelity simulation on physiotherapy students' communication skills.

Professional Skills - Team Working

None of the included studies measured this outcome.

II: Secondary Outcomes – perception of impact

Perception of impact on Communication Skills

No studies were found that objectively assessed whether communication skills improved through use of high fidelity simulation. However, one moderate quality quasi-experimental study by Black and Marcoux investigated students' perceptions of its impact on communication skills.[26] This involved 39 students undertaking a pre-registration MSc with a mean age of 23 yrs and an average 80% female students.[26] Students were asked to complete a visual analogue scale (VAS) for the statement 'the experience was helpful in improving communication skills'and the results for the high (standardized patients) and low fidelity simulation group (peer practice) were compared. Results showed no significant difference in students' perceptions of their communication skills (Simulation 9.05 (+/-1.27), control 8.75(+/-1.2) p=0.482).[26]

General Perceptions

One high quality quasi-experimental study addressed issues of students' perceptions of high fidelity simulation.[26] Black and Marcoux compared the perceptions of 39 students, 20 of whom had

experienced a high fidelity simulated learning experience (assessing gait with a simulated patient) with the control group (n=19) undertaking a normal class where the undertook peer practice. Students who experienced the high fidelity simulation had significantly more positive responses to questions relating to the experience increasing their awareness of: safety issues (p = 0.002), patients' emotional status (p=0.002), handling skills (p<0.0001, abilty to provide instructions to the patient (p<0.0001).

Discussion

This systematic review aimed to investigate the effectiveness of high fidelity simulated learning methods versus low fidelity simulation on clinical/practical skill development in pre-registration physiotherapy students. The main findings suggest there is currently no high quality evidence that high fidelity simulation improves motor skill performance. However there is moderate to high quality evidence from a small number of studies that suggests students may have improved application of knowledge, in the form of clinical reasoning, from participating in high fidelity simulation and also improved self-efficacy in skills performance. There appears to be no improvement in basic knowledge development however. There is also no high quality evidence that students perceive any improvement in communication skills following high fidelity simulation.

In this review 'skills' was widely interpreted to encompass motor skills and, additionally, clinical reasoning and communication skills as well as professional skills such as team working. We also identified a-priori that the review would consider students' perceptions of the benefit of high fidelity simulation but only where comparison with low fidelity simulation was undertaken. The methods used in the retrieved studies were RCTs and quasi-experimental studies. Three hundred and ten participants were included but no meta-analysis was possible due to the heterogeneity in outcome measures which reflected the wide variation in the aspects of 'skills' which were investigated. This also reflected the lack of studies investigating effectiveness of high fidelity simulation that included a low fidelity simulation comparator; a large number of studies on high fidelity simulation were excluded at title/abstract screening stage for this reason, indicating a need for high-quality effectiveness studies in this area.

Only one high quality quasi-experimental study investiged actual skill performance and found that the two groups who received high fidelity simulation to help learn about safety issues had a higher incidence of safety fails than those who practiced on peers.[28] However this study utlised a one-off simulation opportunity. Evidence suggests that while an appropriate level of stress/tension/nerves

improves the arousal level helping students to actively engage in a learning opportunity, raising these negative emotions too much can inhibit learning[14] and performance.[30] It is therefore possible that the results may have been different had more than one simulation session been utilized.

An integrative review published in 2016 investigated the effects of simulation on nursing students' stress and results indicated that students reported simulations to be nerve-wracking and overwhelming.[31] These feelings have been shown to produce increased cortisol levels during simulations although data suggests the cortisol levels may reduce as students are exposed to more simulations.[32] This may support the idea that students who are exposed to simulation on a regular basis may learn more effectively from the experience due to appropriate arousal levels while those who are parachuted into a one off experience may have their learning inhibited. This may explain the negative findings of the quasi-experimental study by Philips.[28]

There is evidence from the studies included in this review that high fidelity simulation may improve clinical reasoning but only two studies considered this.[24,27] Neither showed any improvement in knowledge acquisition and findings relating to application of knowledge were conflicting with only one of the studies suggesting an improvement in this area.[27] However, the quality of the evidence is moderate.[24,27]

The impact of high fidelity simulation on communication skills was only evaluated via students' perceptions and only by one study in this review.[26] This finding is based on visual analogue scale responses to one non-validated question consequently questioning the validity of the finding.

The RCT by Jones and Sheppard[25] which used the standardized, validated APP to measure skills performance failed to show any benefit from including eight hours of high fidelity simulation prior to students undertaking clinical placement. This is in direct contrast to two other studies which have been published on the same topic that had very robust methods and large sample sizes (although slightly underpowered) which suggested that high fidelity simulation could replace some clinical time. The comparator in these studies was real clinical practice resulting in them being excluded from this review.[33,34] There is therefore a need for further high-quality research using standardized, validated tools, to compare high fidelity to low fidelity simulation, in order for future meta-syntheses to be conducted.

Despite the findings of Jones and Sheppard's RCT, two studies, the RCT by Silberman et al and the quasi-experimental study by Boissonnault et al, reported in this review demonstrated positive impact on students'self-efficacy.[23,27] There is evidence to suggest that there is a hierarchy of needs associated with learning. At the bottom is the need for a feeling of safety and security, self-efficacy, knowledge and experience of what to expect in the clinical environment.[9] Consequently the nature of the eight hours of simulated learning provided by Jones may not have been sufficient to address these needs[25] considering RCTs undertaken by Blackstock et al.[33] and Watson et al.[34] provided students with the equivalent of one week of simulated learning which included 18 simulation activities, timeout and rewind options and debriefing. Unfortunately no studies have investigated if improved self-efficacy translates to improved skill performance in physiotherapy students.

A fundamental issue limiting comparisons across studies in this review was the variety of simulation methods used. This not only relates to whether simulated patients or high fidelity manikins were utilized but also how many simulations students were exposed to, whether debriefing was included and how it was incorporated (table 3). Debriefing is considered a core component of simulation to facilitate learning and its omission could strongly influence student outcomes.[14] This lack of debriefing may partly explain why some studies did not find any effect from high fidelity simulation.

A key finding of this review is the limited, high quality evidence available that has investigated the effectiveness of high fidelity simulation for improving the skills of pre-registration physiotherapy students. This may relate to the developing nature of the integration of high fidelity simulation in physiotherapy education. Evaluation studies using pre and post methodology can be found from the 1990s[35-37] but it is only in the last ten years that higher quality studies have been published as evidenced by this review and few have focused on effectiveness in comparison to low fidelitly simulation.[33,34] The lack of evidence may also be a reflection on the developing nature of education research in physiotherapy and the methodological challenges research of this type presents.[17] Another possible reason for the lack of effectiveness studies may be the lack of valid and reliable outcome measures appropriate to assess these skills as evidenced from this review. Developing such outcomes to enable valid and reliable assessments of whether high fidelity simulation is more effective than low fidelity must be a priority considering the cost of undertaking this innovative learning method.[28]

This is the third systematic review to evaluate the effect of simulation in physiotherapy pre-registration education. The first, published in 2015, suggested that simulation improved skill performance through specific output feedback for mobilisation of the spine.[16] However, simulation was not the intervention but the method of measurement in several of the included studies. The second review focused on the use of simulated patients but the authors recognized that their review was limited due to assumptions

that they made to enable pooling of data for meta-analysis.[15] They reported that simulation appears to have an effect but they deduced this from studies that did not measure objective change in skill performance. The consistent finding across all three reviews are that the quality of evidence considering the effectiveness of simulation to enhance skill development is generally of moderate quality; a problem still evident in the most recent research.[28]

Main limitations of included studies

The main limitations of the studies included in this review relate to small sample sizes, heterogenous outcome measures and study designs at moderate to high risk of bias. Only six studies that included a control group fulfilled the inclusion criteria for this review and enabled a true comparison of whether high fidelity simulation is more effective than traditional teaching methods. Power calculations were either not undertaken or, if they were, studies failed to recruit the necessary number of participants resulting in some studies being underpowered to detect statistically significant differences.[25] Additionally a wide range of outcome measures were used in the included studies. Only three validated tools were reported, the APP[25] the health sciences reasoning test[24] and Acute Care Confidence Survey[23] but many custom designed tools (OSCEs, exams and perception questionnaires) were utilized that were subsequently un-validated (or reports of their psychometric properties could not be located). A further limitation is that while some studies reported extensive information on how their simulations were developed to ensure they represented real clinical situations, there was wide variation in how the simulations were undertaken, the number of simulations and durations of each. Additionally, there was variation in whether core simulation aspects such as debriefing were provided and the level to which this was offered when it was used.

Limitations of the review

Very few studies were located that objectively measured the effectiveness of high fidelity simulated learning methods versus low fidelity simulation on clinical/practical skill development in pre-registration physiotherapy students which significantly limits the conclusions that can be drawn. A small number of non-English articles were excluded from the review which does influence the generalizability of findings since education methods may differ from country to country. A further limitation is that meta-analysis was not possible which also limits the conclusions that can be drawn regarding the effectiveness of high fidelity simulation.

Conclusions

From the evidence reviewed there is currently no high quality evidence that high fidelity simulation improves motor skill performance in pre-registration physiotherapy students in comparison to traditional learning methods which constitutes low fidelity simulation. There is moderate quality evidence from three number of studies that suggests HFS may improve students' self-efficacy although it has not been investigated if this translates to improved clinical performance in practice. There is currently no evidence that students perceive any benefit to their communication skills from undertaking HFS

What has not been established from this review however is the core question of whether high fidelity simulation enhances the development of students' skills i.e. the core skills required for one-to-one assessment and treatment sessions. Currently there is very limited moderate quality evidence suggesting there is no impact, although there is a small amount of moderate quality evidence to suggest it could improve clinical reasoning skills. Further research is required to investigate actual skill acquisition and performance to establish if this is influenced by increasing the fidelity of simulated learning. Additionally, it would also be useful to establish if students are more actively engaged in interactions during high fidelity simulations compared to the traditional low fidelity simulations used historically.

A consistent finding is that the reporting of studies must be improved to show that research into the use of high fidelity simulation in physiotherapy pre-registration education is being undertaken in a robust way. Attention needs to be given to whether there is actually an impact on skills performance rather than focusing on the easier to establish 'students' perceptions'. As a consequence, valid and reliable outcome measures need to be developed so that studies can be replicated and findings verified.

Recommendations for practice

The evidence gained from this review suggests that high fidelity simulation may be an effective learning tool to increase students' confidence and self-efficacy in their uni- and inter-professional knowledge and skills. However, currently there is insufficient evidence to suggest that high fidelity simulation improves students' skill performance or knowledge development. As a result, no recommendations can currently be made relating to the use of high fidelity simulation, within the university curriculum, to improve skills performance. This is a concern considering costly, high fidelity simulation is being widely adopted across physiotherapy training programmes and suggests further research on effectiveness would be beneficial to establish if this method of learning is beneficial and consequently cost-effective.

Recommendations for research

Further RCTs should be undertaken with larger sample sizes and robust methods to control for assessor

bias. These need to focus on the impact of high fidelity simulation on student skill development/performance and knowledge development/application in the first instance. Investigation of student activity during high fidelity simulations and comparison to more traditional teaching methods would also be beneficial to clarify if the level of student engagement differs between high and low fidelity simulation. Subsequently further research investigating whether any improvement in skill performance gained through high fidelity simulation is transferred to the real clinical environment would be appropriate.

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Conflicts of interest

The authors declare no conflict of interest

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Appendix I: Search strategy[KC5]

Search conducted on 8th November 2017[KC6]

Cinahl

1. population	(MH(physical therap*) OR "physiotherapy*"kw OR "student physical therap*"kw OR "student physiotherap*"kw	50,975
2. intervention	(MH(simulat*) OR (MH(patient simulat*) OR (MH(Computer simulat*) OR "clinical skill*"kw OR "high fidelity simulat*"kw OR "simulat patient*"kw OR " standard patient*"kw OR "on line skill"kw OR "web based"kw OR "on line technology" kw OR "virtual simulat*" OR "virtual patient*"kw OR "feedback"kw	53,188
3. comparator	(MH(Role play*) OR "low fidelity simulat*"kw OR "paper patient*"kw OR "clinical vignette*"kw	46,179
4. Outcome	(MH (Auscultat*) OR "skill develop*"kw OR "palpation skill"kw	2215
	1 and 2	**1142**[KC7]****
	1 and 2 and 3	25
	1 and 2 and 3 and 4	0

*In order to be as inclusive as possible the bold figures indicate those that were included for screening

Medline

1. population	"physical therap*"kw OR "physiotherapy*"kw OR "student physical therap*"kw OR" student physiotherap*"kw	72,790
2. intervention	(MH (Feedback) OR (MH (High fidelity simulat* train*) OR (MH (Clinical competence) OR (MH (Patient simulat*) OR (MH (Computer simulat*) OR "simulat*"kw OR "simulat* patient" OR "standard* patient" OR "on line skill"kw OR "web based"kw OR "online technology"kw OR "virtual patient" OR "virtual simulat*"	698549
3. comparator	(MH (Role play*) OR "low fidelity simulat*"kw OR "paper patient*"kw OR "clinical vignette*"kw	841023

4. Outcome	(MH (Auscultat*) OR “skill develop*”kw OR (MH (palpation skill)	7079
	English language: 1978 – Oct 2017	
	1 and 2	**3281**
	1 and 2 and 3	100
	1 and 2 and 3 and 4	0

757

758 AMED

1. population	(MH (Physiotherap*) OR “physical therap*”kw OR “student physical therap*”kw OR” student physiotherap*”kw	25945
2. intervention	(MH (feedback) OR (MH (simulat* training) OR (MH (patient simulat*) OR (MH (Computer simulat*) OR “clinical skill*”kw OR “high fidelity simulat*”kw OR “simulat* patient” OR “standard* patient” OR “on line skill”kw OR “web based”kw OR “online technology”kw OR “virtual patient”kw OR “virtual simulat*”kw	3189
3. comparator	(MH (Role play*) OR “low fidelity simulat*”kw OR “paper patient*”kw OR “clinical vignette*”kw	3521
4. Outcome	(MH (Auscultat*) OR (MH (palpation skill) OR “skill develop*”kw	665
	English language: 1978 – Oct 2017[KC8]	
	1 and 2	**532**
	1 and 2 and 3	15
	1 and 2 and 3 and 4	0

759

760

761 ERIC

1. population	(MH (physical therap*) OR "Physiotherap*"kw OR "student physical therap*"kw OR" student physiotherap*"kw	1464
2. intervention	(MH (feedback) OR (MH (simulat*) OR (MH (computer simulat*) OR "patient simulat*"kw OR "clinical skill*"kw OR "high fidelity simulat*"kw OR "simulat* patient" OR "standard* patient" OR "on line skill"kw OR "web based"kw OR "online technology"kw OR "virtual patient"kw OR "virtual simulat*"kw	57539
3. comparator	(MH (Role play*) OR "low fidelity simulat*"kw OR "paper patient*"kw OR "clinical vignette*"kw	32841
4. Outcome	(MH (Skill develop*) OR "Auscultat*"kw OR "palpation skill"kw	47444
	English language: 1978 – Oct 2017	
	1 and 2	**94**
	1 and 2 and 3	1
	1 and 2 and 3 and 4	0

762

763 Ethos Search

Search Term	No of Hits	No included to screening	No excluded and reason
Physiotherapy	319	3	1 – not effectiveness 2 - wrong population
High fidelity simulation	16	1	1 – wrong population
Simulated patients	27	2 (1 duplicate) - 1	1 wrong population

764

765 Google Scholar Literature Search Terms used

766 • Physiotherapy simulation
767 • Physical therapy simulation

- Virtual simulation in physiotherapy education
- Virtual simulation in physical therapy education
- Simulated patients in physiotherapy education
- Simulated patients in physical therapy education
- Standardized patients in physiotherapy education
- Standardized patients in physical therapy education
- High-fidelity simulation in physiotherapy education
- High-fidelity simulation in physical therapy education[KC9]

Appendix II: Studies excluded on full text

*denotes author contacted – result of this contact detailed for each paper

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Appendix III: Modified JBI Data Extraction Tool

Country:

Setting:

Aim of study:

Participant characteristics/Demographics:

Sample size:

Intervention: Control:

Intervention

Simulation type:

Duration:

Number of cases:

Group/individual:

Other (debrief/rewind etc):

Groups:

Outcomes measured:

Description of main results:

Appendix IV: Characteristics of included studies

Characteristics of Included Studies - Quasi-Experimental Study

Author	Setting/ Country	Participant characteristics	Groups	Outcomes measured	Main description of results
Black and Marcoux[26]	University USA	1st year MSc PT students enrolled in Introductory patient management skills course.	Simulated gait training with SP n= 20 Control, role play n= 19	Student perception questionnaire – students rating on a 10 cm line – higher number = greater satisfaction.	Overall usefulness of experience: Scenario 1 HFS = 9.32 control = 8.31 (p< 0.025*), Scenario 2 HFS = 9.21 control = 8.81 (p=0.336), Awareness of patient comfort: Scenario 1 HFS = 9 control = 7.73 (p<0.04*) Scenario 2 HFS = 9.26 control = 8.31 (p=0.133).
Boissonault et al[27]	University, USA	1st year MSc PT students Recruited over 2 yrs.	Control: traditional lecture n = unknown HFS Group: n= unknown n=51 overall	Written exam, self assessment of confidence on VAS, module evaluation	Written exam scores: control = 50% HFS = 59% p=0.01.* Subsets knowledge control = 36% HFS=45% p=0.05.* Application control = 59% HFS =74% p=0.01*. Synthesis control = 58%, HFS = 62% p=0.28. Confidence on VAS control = 45mm, *HFS* = 53mm p<0.05.*

Phillips et al.[28]	University Australia	2nd year UG PT students	HFS n= 37 HFS + video n= 27 Control, role play n= 36	OSCE	HFS group OSE score 7.4, fails 5, safety fails 5 HFS +Video OSCE score 5.9, fails 4, safety fails 4 Peer role play OSCE score 7.1, fails 3, safety fails 1.

Characteristics of Included Studies - Randomized Controlled Trial Form

Country	Setting	Participant characteristics	Groups	Outcomes measured	Description of main results
Silberman et al.[23]	University USA	2nd year DPT students prior to 1st full time CE.	Control n = 8. Simulation n = 8.	Acute care Confidence Survey ACCS. Pre, post and mid placement	ACCS scores difference HFS group T1-T2 p=0.012, effect size 0.630* Control group T1-T2 p=0.735 effect size, 0.08 T2-T3 HFS group 0.012 effect size 0.630* T2-T3 control group p=0.017 effect size 0.60*[FR(10][KC11]

Huhn et al [24]	University USA	1st year DPT students.	Control n= 27, Mean age 23.8 yrs, M:F 5:22, GRE 1030, GPA 3.48, GPA core 3.39. Virtual Sim n = 26, Mean age 23.7yrs, M:F 6:20, GRE 1190 (p=0.30), GPA 3.43, GPA core 3.49.	Health Sciences Reasoning Test and MCQ exam.	No significant difference between groups F=0.766,df=1, p=0.386.
Jones and Sheppard[25]	Australia University	3rd year UG students	Control n= 29, HFS n=21. Power calculation 30/group - recruited over 2 years.	APP. Assessed end week 1, 2, 3, 4, 5, 6.	Pre clinical HFS APP 64.1 +/- 7.2 , control APP 64.9 +/-7.4 (Mann-Whitney U 0.62) Week 6 HFS APP 60-7 +/-9.1, control APP 58.7 +/- 8.4 4 (Mann-Whitney U 0.35) No significant difference between HFS and control group

Key

ACCS = Acute Care Confidence Survey

APP = Assessment of Physiotherapy Practice

CE = clinical education

DPT = Doctor of Physical Therapy

GRE = Graduate Record Examination

GPA = Grade Point Average

HFS = High Fidelity Simulation

MSc = Master of Science

MCQ = Mutliple choice examination

OSCE = Observed Structured Clinical Examination

PT = Physiotherapy

SP = Standardized Patient

UG = Undergraduate

VAS = Visual Analogue Scale

*= statistically significant difference