PEER REVIEW HISTORY

BMJ Open publishes all reviews undertaken for accepted manuscripts. Reviewers are asked to complete a checklist review form (**http://bmjopen.bmj.com/site/about/resources/checklist.pdf**) and are provided with free text boxes to elaborate on their assessment. These free text comments are reproduced below.

This paper was submitted to a another journal from BMJ but declined for publication following peer review. The authors addressed the reviewers' comments and submitted the revised paper to BMJ Open. The paper was subsequently accepted for publication at BMJ Open.

ARTICLE DETAILS

TITLE (PROVISIONAL)	Registered nurse, health care support worker, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study
AUTHORS	Griffiths, Peter; Ball, Jane; Murrells, Trevor; Jones, Simon; Rafferty, Anne Marie

VERSION 1 - REVIEW

REVIEWER	Bottle, Alex Imperial College, Primary Care and Social Medicine
REVIEW RETURNED	20-Mar-2015

GENERAL COMMENTS	This observational study compares levels of different staff types with mortality rates, using data on the former taken from both national info and a nursing survey subset at ward level. It's therefore a useful advance on prior work. Prior studies often use only nursing or dr info and ignore HCSW and staff mix; also, differences are found if using hospital-level nursing or ward-level info. The use of ward-level info may help with the ecological fallacy, but the mortality data are still limited to hosp level (split by medicine v surgery). The outcome was risk-adjusted mortality. How did you adjust for Charlson – SHMI way (which greatly truncates the scores) or using the full range of scores? Adms were divided into med v surg using specialty code of admitting consultant – is that right? The consultant code isn't at all reliable for emergency adms. TRETSPEF would be much better. All-cause mort was used, presumably for power reasons. Did you consider e.g. condition rich in avoidable deaths (Coleman et al)? Please amend terms 'univariate' and 'multivariable', e.g. by using crude and adjusted or unadjusted and multiple regression GEE was used with O and E. Adjustment was made for bed numbers, teaching status, year. Were these confounders? Should some interaction be tried instead? Also, did you consider multilevel modelling? That would allow analysis of contextual effects like # patients, # elderly patients on mortality and to estimate the proportion of the variance in the outcome that is associated with staffing levels, which would be very useful. Ward-based RN levels were analysed in 4 groups – why? Why these cut-offs and why not as linear? What about staff mix? Each staff variable is considered separately as independent effects. Also, was collinearity tested? Other studies have struggled to include both nursing and dr levels in models. Table 2: CI for beds per nurse much wider than for beds per dr / HCSW. Correlations between staffing levels would be helpful.

REVIEWER	West, Elizabeth
	University of Greenwich, Faculty of Education & Health
REVIEW RETURNED	06-Apr-2015

GENERAL COMMENTS	The main contribution of this paper is the inclusion of both medical staff and HCSW in models of the impact of RN staffing on patient mortality. This is an original contribution. I would like to see more discussion of the approach to modelling and why the variables were selected. Is mortality really the most relevant dependent variable for nurse staffing research? Does the focus on mortality not make it inevitable that medical staffing will emerge as the only significant variable in the multi-variate models? I am concerned about the collinearity of RN and HCSW staffing--does this mean that you can make separate inferences about how they are affecting mortality if they are varying together? Could total nurse staffing (RN and HCSW) be a proxy for other unmeasured variables that are omitted from this analysis. This is important because there are policy implications here. I think it would be easier to interpret the results if there were more attention to theory, mechanisms, modelling, and the operationalization of the variables at the beginning of the paper. As I reader I found it difficult to follow the paper--this is something that you could help the reader with--but I also found it difficult to interpret the meaning of the findings. The strengths and weaknesses of the paper need to be brought out more clearly with clear indications of the implications, if any, for policy.
	The unit of analysis, which is the hospital is probably not justifiable given the current status of staffing research which is moving towards the patient as the unit of analysis. We know that the danger of the "ecological fallacy" so you really do need to make a convincing argument about why research at the hospital level is important.

VERSION 1 – AUTHOR RESPONSE

Reviewer: 1	
This observational study compares levels of different staff types with mortality rates, using data on the former taken from both national info and a nursing survey subset at ward level. It's therefore a useful advance on prior work. Prior studies often use only nursing or dr info and ignore HCSW and staff mix; also, differences are found if using hospital-level nursing or ward-level info.	This is very much our aim – to provide a "useful advance on prior work" in terms of considering staff groups beyond RNs, and looking at two different means of estimating staffing levels (at ward and at hospital).
The use of ward-level info may help with the ecological fallacy, but the mortality data are still limited to hosp level (split by medicine v surgery).	Agreed. Sadly HES data is not available at the ward level which leaves us with data at the Trust level.
The outcome was risk-adjusted mortality. How did you adjust for Charlson – SHMI way (which greatly truncates the scores) or using the full range of scores?	We used the SHMI approach which truncates the data.
Adms were divided into med v surg using specialty code of admitting consultant – is that right? The consultant code isn't at all reliable for emergency adms. TRETSPEF	Apologies. In fact we can confirm that we did use treatment speciality (TRETSPEF) for the admitting

would be much better.	episode.
All-cause mort was used, presumably for power reasons. Did you consider e.g. condition rich in avoidable deaths (Coleman et al)?	While we recognise that there are limitations in our approach, research such as this is used to inform staffing decisions for the hospital as a whole. Typically hospital level nurse staffing levels are associated with mortality in a select (high mortality) sub group (typically surgical only). Our approach is based on outcomes for all patients in all general wards. As far we are aware it would not be possible to use the approach of Coleman and Nicholl using HES.
Please amend terms 'univariate' and 'multivariable', e.g. by using crude and adjusted or unadjusted and multiple regression	Gee was used – see comment above. Potentially bed numbers and teaching status.
GEE was used with O and E. Adjustment was made for bed numbers, teaching status, year. Were these confounders? Should some interaction be tried instead? Also, did you consider multilevel modelling? That would allow analysis of contextual effects like # patients, # elderly patients on mortality and to estimate the proportion of the variance in the outcome that is associated with staffing levels, which would be very useful.	Data were used across two years (2009, 2010). We would have opted for a multilevel model had we been able to obtain patient level, rather than aggregated data which would have conferred the advantages indicated opposite.
Ward-based RN levels were analysed in 4 groups – why? Why these cut-offs and why not as linear?	…see above
What about staff mix? Each staff variable is considered separately as independent effects. Also, was collinearity tested?	…see above
Other studies have struggled to include both nursing and dr levels in models.	Yes. We thought it was important to establish the effect of nurse staffing after adjustment for medical staffing
Table 2: CI for beds per nurse much wider than for beds per dr / HCSW. Correlations between staffing levels would be helpful.	Noted. We have added these correlations to the text.
Reviewer: 2 Comments to the Author	
The main contribution of this paper is the inclusion of both medical staff and HCSW in models of the impact of RN staffing on patient mortality. This is an original contribution.	Thank you. Certainly this was the motivation to write the paper, despite the data challenges presented.
I would like to see more discussion of the approach to modelling and why the variables were selected. Is mortality really the most relevant dependent variable for nurse staffing research? Does the focus on mortality not	Mortality has frequently been selected as an outcome variable in research on staffing and outcomes, and in multivariate models a relationship has repeatedly found (eg. Aiken et al,

make it inevitable that medical staffing will emerge as the only significant variable in the multi-variate models?	2014, Lancet). Its strength is that it is one of the few outcomes consistently recorded in the NHS, and is therefore the main outcome available in routinely collected data sources.
I am concerned about the collinearity of RN and HCSW staffing--does this mean that you can make separate inferences about how they are affecting mortality if they are varying together? Could total nurse staffing (RN and HCSW) be a proxy for other unmeasured variables that are omitted from this analysis. This is important because there are policy implications here.	We have added a paragraph on collinearity to the paper. We have kept RN and HCSW staffing apart for the reasons stated above
I think it would be easier to interpret the results if there were more attention to theory, mechanisms, modelling, and the operationalization of the variables at the beginning of the paper. As I reader I found it difficult to follow the paper--this is something that you could help the reader with--but I also found it difficult to interpret the meaning of the findings. The strengths and weaknesses of the paper need to be brought out more clearly with clear indications of the implications, if any, for policy.	The challenge is that the more complex endeavour – of looking at three staff groups not just one – has required use data at both Trust and ward level, with different measure of staffing, and reporting by specialty. It's a complex endeavour that has produced a complex set of findings.

We would welcome further input on this point, to see if there are ways we could make the article (the methods, results and policy implications) more accessible to readers of BMJ Open. |
| The unit of analysis, which is the hospital is probably not justifiable given the current status of staffing research which is moving towards the patient as the unit of analysis. We know that the danger of the "ecological fallacy" so you really do need to make a convincing argument about why research at the hospital level is important. | We have addressed this issue (the challenges of the data that are available) at different points above. Unfortunately NHS systems don't provide staffing data at ward level which limits what is possible.

However, It could be regarded as something that we all need to push for– and perhaps a point that could form an opinion piece or editorial, given the significant interest understanding variation in health care outcomes. |

VERSION 2 – REVIEW

REVIEWER	Alex Bottle Imperial College London, UK
REVIEW RETURNED	30-Sep-2015

GENERAL COMMENTS	The study combines data from the NHS staff census, HES, bed occupancy and ward-level information for a random sample of 31 trusts. GEEs were used to assess the relations between Trust-level mortality and staffing and deal with potential clustering of patients

	within hospitals. GEEs make for easier interpretation of coefficients than multilevel models, though the choice of GEEs should still be given as they can't address contextual effects. The ward-level survey part had a 39% response rate among the nurses. How were the respondents split across the trusts? For instance, does this mean that you had data from 39% of the 31 trusts, from 39% of the wards in those 31 trusts (but some responses from every trust), or something else? I had previously asked about collinearity, and this has now been addressed satisfactorily. Table 2 shows how the staffing variables are intercorrelated, as I had previously suggested. Sentence in Discussion doesn't make sense: "When all staff groups were included 137 hospital Trusts analysis the adjusted associations with mortality…" There are a number of minor issues with punctuation elsewhere.

VERSION 2 – AUTHOR RESPONSE

1. The ward-level survey part had a 39% response rate among the nurses. How were the respondents split across the trusts? For instance, does this mean that you had data from 39% of the 31 trusts, from 39% of the wards in those 31 trusts (but some responses from every trust), or something else? We couldn't spot this.

Text amended:

"The survey was undertaken from January to September 2010 as part of the RN4CAST study. Registered Nurses in 31 Trusts (covering 46 hospitals and 401 wards) were surveyed; 2990 of 7609 (39%), responded. The nurse response rate varied between the 31 Trusts from 19% to 69%."

2. A clearer definition or explanation of what HCSWs do may be useful for international readers.

Text added:

"HCSW in England are unregistered care staff (without nursing qualifications) who undertake many aspects of fundamental care for patients in NHS hospital wards (from helping patients to wash, use the toilet, through to monitoring vital signs, and in some cases dressings)."

3. IGEEs were used to assess the relations between Trust-level mortality and staffing and deal with potential clustering of patients within hospitals. GEEs make for easier interpretation of coefficients than multilevel models, though the choice of GEEs should still be given as they can't address contextual effects.

Text added:

"GEE was used in preference to a multilevel model because it is more suited to estimating population average effects. There were only two time-points which would have limited the usefulness of a multilevel model."

4. Sentence in Discussion doesn't make sense: "When all staff groups were included 137 hospital Trusts analysis the adjusted associations with mortality…"

This sentence has been amended and now reads:

"When all staff groups were included (in the analysis of 137 hospital Trusts) the adjusted associations with mortality were not statistically significant for nurse staffing but were for doctor staffing."

5. There are a number of minor issues with punctuation elsewhere.

The paper has been proof read and punctuation issues corrected.

Two further issues regarding the manuscript - reference 29 not cited in the text, and the contributors statement needing to be in words (not a table) have also been corrected.

Correction

Griffiths P, Ball J, Murrells T, *et al*. Registered nurse, health care support worker, medical staffing levels and mortality in English hospital Trusts: a cross-sectional study. *BMJ Open* 2016;5:e008751.

The correlations in the bottom half of table 2 of this paper are incorrect – the current version relates to the correlation RN per patient and HCSW per patient rather than Patients per RN and Patients per HCSW. There are no resulting changes to the text but the revised figures for 31 Trusts are:

RN-HCSW r=0.24, p=0.063
RN-Doctor r=0.55, p<0.001
HCSW-Doctor r=0.16, p=0.21

BMJ Open 2016;**6**:e008751corr1. doi:10.1136/bmjopen-2015-008751corr1

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