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## Review Article

## Effects of Nurse Staffing on Resident Outcomes in Nursing Homes: A Systematic Review



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## ABSTRACT

**Objectives:** To evaluate the evidence on effects of nurse staffing in nursing homes on resident outcomes.

**Design:** Systematic review.

**Setting and Participants:** Studies evaluating the effects of nurse staffing levels, total staffing, or skill mix on pressure ulcers, nursing home associated infections, and pain outcomes for adult residents in US nursing homes.

**Methods:** We searched MEDLINE, Embase, CINAHL, and the Cochrane Database for English-language articles published between January 2000 and May 2021. We also searched for gray literature and sought expert referrals. Two reviewers participated in determination of eligibility, assessment of methodological quality, and abstraction of data. Abstracted data included study design; setting and population characteristics; and resident outcomes. We rated overall certainty of evidence (very low, low, moderate, and high) for each outcome using GRADE.

**Results:** Of 9152 unique citations, 378 articles underwent full-text review. We identified 22 eligible studies that addressed pressure ulcers ( $k = 15$ ), COVID-19 cases and/or mortality ( $k = 4$ ), other infections ( $k = 8$ ), and moderate-severe pain among residents ( $k = 7$ ); some examined multiple outcomes. Most studies ( $k = 17$ ) were rated moderate or high quality. All studies were observational. Overall, registered nurse (RN) staffing was probably associated with fewer pressure ulcers (moderate certainty) and possibly fewer COVID-19 infections/mortality (low certainty), other infections (low certainty) and lower rates of moderate-severe pain (low certainty). Higher skill mix was probably associated with fewer pressure ulcers, higher resident COVID-19 infections, fewer other infections, and lower rates of moderate-severe pain (low certainty for all outcomes).

**Conclusions and Implications:** Higher RN staffing and skill mix may be associated with better nursing home resident outcomes, while results were mixed for total staffing. Increasing RN staffing levels and skill mix are one of a variety of approaches to improve nursing home care.

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In the United States (US), 1.3 million people reside in more than 15,000 nursing homes.<sup>1,2</sup> Nursing homes are complex environments with populations needing post-acute, end-of-life, or custodial long-term care.<sup>3</sup> Within nursing homes, direct care nursing staff [ie, registered nurses (RN), licensed vocational or practical nurses (LPN), and nursing assistants (NA)] are the primary caregivers for residents<sup>4</sup>; thus, the level and characteristics of nurse staffing are likely to impact resident health and safety.

The Institute of Medicine recommends that nursing homes have at least 1 RN on duty 24 hours a day,<sup>5,6</sup> but federal and state regulations do not require this level of staffing.<sup>7</sup> Federal regulations mandate having at least 1 RN on duty 8 hours a day and that nursing homes have sufficient staff to provide nursing care to all residents.<sup>8</sup> States can impose more stringent regulations, but none currently require that nursing homes have an RN on duty 24 hours per day.

As part of the Nursing Home Compare 5-Star Rating System, the Centers for Medicare and Medicaid Services (CMS) calculates expected staffing levels based on resident acuity; CMS estimates that the average US nursing home should have 4.2 nursing hours per resident day (HPRD).<sup>4</sup> However, most nursing homes have staffing levels far below this.<sup>4,9</sup> In addition, there are variations in daily staffing levels within facilities.<sup>9</sup> CMS recently announced plans to conduct a study evaluating the staffing needed to assure resident safety and quality of care; CMS then plans to issue a new rule in 2023 on minimum staffing requirements for nursing homes.<sup>10</sup>

Although some studies have indicated that higher nurse staffing levels lead to better resident outcomes,<sup>11–13</sup> it remains unclear how overall nurse staffing levels and skill mix can be optimized to achieve improvements in resident outcomes. The Veterans Affairs (VA) Evidence Synthesis Program was asked by the VA Office of Nursing Services, in collaboration with VA Geriatrics and Extended Care, to conduct an evidence review on the effects of nursing home staffing levels (eg, HPRD), total staffing, and staff mix (eg, ratio of RN to other nursing staff) on processes of care and resident outcomes in nursing homes. In this report, we focus on evidence regarding the effects of nurse staffing levels, total staffing, and staff mix on 4 important nursing home resident outcomes: pressure ulcers, COVID-19 cases and mortality, other nursing home-associated infections, and pain. These outcomes were rated as critical or important for decision-making based on discussion with our VA partners and external Technical Expert Panel members. The full report, which evaluated a broader set of outcomes, is available on the VA webpage (<https://www.hsrd.research.va.gov/publications/esp/reports.cfm>).

## Methods

The review protocol is registered in PROSPERO (CRD42021266319).

### Scope and Key Questions

With our stakeholders and technical expert panel, we developed a conceptual framework based on the Donabedian model<sup>14</sup> to guide refinement of the scope and key questions. We conceptualized that the structure of care includes nurse staffing levels and skill mix, which in turn impact processes of care and then affect resident outcomes (eg, rates of pressure ulcers) (Supplementary Figure 1).

### Search Strategy

We searched MEDLINE, Embase, CINAHL, and the Cochrane Database of Systematic Reviews for peer-reviewed English language articles from January 2000 to May 2021 (Supplementary Appendix 1). The search used Medical Subject Headings, keywords, and title/abstract terms for nurse staffing and nursing homes. We supplemented the

database search by hand-searching bibliographies of systematic reviews. We also requested our stakeholders and expert advisory panel share potentially relevant articles. We searched for gray literature using websites of organizations that may produce relevant reports or white papers, though none were identified.

### Screening and Selection

Using prespecified criteria (Supplementary Appendix 2), search results were evaluated and excluded with the consensus of 2 individuals. Two reviewers conducted full-text review of potentially eligible articles; eligibility was determined by consensus. If needed, a third reviewer assisted with reaching consensus. Eligible studies evaluated the effects of nurse staffing levels (eg, nurse HPRD), total staffing, or skill mix on outcomes for adult residents in US nursing homes.

### Quality Assessment and Data Abstraction

Quality was independently assessed by 2 reviewers using a modified version of the JBI Critical Appraisal Checklist.<sup>15</sup> The following were abstracted from all eligible studies: study design; setting and population characteristics; data sources; definitions of nurse staffing and/or skill mix; and processes of care or resident outcomes evaluated. For studies of moderate or high quality, we also abstracted detailed characteristics of staffing measures [amount and different types of nurse staffing, including total staffing (RN, LPN, and NA)]; associations between nurse staffing (or skill mix) and resident outcomes; and analytic methods (eg, consideration of confounders). Data were abstracted by one reviewer and over-read by a second.

### Data Synthesis and Certainty of Evidence

Due to heterogeneity in populations, methods, and outcomes of eligible studies, we performed qualitative synthesis of the results. For each category of resident outcomes, we summarized key findings from moderate or high-quality studies, and rated overall certainty of evidence using a GRADE approach.<sup>16–19</sup> Briefly, for each outcome and nurse staffing variable, we evaluated characteristics of the evidence across 5 domains: methodological limitations, imprecision, inconsistency, indirectness, and publication bias. The overall certainty of evidence (very low, low, moderate, and high) takes into consideration individual ratings in each of these 5 domains, but domains may not be weighted equally in determining the overall rating.

## Results

Of 9152 unique titles and abstracts screened, 378 articles underwent full-text review (Supplementary Figure 2). Twenty-two eligible studies addressed pressure ulcers ( $k = 15$ ), COVID-19 cases and/or mortality ( $k = 4$ ), other infections ( $k = 8$ ), or moderate to severe pain ( $k = 7$ ); 15 studies examined 2 or more outcomes. Most studies used national US samples of nursing homes ( $k = 11$ ) and were cross-sectional ( $k = 15$ ). Seventeen of the 22 studies were moderate or high-quality (Supplementary Appendix 3). Most studies conducted analyses at the nursing home level and do not distinguish between post-acute and long-stay populations. The appendix tables note when studies report outcomes for long- and short-stay residents. Detailed study characteristics and results are found in Supplementary Appendices 4–7. Below, we summarize results for pressure ulcers, COVID-19 and other infections, and moderate-severe pain.

**Table 1**  
Summary Findings for Pressure Ulcers in Nursing Home Residents

Staffing Measure or Skill Mix	Summary of Findings	Methodological Limitations	Indirectness	Imprecision	Inconsistency	Publication Bias	Overall Certainty
RN Staffing <sup>13,20–24,26–30</sup>	Higher RN staffing is probably associated with less pressure ulcers (rates or likelihood) among NH residents	Serious*	Not Serious	Not serious	Not Serious <sup>†</sup>	Not Suspected	Moderate
LPN Staffing <sup>26–28,31,32</sup>	Higher LPN staffing may be associated with less pressure ulcers (rates or likelihood) among NH residents	Serious*	Not Serious	Not serious	Serious <sup>‡</sup>	Not Suspected	Low
NA Staffing <sup>20,22,26–30</sup>	Higher NA staffing may be associated with less pressure ulcers (rates or likelihood) among NH residents	Serious*	Not Serious	Not serious	Serious <sup>§</sup>	Not Suspected	Low
Total Staffing <sup>24,25</sup>	Total staffing is probably not associated with pressure ulcers among NH residents	Serious*	Not Serious	Not serious	Not Serious	Not Suspected	Moderate
Skill Mix <sup>13,20,21,24,26,30</sup>	Higher skill mix may be associated with less pressure ulcers (rates or likelihood) among NH residents	Serious*	Not Serious	Not serious	Serious <sup>  </sup>	Not Suspected	Low

NH, nursing home.

\*Pressure ulcers data relied on report by NH staff; most studies were cross-sectional; one-half or most of the results from studies conducted by the same lead author.

<sup>†</sup>Nine of 11 studies found an association between RN staffing levels and a reduction in pressure ulcers among residents.

<sup>‡</sup>Four of the 5 studies were from the same lead author and all found an association; the 1 study not by the same author group found no association.

<sup>§</sup>Three studies reported no association and the remaining 4 reported an association.

<sup>||</sup>Three studies reported no association and 3 reported an association.

### Pressure Ulcers

One high-quality<sup>13</sup> and 11 moderate-quality studies<sup>20–30</sup> evaluated the association of pressure ulcers with nurse staffing (Supplementary Appendix 3). Ten studies examined the prevalence of pressure ulcers among nursing home residents.<sup>20</sup> One of the 12 studies addressed the incidence of pressure ulcer only within the past 14 days,<sup>13</sup> and a second study measured the number of residents with dementia who had a pressure ulcer on their last assessment before death.<sup>21</sup> Six studies used data from national samples of nursing homes, while the remaining used data from selected states. Five studies were conducted by a research team led by Castle, NC.<sup>20,26,28–30</sup> Summary of findings for pressure ulcers are shown in Table 1.

Higher RN staffing is probably associated with fewer pressure ulcers among residents of nursing homes (moderate certainty). Nine of 11 studies addressing RN staffing and pressure ulcers found that higher RN staffing was associated with fewer pressure ulcers.<sup>13,20–23,26,28–30</sup> The remaining 2 studies found no association between RN staffing and pressure ulcers.<sup>24,27</sup> Six of the 9 studies conducted analyses adjusting for case mix, and all studies adjusted for other confounders such as nursing home bed size and other staffing metrics.

Higher LPN staffing may be associated with fewer pressure ulcers (low certainty). Four reports were from the same lead author and showed that higher LPN staffing was associated with fewer pressure ulcers.<sup>26,28–30</sup> The fifth study (not by Castle et al.) found no association between LPN staffing and resident outcomes.<sup>27</sup>

Higher NA staffing may be associated with fewer pressure ulcers (low certainty). Four<sup>20,22,26,30</sup> of 7 studies<sup>20,22,26–30</sup> examining associations between NA staffing and pressure ulcers found that higher NA staffing was associated with a decrease in pressure ulcers. Three studies found no association between NA staffing levels and the outcome of interest.<sup>27–29</sup>

Total staffing is probably not associated with pressure ulcers in nursing home residents (moderate certainty). Two studies evaluated total staffing and pressure ulcers in residents and found no statistically significant association between total staffing and the presence of pressure ulcers.<sup>24,25</sup> One study by Temkin-Greener et al was conducted in 162 facilities and found nursing HPRD was not significantly associated with an increase in high-risk residents' odds of having pressure ulcers [odds ratio (OR) 1.11,  $P = .62$ ].<sup>25</sup> The second study by Trinkoff et al used data from 1142 residents and was not limited to

those considered high-risk. They found staffing hour categories [ $\geq 5$  HPRD (exposure) vs  $< 5$  HPRD] were not significantly associated with pressure ulcers for either high-risk residents [OR 1.01 (0.56, 1.82)] and low-risk residents [OR 1.21 (0.58, 2.53)].<sup>24</sup>

Higher skill mix may be associated with fewer pressure ulcers among residents (low certainty). Six studies evaluated effects of skill mix, all defined as ratio of RN to total staffing.<sup>13,20,21,24,26,30</sup> Three studies reported no association,<sup>13,21,24</sup> and 3 studies reported an association between skill mix and pressure ulcers.<sup>20,26,30</sup> Four studies controlled for case mix, and all studies adjusted for other confounders such as environment, policy, and other staffing metrics.

### COVID-19 Cases and Mortality in Nursing Homes

Three high<sup>33–35</sup> and 1 moderate-quality study<sup>36</sup> evaluated the association between nurse staffing and COVID-19 cases and/or mortality (Supplementary Appendix 5). Two studies evaluated nursing homes in a single state,<sup>35,36</sup> while 1 examined facilities in 17 states,<sup>33</sup> and the fourth used national data.<sup>34</sup> All 4 studies obtained staffing data from the CMS Payroll-Based Journal, and controlled for the facility size.<sup>33–36</sup> Three studies accounted for the prevalence of COVID-19 in the local community,<sup>33,34,36</sup> COVID-19 data were obtained from a variety of federal,<sup>33,34</sup> state,<sup>35,36</sup> county,<sup>35</sup> and news organization sources.<sup>35,36</sup> Summary of findings for COVID-19 outcomes are shown in Table 2.

Higher RN staffing may be associated with lower resident COVID-19 infection and mortality (low certainty). Four studies investigated the relationship between RN staffing and COVID-19 cases or mortality.<sup>33–36</sup> The two state-level studies and one regional study of a combined 3807 nursing homes all found that higher RN staffing was significantly associated with fewer COVID-19 cases and/or mortality.<sup>33,35,36</sup> However, one national study of 13,167 nursing homes found higher RN staffing was significantly associated with higher likelihood (OR 1.34,  $P < .01$ ) of a nursing home having any COVID-19 cases.<sup>34</sup>

LPN staffing may not be associated with COVID-19 outcomes (low certainty). In contrast higher NA staffing may be associated with lower COVID-19 infection and mortality (low certainty). A single national study found no statistically significant association between LPN staffing and COVID-19 cases.<sup>34</sup> It also found that low LPN staffing, but not high LPN staffing, relative to medium LPN staffing, was associated with fewer COVID-19 deaths. For the relationship between NA staffing

**Table 2**  
Summary Findings for Nursing Home Associated Infections

Staffing Measure or Skill Mix	Summary of Findings	Methodological Limitations	Indirectness	Imprecision	Inconsistency	Publication Bias	Overall Certainty
<b>COVID-19 Cases and Mortality</b>							
RN Staffing <sup>33–36</sup>	Higher RN staffing may be associated with lower COVID infection and mortality (likelihood and rates).	Serious*	Not Serious	Serious, borderline <sup>†</sup>	Serious <sup>‡</sup>	Not Suspected	Low
LPN Staffing <sup>34</sup>	Higher LPN staffing may not be associated with lower resident COVID infection (likelihood) and mortality (count).	Serious*	Not Serious	Not Serious	—	Not Suspected	Low
NA Staffing <sup>34</sup>	Higher NA staffing may be associated with lower resident COVID infection (likelihood) and mortality (count).	Serious*	Not Serious	Not Serious	—	Not Suspected	Low
Total Staffing <sup>34,35</sup>	It is unknown if total staffing is associated with resident COVID infection or mortality.	Serious*	Not Serious	Serious, borderline <sup>†</sup>	Serious <sup>§</sup>	Not Suspected	Very Low
Skill Mix <sup>34</sup>	Higher nursing skill mix may be associated with higher resident COVID infection (likelihood).	Serious*	Not Serious	Not Serious	—	Not Suspected	Low
<b>Other Infections</b>							
RN <sup>13,23,29</sup>	Higher RN staffing may be associated with less UTI (likelihood and rates) among NH residents.	Serious <sup>  </sup>	Not Serious	Not Serious	Serious, borderline**	Not Suspected	Low
LPN <sup>29</sup>	LPN staffing may not be associated with rates of UTI among NH residents.	Serious <sup>  </sup>	Not Serious	Not serious	—	Not Suspected	Low
NA <sup>24,29</sup>	Higher NA staffing may be associated with fewer UTI among NH residents.	Serious <sup>  </sup>	Not Serious	Not serious	—	Not Suspected	Low
Total Staffing <sup>37</sup>	Total staffing may not be associated with UTI (rates and likelihood).	Serious <sup>  </sup>	Not Serious, borderline <sup>  </sup>	Not serious	Not Serious	Not Suspected	Low
Skill Mix <sup>13,24,38</sup>	Higher nursing skill mix may be associated with fewer UTI among NH residents.	Serious <sup>  </sup>	Not Serious, borderline <sup>††</sup>	Not serious	Serious, borderline <sup>‡‡</sup>	Not Suspected	Low

NH, nursing home.

\*Concerns due to accuracy of COVID-19 data, timing of nursing home staffing data vs COVID-19 outcomes, and possible staff shortages due to COVID-19 outbreaks.

<sup>†</sup>Wide confidence intervals for some effect estimates.

<sup>‡</sup>Three studies found significant associations, while 1 study found opposite effect (higher RN staffing was associated with higher likelihood of COVID-19).

<sup>§</sup>One study found no significant associations and the other study showed that both low and high total staffing (compared with middle tertile) were associated with higher COVID-19 mortality.

<sup>||</sup>Cross-sectional studies with outcomes reported by NH staff.

\*\*Two studies showed significant associations, and 1 did not find significant association.

<sup>††</sup>One study used composite outcome of UTI, pneumonia, and pressure ulcers.

<sup>‡‡</sup>Variable definitions of skill mix, with 1 study finding significant association and 2 studies not finding significant associations.

and COVID-19 outcomes, the same study showed that among nursing homes with at least one COVID-19 case, those with high NA staffing (compared with middle tertile) had a lower likelihood of having an outbreak and fewer COVID-19 resident (and staff deaths).<sup>34</sup>

It is unknown if total nurse staffing is associated with COVID-19 outcomes (very low certainty). One national study found that nursing homes with both low and high total staffing (compared with middle tertile) had fewer COVID-19 deaths.<sup>34</sup> A state-level study found no association between nursing hours and COVID-19 cases.<sup>35</sup>

Higher skill mix (RN to total nurse staffing) may be associated with higher resident COVID-19 infection (low certainty). The same national study described above found that lower staff skill mix was significantly associated with a lower likelihood of having any COVID-19 cases, and higher skill mix was associated with greater likelihood of having any cases.<sup>34</sup> The study found no association between staff skill mix and COVID-19 mortality.

#### Other Infections in Nursing Homes

Six articles evaluated the association between nursing home staffing and infections (Supplementary Appendix 6).<sup>13,23,24,29,38,39</sup> Four studies evaluated urinary tract infection (UTI),<sup>13,23,24,29</sup> another study examined a composite measure of UTI, pneumonia, and pressure ulcers,<sup>38</sup> and the sixth study addressed hospitalizations and mortality during norovirus outbreaks.<sup>39</sup> Two of these were high quality<sup>13,38</sup> and 3 were moderate quality.<sup>23,24,29,39</sup> One study focused specifically on VA nursing homes,<sup>38</sup> three evaluated nursing homes in a single state<sup>23</sup> or a small number of states,<sup>13,39</sup> and 2 included national samples of US nursing homes.<sup>24,29</sup> Summary of findings are reported in Table 2.

Higher RN staffing may be associated with fewer UTI (low certainty). Three studies addressed the relationship between RN staffing and UTI.<sup>13,23,29</sup> One study using instrumental variable approach found greater RN staffing was significantly associated with a lower incidence of UTI.<sup>13</sup> Another instrumental variable study found no significant association between RN staffing and UTI incidence.<sup>23</sup> A national study found that higher RN staffing was significantly associated with higher incidence of UTI.<sup>29</sup> Higher RN staffing may also be associated with no increase in hospitalizations and mortality among nursing home residents during norovirus outbreaks.<sup>39</sup>

LPN staffing may not be associated with UTI among nursing home residents (low certainty). One national study of nursing homes found no significant association between LPN staffing and incidence of UTI.<sup>29</sup> Higher NA staffing may be associated with fewer UTIs in residents (low certainty). One national study of moderate quality found higher NA staffing was significantly associated with a decrease in the prevalence of UTI.<sup>29</sup>

Total staffing may not be associated with UTI incidence (low certainty). One study of VA nursing homes found no significant association between total nurse staffing and a composite measure of UTI, pneumonia, and pressure ulcers.<sup>38</sup> A national study of non-VA US nursing homes also found no association between total staffing and UTI incidence.<sup>24</sup>

Higher skill mix may be associated with fewer UTIs (low certainty). Three studies investigated the relationship between nurse skill mix and infections.<sup>13,24,38</sup> One study of a national sample found that licensed nurse (RN and LPN) to total nurse staffing was not significantly associated with incidence of UTIs.<sup>24</sup> One study examining nursing homes from multiple states and using an instrumental variable approach found that higher skill mix (RN to total) was associated

**Table 3**  
Summary Findings for Pain (Moderate to Severe) in Nursing Home Residents

Staffing Measure or Skill Mix	Summary of Findings	Methodological Limitations	Indirectness	Imprecision	Inconsistency	Publication Bias	Overall Certainty
RN Staffing <sup>20,26,28–30</sup>	Higher RN staffing may be associated with lower rates of moderate-severe pain among NH residents	Serious*	Not serious	Not serious	Not serious, borderline <sup>†</sup>	Not Suspected	Low
LPN Staffing <sup>20,26,28–30</sup>	Unknown if LPN staffing is associated with rates of moderate-severe pain among NH residents.	Serious*	Not serious	Not serious	Serious <sup>‡</sup>	Not Suspected	Very Low
NA Staffing <sup>20,26,28–30</sup>	Unknown if NA staffing is associated with rates of moderate-severe pain among NH residents	Serious*	Not serious	Not serious	Serious <sup>§</sup>	Not Suspected	Very Low
Total Staffing <sup>24</sup>	Unknown if total staffing is associated with rates in moderate-severe pain among NH residents.	Serious*	Not serious	Not serious, borderline <sup>  </sup>	—	Not Suspected	Very Low
Skill Mix <sup>20,24,26,30</sup>	Higher nursing skill mix may be associated with lower rates of moderate-severe pain among NH residents	Serious*	Not serious	Not serious	Not serious, borderline <sup>†</sup>	Not Suspected	Low

NH, nursing home.

\*Pain outcomes reported by NH staff; most cross-sectional studies; all or most results from studies conducted by same lead author.

<sup>†</sup>No significant association in 2 studies.

<sup>‡</sup>Association with lower rates in 2 studies, no significant association in 1 study, significant association only with lower rates for short-stay residents in 1 study, and both higher and lower rates (for long and short-stay patient outcomes, respectively) in 1 study.

<sup>§</sup>Association with lower rates in 3 studies, no significant association in 1 study, and both higher and lower rates (for long and short-stay patient outcomes, respectively) in 1 study.

<sup>||</sup>Wide confidence intervals.

with fewer UTIs.<sup>13</sup> The VA nursing home study examined both percent RN staffing (of total) and percent NA staffing; it found no significant associations between either and the composite outcome of UTI, pneumonia, and pressure ulcers.<sup>38</sup>

### Pain (Moderate to Severe)

Six moderate-quality studies examined associations between nurse staffing and moderate-severe pain in nursing home residents (Supplementary Appendix 7).<sup>20,24,26,28–30</sup> All these studies used the Minimum Data Set 2.0 data for outcomes, which relied on reports by nursing home staff (beginning in 2010, pain outcomes in Minimum Data Set 3.0 have been assessed by resident interviews). Five studies used data from national nursing home samples,<sup>20,24,26,29,30</sup> and one study evaluated nursing homes in 6 states.<sup>28</sup> Summary of findings are reported in Table 3 and described in detail below.

Higher RN staffing may be associated with lower rates of moderate-severe pain among nursing home residents (low certainty). Three of 5 studies found higher RN staffing was significantly associated with lower rates of moderate-severe pain among residents.<sup>40–42</sup> For example, one of these found 0.5% fewer residents with moderate-severe pain (per nursing home) for every 1 full-time equivalent (FTE) more RN staffing (per 100 residents).<sup>26</sup> Two studies did not find significant associations between RN staffing and rates of moderate-severe pain in residents.<sup>20,28</sup>

It was unclear if LPN and NA staffing were also associated with rates of moderate-severe pain among residents (very low certainty). Two studies reported that higher LPN and NA staffing were both associated with lower rates of moderate-severe pain among long-stay patients.<sup>20,26</sup> One study found that higher LPN and NA FTE (per 100 residents) were each associated with higher rates of moderate-severe pain in long-stay residents but lower rates in short-stay residents.<sup>29</sup> One study found no significant associations for either LPN or NA staffing.<sup>28</sup> One study reported that LPN staffing had no significant association with moderate-severe pain in long-stay residents but did have significant associations with lower rates in short-stay residents.<sup>30</sup> This same study reported that higher NA FTE was associated with lower rates of moderate-severe pain in both long-stay and short-stay residents.<sup>30</sup>

It was unclear if total nurse staffing is associated with moderate-severe pain in nursing home residents (very low certainty). One study examined data for a national nursing home sample found total nurse staffing (RN, LPN, and NA) was not significantly associated with the nursing home being in the top quartile for highest rates of residents with moderate to severe pain.<sup>24</sup>

Higher skill mix may be associated with lower rates of moderate-severe pain among nursing home residents (low certainty). Four studies evaluated associations between skill mix and rates of moderate-severe pain.<sup>20,24,26,30</sup> Three studies were conducted by the same lead author and found that higher ratios [RN FTE to total non-RN FTE (LPN and NA)] were associated with lower rates of moderate-severe pain among long-stay residents.<sup>20,26,30</sup> One of these studies also evaluated moderate-severe pain among short-stay residents but found no significant association with skill mix.<sup>30</sup> Finally, 1 study evaluated the association between skill mix and likelihood of the nursing home being in highest 75<sup>th</sup> percentile for residents with moderate-severe pain.<sup>24</sup> This study measured skill mix as a ratio of total licensed nurse staffing (RN and LPN) to total direct care staffing (RN, LPN, and NA), and reported no significant association.<sup>24</sup>

### Discussion

We identified 22 eligible studies addressing the relationship between nurse staffing and resident pressure ulcers, nursing home associated infections, and/or pain (moderate to severe) in US nursing homes. Our findings found that higher RN staffing and skill mix was associated with improvements in all resident outcomes. In contrast, total staffing was not associated with improvements in pressure ulcers or urinary tract infections and there was insufficient evidence related to other resident outcomes. Evidence on the association between LPN and NA staffing and pressure ulcers, nursing home-associated infections, and pain are ambiguous. Similar to a recent review by Clemens et al, we found that higher RN staffing in nursing homes is generally associated with better resident outcomes, including fewer pressure ulcers.<sup>43</sup> We compliment Clemens et al review by examining the relationship between staffing and a broader set of resident outcomes and by rating the overall certainty of evidence.

Consistent with other reviews, we find there are substantial challenges to determine causal relationships between nurse staffing and

resident outcomes.<sup>43,44</sup> All studies relied on CMS-mandated data, which is practical but presents several challenges. These data directly inform payment or ability to operate, and most were reported by nursing home staff. In 2016, CMS started to require that staffing data be based on payroll or other auditable information. Only the 4 eligible studies that evaluated COVID-19 related outcomes used CMS payroll data, the remaining used CMS data collected before this change. In many studies, outcomes data were not clearly collected after nurse staffing data, a concern as staffing levels may fluctuate over time.<sup>9,45</sup> Furthermore, as CMS data collection occurs at prespecified intervals it is not ideal for capturing rates of acute outcomes.<sup>46</sup> These methodological concerns may contribute to counter-intuitive results, such as when insufficient nurse staffing leads to under-detection of pressure ulcers or pain.

Variation in nurse staffing definitions and analytic approaches added interpretation challenges.<sup>47</sup> Other factors in a nursing home that may impact outcomes include other healthcare staff (eg, physicians) and the physical environment.<sup>31,48–50</sup> Although many eligible studies considered these other factors and their complex interplay in conceptual models, data were generally not available to control for all of these confounders. Thus, it is difficult to distinguish causal effects of nurse staffing independent from higher nurse staffing or skill mix being an indicator of higher resources in nursing homes.

None of the 378 studies that underwent full-text review included cost-effectiveness analysis related to nursing staffing. Cost-effectiveness data would help administrators to determine the allocation of resources to maximize resident total quality of care (eg, hire additional RN or other staff). For nursing homes that want to increase staffing, there may be larger environmental challenges (eg, nursing shortages). Although outside the scope of this current review, other options nursing homes may consider for improving resident outcomes include greater resources for allied health professionals (eg, social workers).

Our review has several limitations. We focused on nursing home staffing, and not on other structural factors of nursing homes that may be important for resident outcomes. We also prioritized resident outcomes based on the needs of our VA stakeholders. Our results are likely not applicable to outcomes in non-US nursing homes. Nursing homes are governed by a complex set of regulations, which have substantially changed since 2000 and likely differ in other countries. Training and experience for nursing staff may also vary across different countries. There may also be differences in resident characteristics, varying national regulations and financial policies for nursing home benefits.

## Conclusions and Implications

Higher RN staffing and staffing mix may be associated with fewer pressure ulcers, fewer COVID-19 cases/mortality, fewer nursing home-associated infections, and lower rates of moderate-severe pain. In contrast, total staffing was not associated with improvements in pressure ulcers or urinary infections and the effect on other outcomes was uncertain. Increasing RN staffing and skill mix are one of a variety of approaches to improve nursing home care. Nursing home nurse hiring policies and staff quality evaluation metrics should consider the number, type and costs of adverse outcomes that can be avoided with higher skilled nursing staffing and alternative approaches to improving care.

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substantive issues or possibly overlooked areas of research; and provides feedback on work in progress. We are thankful to the contribution of expert advisory panel whose members are listed below:

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**Supplementary Appendix 1**

## Search Strategies

MEDLINE	
1	Long term care/
2	Exp nursing homes/
3	Exp homes for the aged/
4	((senior* or continuity care or disabled or old age or geriatric* or elder care*) adj2 (lodge* or facility* or home* or residence* or centre* or center*)).mp.
5	Or/1-4
6	Nurses/or nurse administrators/ or nurse clinicians/ or nursing staff/ or licensed practical nurses/ or nursing assistants
7	workload/or shift work schedule/
8	nursing/ or nursing administration research/
9	((((RN or staff* or care or case or nurse* or skill) adj1 mix) or (staffing adj1 model* or care model*) or ((nurs* or staff* or patient* or client) adj1 ratio*) or (nursing adj1 delivery systems\$1) or (staff* adj1 level*) or (nurs* adj1 (availb* or coverage or presence or hours or role or dose) or schedul* or workforce)) or (minute* or hour* or time) adj1 (patient* or client* or resident*)).ti,ab.
10	OR/6-9
11	5 and 10
12	Limit 11 to English
13	Limit 12 to yr="2001-current"
14	Limit 12 to yr="2013 – current"

Embase	
1	Institutional care/
2	Nursing home patient/
3	Exp nursing homes/
4	Exp homes for the aged/
5	((senior* OR continuity care OR disabled OR old age OR geriatric* OR elder care*) ADJ2 (lodge* OR facility* OR home* OR residence* OR centre* OR center*)).mp.
6	Or/1-5
7	Nurse/or nurse administrator/ or clinical nurse specialist/ or nursing staff/ or nursing assistants/
8	workload/or shift schedule/
9	((RN OR staff* OR care OR case OR nurse* OR skill) ADJ1 mix) OR (staffing ADJ1 model* OR care model*) OR ((nurs* OR staff* OR patient* OR client) ADJ1 ratio*) OR (nursing ADJ1 delivery systems\$1) OR (staff* ADJ1 level*) OR (nurs* ADJ1 (availb* OR coverage OR presence OR hours OR role OR dose)) OR (minute* OR hour* OR time) ADJ1 (patient* OR client* OR resident*)
10	OR/7-9
11	6 and 10
12	Limit 11 to English
13	Limit 12 to yr="2001-current"
14	Limit 12 to yr="2013-current"

CINAHL	
1	MH "long term care"
2	MH "nursing homes"
3	TI ((senior* OR "continuity care" OR disabled OR "old age" OR geriatric* OR "elder care*") N2 (lodge* OR facility* OR home* OR residence* OR centre* OR center*))
4	AB ((senior* OR "continuity care" OR disabled OR "old age" OR geriatric* OR "elder care*") N2 (lodge* OR facility* OR home* OR residence* OR centre* OR center*))
5	S1 OR S2 OR S3 OR S4
6	(MH "Nurses") OR (MH "clinical nurse specialists") OR (MH "practical nurses") OR "nursing assistants"
7	MH "workload"
8	MH nursing administration research
9	TI ((RN OR staff* OR care OR case OR nurse* OR skill) N1 mix) OR ("staffing" N1 "model*" OR "care model*") OR ((nurs* OR staff* OR patient* OR client) N1 ratio*) OR (nursing N1 "delivery systems*1") OR (staff* N1 level*) OR (nurs* N1 (availb* OR coverage OR presence OR hours OR role OR dose)) OR (minute* OR hour* OR time) N1 (patient* OR client* OR resident*)
10	AB ((RN OR staff* OR care OR case OR nurse* OR skill) N1 mix) OR ("staffing" N1 "model*" OR "care model*") OR ((nurs* OR staff* OR patient* OR client) N1 ratio*) OR (nursing N1 "delivery systems*1") OR (staff* N1 level*) OR (nurs* N1 (availb* OR coverage OR presence OR hours OR role OR dose)) OR (minute* OR hour* OR time) N1 (patient* OR client* OR resident*)
11	S6 OR S7 OR S8 OR S9 OR S10
12	S5 AND S11
13	English (use the LA language field)
14	EM 200101- (limits to Jan 2001 to present)
15	EM 201301- (limits to Jan 2013 to present)



Gray Literature		
Site	Date of Access	Terms
Centers for Medicare and Medicaid services <a href="http://www.cms.gov">www.cms.gov</a>	9-15-2021	"staffing levels"
Centers for Disease Control <a href="http://www.cdc.gov">www.cdc.gov</a>	9-15-2021	"staffing levels" as exact phrase; "nursing home, long term care, community living center" as any of these words
American Association of Retired Persons <a href="http://www.aarp.org">www.aarp.org</a>	9-14-2021	"staffing levels"
American Health Care Association/National Center for Assisted Living Ahcancal.org	9-14-2021	"staffing levels"
Office of the Assistant Secretary for Planning and Evaluation <a href="https://aspe.hhs.gov/">https://aspe.hhs.gov/</a>	9-8-2021	"nursing home" and filtered by topic of "Nursing Home and Facilities" "staffing levels" and filtered by topic of "Long-Term Services & Supports, Long-Term Care"
American Nurses Association Nursingworld.org	9-10-2021	"staffing levels"
Leading age <a href="https://www.leadingagemn.org/">https://www.leadingagemn.org/</a>	9-13-2021	"nursing home"
McKnight <a href="https://www.mcknight.org/">https://www.mcknight.org/</a>	9-10-2021	"nursing home"
Pioneer Network <a href="https://www.pioneernetwork.net/">https://www.pioneernetwork.net/</a>	9-10-2021	"nursing home"
Gerontological Society of America <a href="https://www.geron.org/">https://www.geron.org/</a>	9-10-2021	"nursing home"
American Association of Colleges of Nursing <a href="https://www.aacnnursing.org/">https://www.aacnnursing.org/</a>	9-10-2021	"nursing home"
Kaiser Family Foundation <a href="https://www.kff.org/">https://www.kff.org/</a>	9-13-2021	"nursing home" and filtered by content type of "report"

## Supplementary Appendix 2

### Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria
Population	18 y or older residents of nursing homes	<18 y of age; living in group homes for mental health or developmental disabilities, or transitional housing for addiction recovery, etc.
Intervention	Staffing levels and staff mix: RN, LPN, NA (eg, nurse hours per resident, nurse to resident ratios, RN to total nurse staffing ratios)	Non-nurse disciplines
Comparator	Any	
Outcomes	<ul style="list-style-type: none"> <li>• Resident Outcomes               <ul style="list-style-type: none"> <li>— Nursing home-associated infections (eg, urinary tract infection, influenza, pneumonia, COVID-19)</li> <li>— Pressure ulcers (new or worsened)</li> <li>— Pain severity</li> </ul> </li> </ul>	
Timing	Any	
Setting	United States nursing homes (includes Community Living Centers and State Veterans Homes)	Assisted living facilities, facilities exclusively focused on acute care settings (ie, emergency rooms and inpatient floors) or congregant settings that are not providing skilled nursing services (ie, prison, etc)
Study Design	Randomized controlled trials or observational studies	Reviews, study protocols, case studies, editorials, qualitative, no comparison group

**Supplementary Appendix 3**  
Quality Rating for Included Studies

Author	Is it Clear in the Study that the "Staffing Level/Mix" Preceded the Outcome of Interest?	Were the Criteria for Inclusion in the Sample Clearly Defined?	Were the Study Subjects (ie Nursing Homes) and the Setting (ie, Geography, National vs State, Number of Homes) Described in Detail?	Was the Exposure (Staffing Level/Mix) Measured in a Valid and Reliable Way?	Were Confounding Factors Identified?	Were Strategies to Deal with Confounding Factors Stated?	Were the Outcomes Measured in a Valid and Reliable Way?	Was Follow up Complete and if Not, Were Differences Between Groups in Terms of Their Follow up Adequately Described and Analyzed?	Was the Appropriate Statistical Analysis Used?	Overall
Alexander <sup>41</sup>	Unclear	Yes	Yes	Yes	No	No	Yes	Not applicable	Yes	Low
Bosco <sup>39</sup>	Unclear	Yes	Yes	Yes	Unclear	No	Yes	Not applicable	Yes	Low
Bostick <sup>37</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Low
Castle <sup>25</sup>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Moderate
Castle <sup>27</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Moderate
Castle <sup>29</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Moderate
Castle <sup>19</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Moderate
Castle <sup>28</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Moderate
Castle <sup>40</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	No	Unclear	No	Low
Domi <sup>30</sup>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Flynn <sup>26</sup>	Unclear	Yes	Yes	Yes	Unclear	Unclear	Yes	Not applicable	Unclear	Moderate
Gorges <sup>33</sup>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	High
Harrington <sup>34</sup>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High
Konetzka <sup>13</sup>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	High
Lee <sup>22</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Moderate
Li <sup>35</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Moderate
Lin <sup>21</sup>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Moderate
Orth <sup>20</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	No	Moderate
Temkin-Greener <sup>24</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Unclear	Not applicable	Yes	Moderate
Trinkoff <sup>23</sup>	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	Moderate
Uchida-Nakajoji <sup>36</sup>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Not applicable	Yes	High
White <sup>51</sup>	Unclear	Unclear	Yes	Unclear	Yes	No	Yes	Unclear	No	Low

**Supplementary Appendix 4**

## Detailed Results—Nursing Home Staffing Associations Pressure Ulcers

Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition and Descriptives	Outcome Data Sources (Year); Analytic Strategy	Pressure Ulcers
Castle, 2015 <sup>19</sup> ; Moderate; Cross-sectional; 3939 free-standing NH ( $\geq 30$ beds) national sample	OSCAR (2008); FTE per 100 residents (not including agency staff), mean (SD): RN 11.7 (9.3), LPN 14.6 (8.4), NA 30.4 (9.5) Skill mix—RN/(LPN+NA), mean (SD): 0.25 (0.4) % FTE filled by agency staff, mean (SD): RN 9.7% (3.3), LPN 11.2% (3.5), NA 12.1% (4.2)	NH Compare, AHRF, Survey (2008); Negative binominal regression models were used, case mix adjusted	<b>Association between staffing and percent of residents with pressure ulcers (IRR [95% CI])</b> NA staffing level 0.93* [0.81, 0.97] LPN staffing level 0.83 [0.77, 1.01] RN staffing level 0.97* [0.91, 0.99] Staff mix 0.98** [0.88, 0.99] * $P < .5$ ** $P < .01$
Castle, 2011 <sup>25</sup> ; Moderate; Longitudinal; 2839 free-standing NH ( $\geq 30$ beds) national sample	OSCAR (2003 – 2007); FTE per 100 residents (not including agency staff), mean (SD): RN 11.7 (9.3), LPN 14.6 (8.4), NA 30.4 (9.5) Skill mix—RN/(LPN+NA), mean (SD): 0.25 (0.4) % FTE filled by agency staff, mean (SD): RN 9.7% (3.3), LPN 11.2% (3.5), NA 12.1% (4.2)	NH Compare, Survey (2003 – 2007); Negative binominal regression models were used.	<b>Association between change in staffing and percent of low-risk residents with pressure sores (<math>\beta</math> (SE)):</b> higher NA staffing levels $-0.81^*$ (0.11) higher LPN staffing levels $-0.16^*$ (0.04) higher RN staffing levels $-0.46^*$ (0.17) higher staff mix $-0.42^{***}$ (0.21) * $P < .001$ , ** $P < .05$
Castle, 2007 <sup>27</sup> ; Moderate; Cross-sectional; 1071 free-standing NH ( $\geq 30$ beds) national sample	OSCAR (March – June 2003); FTE per 100 residents (not including agency staff), mean (SD): RN 14.7 (9.3), LPN 16.6 (8.1), NA 33.4 (10.1) % FTE filled by agency staff, mean (SD): RN 7.7% (12.7), LPN 1.9% (3.9), NA 20.2% (18.9)	NH Compare, AHRF, Survey (2003 – 2005); Negative binominal regression models, coefficients (SE), *significant at 5%; **significant at 1%	<b>Association between staffing characteristics and pressure sores for low and high risk residents:</b> <u>Low Risk Residents</u> Log RN Staffing 0.939 (0.101) Log LPN Staffing 1.137** (0.055) Log NA Staffing 1.076 (0.173) <u>High Risk Residents</u> Log RN Staffing 0.808** (0.045) Log LPN Staffing 0.919 (0.111) Log NA Staffing 1.099 (0.084)
Castle, 2010 <sup>28</sup> ; Moderate; Cross-sectional; 2840 free-standing NH ( $\geq 30$ beds) national sample	NHA survey (2005); FTE per 100 residents (not including agency staff), mean (SD): RN 12.2 (8.2), LPN 12.5 (6.5), NA 25.8 (7.0) Agency staff FTE per 100 beds, mean (SD): RN 1.6 (1.2), LPN 2.9 (1.9), NA 6.9 (3.4)	NH Compare (2005); SEM path analysis, only coefficients with $P \leq .5$ were reported (otherwise NR), case mix adjusted	<b>SEM path coefficients for % of residents with pressure ulcer:</b> <u>RN staffing</u> Long-stay (high risk) NR Long-stay (low risk) $-0.10$ Short-stay $-0.05$ <u>LPN staffing</u> Long-stay (high risk) NR Long-stay (low risk) $-0.07$ Short-stay NR <u>NA staffing</u> Long-stay (high risk) $-0.02$ Long-stay (low risk) $-0.04$ Short-stay $-0.07$ <u>RN agency</u> Long-stay (high risk) NR Long-stay (low risk) NR Short-stay NR <u>LPN agency</u> Long-stay (high risk) $-0.12$ Long-stay (low risk) 0.05 Short-stay NR <u>NA agency</u> Long-stay (high risk) 0.65 Long-stay (low risk) 0.56 Short-stay 0.33

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## Supplementary Appendix 4 (continued)

Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition and Descriptives	Outcome Data Sources (Year); Analytic Strategy	Pressure Ulcers
Castle, 2008 <sup>29</sup> ; Moderate; Cross-sectional; 6005 free-standing NH ( $\geq 30$ beds) national sample	OSCAR (2004); NA, LPN, and RN FTE per 100 residents. mean (SD): RN 11.7 (9.5), LPN 15.6 (8.6), NA 31.4 (9.9) Skill mix—RN/(LPN+NA), mean (SD): 0.25 (0.4) % FTE filled by agency staff, mean (SD): RN 8.7% (3.1), LPN 10.2% (3.4), NA 11.1% (4.6)	MDS, NH compare, AHRF, Survey (2004); Negative binominal regression models, coefficients (SE), * $P < .05$ , ** $P < .01$ , *** $P < .001$	<b>Association between staffing measures and pressure ulcers among low and high risk populations:</b> <u>Low Risk Population</u> Log NA staffing 0.932*** (0.024) Log LPN staffing 0.944 (0.042) Log RN staffing 0.836* (0.082) Log staff mix 0.836* (0.086) <u>High Risk Population</u> Log NA staffing 0.940*** (0.017) Log LPN staffing 0.856*** (0.043) Log RN staffing 0.878** (0.051) Log staff mix 0.878** (0.053)
Flynn, 2010 <sup>26</sup> ; Moderate; Cross-sectional; 63 NH in New Jersey	NHC (2006); Mean minutes of care per resident day, mean (SD): RN 51 (29), LPN 43 (26), NA 135 (29), total nurse staffing 93 (44)	NHC (2006); Linear regression models for percentage of residents with pressure ulcers	<i>"There were no significant associations between any of these metrics of nurse staffing levels and other study variables."</i> (coefficients and other statistics NR)
Konetzka, 2008 <sup>13</sup> ; High; Longitudinal; 1366 NH (399,206 residents)	OSCAR (1997 – 2000); RN HPRD, Skill mix measured as RN staffing hours as a proportion of total (RN, LPN, and NA) staffing hours. Mean (SD) RN HPRD: 0.350 (0.291) Skill Mix: 0.117 (0.064) Instrumental variables: Indicator for when a facility implemented Medicare a Prospective Payment System and percent of residents in a nursing home with Medicare payer source in the baseline year (1997)	MDS, Medicare Cost Reports (1997 – 2000); Logistic mixed model including an instrumental variable using the introduction of the Prospective Payment System (PPS) for Medicare payment in nursing homes, case mix adjusted	<b>Risk of stage 2+ Pressure Sores in past 14 days (<math>\beta</math> (SE), (P value)).</b> Facility Fixed Effects Model: RN HPRD -0.222 (0.123) Skill Mix 0.632 (0.424) Instrumental Variable, Medicare PPS Model: RN HPRD -3.006* (0.515) Skill Mix -0.0009 (0.254) Instrumental Variable PPS w/residuals: RN HPRD -3.002* (0.515) Skill Mix 0.045 (0.437) * $P < .01$
Lee, 2014 <sup>22</sup> ; Moderate; Cross-sectional; 195 free-standing NH in Colorado	OSCAR (2000); RN HPRD Mean (SD) [Range]: 0.6 (0.2) [0.2-1.6] Estimated RN staffing using 2 instrumental variables (percent of the population over 65 and percent of females in workforce)	MDS (2000); Ordinary least squares regression model for rates outcomes among NH residents, also instrumental variable models (uses estimated RN staffing), case mix adjusted, coefficients (SE)	<b>Association between estimated RN staffing and pressure ulcers in low-risk residents, <math>\beta</math> (SE), (P value)</b> $\beta = -1.1.272$ (SE=5.026), ( $P < .05$ )
Lin, 2014 <sup>21</sup> ; Moderate; Longitudinal; 3275 NH national sample	OSCAR (1999 and 2003); Includes full-time, part-time, and contract nurses Mean (SD) RN: 0.338 (0.316) NA: 2.438 (0.589) LN: 1.101 (0.550) LPN: 0.759 (0.399)	AHRF, Census (1999 and 2003); Two stage model with an instrumental variable predicting the change in nurse staffing after a policy change with required staffing levels was included in the model	<b>Association between predicted change in staffing after policy change and the fraction of residents with pressure ulcers (<math>\beta</math> (SE))</b> Distance RN 0.041** (0.021) Distance NA 0.0007 (0.006) * $P$ value $< .10$ , ** $P$ value $< .05$ , *** $P$ value $< .01$
Orth, 2021 <sup>20</sup> ; Moderate; Cross-sectional; 14,618 NH national sample (191,435 residents with dementia who died in 2017)	Nursing Home Compare (2018) and LTCfocus; HPRD, mean (SD): total 3.8 (0.7) Skill mix—RN/total staffing, mean (SD): 0.16 (0.07)	MDS (2018); Mixed-effects logistic models for odds of resident with pressure ulcers at time of death, case mix adjusted and stratified analyses for severity of dementia, OR (95% CI), $P$ values	<b>Total staffing hours per day (10-min increments) and pressure ulcers at time of death, stratified by dementia severity:</b> mild: 1.00 (0.98, 1.01), $P = .50$ moderate: 1.00 (0.99, 1.01), $P = .50$ severe: 0.99 (0.98, 1.01), $P = .07$ <b>Skill mix and pressure ulcers at time of death, stratified by dementia severity:</b> mild: 0.98 (0.85, 1.12), $P = .75$ moderate: 0.93 (0.85, 1.02), $P = .12$ severe: 0.91 (0.82, 1.00), $P = .048$
Temkin-Greener, 2012 <sup>24</sup> ; Moderate; Cross-sectional; 162 NH in New York (20,929 residents with stays $\geq 90$ d and impaired with bed mobility or transfer, comatose or malnourished)	Survey, study specific (2006-2007); HPRD, mean (SD): RN 0.6 (0.2), LPN 0.8 (0.3), NA 2.3 (0.4), total staffing NR	MDS (2006 – 2007); Generalized estimating equations were used after risk-adjusted outcomes were identified, case mix adjusted	<b>Association of nurse staffing (HPRD) with pressure ulcers, (OR (P value)).</b> Total staffing 1.107 ( $P = .615$ )

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Supplementary Appendix 4 (continued)

Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition and Descriptives	Outcome Data Sources (Year); Analytic Strategy	Pressure Ulcers
Trinkoff, 2013 <sup>23</sup> ; Moderate; Cross-sectional; 1142 NH national sample	NNHS (2004); Total nurse staffing HPRD, dichotomized as $\geq 5.0$ vs $<5.0$ (88% NH) Skill mix— $(RN+LPN)/(RN+LPN+NA)$ Mean 34% (SD, NR)	MDS (2004); Logistic regression (NH $>75$ th percentile in outcome rate), separate models for NA or licensed nurse (RN+LPN) turnover as main predictor, OR (95% CI)	<b>Pressure ulcer in low and high risk residents:</b> <u>NA turnover model</u> high risk: Staffing 1.01 (0.56, 1.82) Skill mix 1.02 (0.99, 1.05) low risk: Staffing 1.21 (0.58, 2.53) Skill mix 1.02 (0.98, 1.05) <u>Licensed nurse turnover model</u> High risk: Staffing 1.18 (0.66, 2.12) Skill mix 1.02 (0.99, 1.04) low risk: Staffing 0.80 (0.38, 1.66) Skill mix 1.02 (0.98, 1.05)

AHRF, Area Health Resource File; CDC, Centers for Disease Control and Prevention; CI, confidence interval; CLC, community living center; IQR, interquartile range; IRR, incident rate ratio; NH, nursing home; NHC, Nursing Home Compare (CMS data); NNHS, National Nursing Home Survey; PBJ, payroll based journal; PPS, prospective Payment System; RR, rate ratio; SEM, structural equation modeling.

Supplementary Appendix 5

Detailed Results—Nursing Home Staffing Associations with COVID-19

Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition & Descriptives	Outcome Data Sources (Year); Analytic Strategy	COVID-19 Results
Domi, 2021 <sup>30</sup> ; High; Repeated time series; 2501 NH in 17 states (had vaccine clinics as part of Pharmacy Partnership for Long Term Care Program)	PBJ (2020) RN HPRD in 3 categories, %NH in categories across 3 cohorts: $\leq 0.449$ —23-30% (low staffing) $0.499$ — $0.987$ —51-55% (reference) $>0.987$ —51-55% (high staffing)	NHSN (2021) Zero-inflated negative binomial mixed effects regression for number of resident cases and number of resident deaths (due to COVID-19), IRR	<b>Resident COVID-19 Cases:</b> RN low staffing ( $\leq 0.499$ ) 0.92, $P=.47$ RN high staffing ( $>0.987$ ) 0.84, $P=.16$ <b>Confirmed Resident COVID-19 Deaths:</b> RN low staffing ( $\leq 0.499$ ) 1.05, $P=.73$ RN high staffing ( $>0.987$ ) 0.68, $P=.02$
Gorges, 2020 <sup>33</sup> ; High; Cross-sectional; 13,167 NH national sample (85% of facilities that had reported data to CMS COVID-19 Nursing Home dataset)	PBJ (2020) Case-mix adjusted HPRD, mean (SD NR): RN 0.7, LPN 0.9, NA 2.3, total nurse staffing 3.9 Skill mix—RN/total nurse staffing, mean (SD NR): 17.9	CMS COVID-19 Nursing Home dataset (2020) 2 separate models per each outcome: 1) RN, LPN, and NA staffing 2) Total nurse staffing and skill mix (all staffing categorized in 3 quantiles—low, middle-reference, and high) 3 NH outcomes: • Any COVID-19 cases (logistic regression) • Any COVID-19 outbreak (logistic regression) • Count of COVID-10 deaths in NH with any cases (hurdle negative binomial-2 regression) Models not adjusted for case mix	<b>Any COVID-19, COVID-19 Outbreak, Deaths, marginal</b> <u>Model 1 OR (SE) OR (SE) effect (SE)</u> Low RN 0.838 (0.069)* 0.874 (0.070) -0.415 (0.196)* High RN 1.341 (0.088)** 1.031 (0.079) -0.243 (0.217) Low LPN 0.975 (0.052) 0.847 (0.073) -0.702 (0.203) High LPN 1.083 (0.066) 1.064 (0.081) -0.183 (0.197) Low NA 0.887 (0.058) 1.001 (0.078) -0.34 (0.184) High NA 1.027 (0.071) 0.790 (0.058) * -0.981 (0.229)** <u>Model 2</u> Low total 0.827 (0.071)* 0.924 (0.073) -0.371 (0.186)* High total 1.153 (0.109) 0.822 (0.057) ** -1.059 (0.229)** Low skill mix 0.887 (0.052)* 1.018 (0.062) -0.389 (0.207) High skill mix 1.218 (0.078)** 1.034 (0.069) -0.296 (0.195) * $P < .05$ ; ** $P < .01$
Harrington, 2020 <sup>34</sup> ; High; Cross-sectional; 1091 NH in California (272 with COVID-19 cases, 819 without)	PBJ (2019); HPRD, mean (SD): RN 0.6 (0.6), total staffing 4.3 (1.1)	LA County Department of Public Health, California Department of Public Health, and news organizations (March-May 2020) Logistic regression for NH having any COVID-19 cases, separate models for RN and total staffing, not adjusted for case mix, OR (95% CI)	<b>Any COVID-19 Cases</b> RN $<0.75$ vs $\geq 0.75$ HPRD: 2.086 (1.318, 3.301) Total staffing $<4.1$ vs $\geq 4.1$ HPRD: 1.269 (0.932, 1.72)

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**Supplementary Appendix 5** (continued)

Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition & Descriptives	Outcome Data Sources (Year); Analytic Strategy	COVID-19 Results
Li, 2020 <sup>35</sup> ; Moderate; Cross-sectional; 215 NH in Connecticut	NHC, PBJ (2019); HPRD, mean (IQR): RN 0.7 (0.5-0.8), total staffing 3.7 (3.3-4.0)	News organizations, state agency data (2019-2020); Logistic regression for NH having any confirmed case or death, and linear model (Poisson distribution) for number of cases or deaths in NH with any, case mix adjusted	<b>Resident COVID-19 Cases</b> <u>Any cases, OR (95% CI)</u> RN staffing, per 0.33 HPRD: 0.81 (0.41,1.60), $P=.54$ <u>Count of cases, IRR (95% CI)</u> RN staffing, per 0.33 HPRD: 0.78 (0.68, 0.89), $P=<0.001$ <b>Resident COVID-19 Deaths</b> <u>Any deaths, OR (95% CI)</u> RN staffing, per 0.33 HPRD: 0.62 (0.29, 1.35), $P=.229$ <u>Count of cases, IRR (95% CI)</u> RN staffing, per 0.33 HPRD: 0.74 (0.55, 1.00), $P=.047$

CI, confidence interval; IRR, incident rate ratio; IQR, interquartile range; NH, nursing home; NHC, Nursing Home Compare (CMS data); PBJ, payroll based journal; SD, standard deviation; SE, standard error.

**Supplementary Appendix 6**

Detailed Results—Nursing Home Staffing Associations with Nursing Home-Associated Infections (non-COVID-19)

Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition and Descriptives	Outcome Data Sources (Year); Analytic Strategy	Nursing Home-Associated Infections
Castle, 2010 <sup>28</sup> ; Moderate; Cross-sectional; 2840 free-standing NH ( $\geq 30$ beds) national sample	NHA survey (2005); FTE per 100 residents (not including agency staff), mean (SD): RN 12.2 (8.2), LPN 12.5 (6.5), NA 25.8 (7.0) Agency staff FTE per 100 beds, mean (SD): RN 1.6 (1.2), LPN 2.9 (1.9), NA 6.9 (3.4)	NH Compare (2005); SEM path analysis, only coefficients with $P \leq .5$ were reported (otherwise NR), case mix adjusted	<b>SEM path coefficients for % residents with UTI:</b> RN staffing 0.05 LPN staffing NR NA staffing -0.03 RN agency NR LPN agency -0.07 NA agency 0.11 Unstandardized structural equation model coefficients for staffing represent the percent change in urinary tract infection per a 1% change in the staffing measure.
Konetzka, 2008 <sup>13</sup> ; High; Longitudinal; 1366 NH (399,206 residents)	OSCAR (1997 – 2000); RN HPRD, Skill mix measured as RN staffing hours as a proportion of total (RN, LPN & NA) staffing hours. Mean (SD) RN HPRD: 0.350 (0.291) Skill Mix: 0.117 (0.064) Instrumental variables: Indicator for when a facility implemented Medicare a Prospective Payment System and percent of residents in a nursing home with Medicare payer source in the baseline year (1997)	MDS, Medicare Cost Reports (1997 – 2000); Logistic mixed model including an instrumental variable using the introduction of the Prospective Payment System (PPS) for Medicare payment in nursing homes, case mix adjusted	<b>Resident Urinary Tract Infection</b> Fixed Effects Model Coefficient (SE) RN HRPD: 0.194 (0.106; $P < .10$ ) Skill Mix: -0.504 (0.352; $P = R$ ) Two-stage least squares Coefficient (SE) RN HRPD: -1.528 (0.410; $P < .001$ ) Skill Mix: -1.634 (0.525; $P < .0-1$ ) Two-stage residual inclusion Coefficient (SE) RN HRPD: -1.556 (0.411; $P < .001$ ) Skill Mix: -1.662 (0.495; $P < .001$ )
Lee, 2014 <sup>22</sup> ; Moderate; Cross-sectional; 195 free-standing NH in Colorado	OSCAR (2000); RN HPRD Mean (SD) [Range]: 0.6 (0.2) [0.2-1.6] Estimated RN staffing using 2 instrumental variables (percent of the population over 65 and percent of females in workforce)	MDS (2000); Ordinary least squares regression model for rates outcomes among NH residents, also instrumental variable models (uses estimated RN staffing), case mix adjusted, coefficients (SE)	<b>Percent of Residents with Urinary Tract Infection</b> 2-stage least squares regression beta coefficient RN HPRD: 3.090 (SE = 4.017; $P$ value=NR). Non-Instrumental Variables Estimate: NR
Trinkoff, 2013 <sup>23</sup> ; Moderate; Cross-sectional; 1142 NH national sample	NNHS (2004); Total nurse staffing HPRD, dichotomized as $\geq 5.0$ vs $<5.0$ (88% NH) Skill mix—(RN+LPN)/(RN+LPN+NA) Mean 34% (SD, NR)	MDS (2004); Logistic regression (NH $>75$ th percentile in outcome rate), separate models for NA or licensed nurse (RN+LPN) turnover as main predictor, OR (95% CI)	<b>UTI</b> <u>NA turnover model</u> Staffing 0.77 (0.40, 1.47) Skill Mix 1.02 (1.00, 1.04) <u>Licensed nurse turnover model</u> Staffing 0.68 (0.37, 1.27) Skill Mix 1.02 (1.00, 1.04)

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**Supplementary Appendix 6** (continued)

Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition and Descriptives	Outcome Data Sources (Year); Analytic Strategy	Nursing Home-Associated Infections
Trivedi, 2012 <sup>38</sup> ; Moderate; Longitudinal; 308 NH in Oregon, Wisconsin, and Pennsylvania that reported norovirus outbreak	NHC (2009–2010) HPRD, mean (IQR): RN 0.8 (0.7–1.0)	MDS and CDC National Outbreak Reporting System (2009–2010) Mixed effects Poisson regression models to compare NH resident hospitalizations and mortality during norovirus outbreak and non-outbreak periods, stratified by RN HPRD (<0.75, 0.75–0.95, and >0.95)	<u>Hospitalization RR (95%CI)</u> RN HPRD: <0.75 1.10 (1.03–1.19), <i>P</i> = .006 0.75–0.95 1.13 (1.05–1.21), <i>P</i> = .001 >0.95 1.04 (.97–1.11), <i>P</i> = .300 <u>Mortality RR (95%CI)</u> RN HPRD: <0.75 1.26 (1.14–1.40), <i>P</i> < .001 0.75–0.95 1.01 (0.91–1.12), <i>P</i> = .87 >0.95 1.06 (0.94–1.19), <i>P</i> = .32
Uchida-Nakakoji, 2015 <sup>36</sup> ; High; Longitudinal; 84 VA NH (CLCs) national sample	VA payroll data (2003–2008); HPRD, mean (SD): Total nurse staffing 4.6 (1.2) Skill Mix—each type/total staffing, mean (SD): RN 31% (10%), LPN 26% (10%), NA 42% (13%)	MDS (2003–2008) Negative binomial regression models for total counts per NH (UTI, pneumonia and pressure ulcers), case mix adjusted	<b>Composite of UTI, pneumonia, and pressure ulcers</b> IRR (SE) Total staffing: 1 (0.01), <i>P</i> = .985 Percent RN: 1.233 (0.232), <i>P</i> = .264 Percent NA: 1.160 (0.180), <i>P</i> = .336

AHRF, Area Health Resource File; CI, confidence interval; CLC, community living center; IQR, interquartile range; IRR, incident rate ratio; NH, nursing home; NHC, Nursing Home Compare (CMS data); NNHS, National Nursing Home Survey; PBJ, payroll based journal; PPS, prospective payment system; RR, rate ratio; SEM, structural equation modeling.

**Supplementary Appendix 7**

Detailed Results—Nursing Home Staffing Associations with Resident Pain

Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition and Descriptives	Outcome Data Sources (Year); Analytic Strategy	Moderate to Severe Pain
Castle, 2015 <sup>19</sup> ; Moderate; Cross-sectional; 3939 free-standing NH, ≥30 beds, national sample	NHA survey (2008); FTE per 100 residents (not including agency staff), mean (SD): RN 11.7 (9.3), LPN 14.6 (8.4), NA 30.4 (9.5) % FTE filled by agency staff, mean (SD): RN 9.7% (3.3), LPN 11.2% (3.5), NA 12.1% (4.2) Skill mix—RN/(LPN+NA), mean (SD): 0.25 (0.4)	NH Compare (2008); Negative binomial regression (counts of cases per NH), case-mix adjusted, IRR (95% CI)	Residents (long-stay) with moderate-severe pain: <u>FTE</u> RN 1.02 (0.99, 1.13) LPN 0.98* (0.89, 0.99) NA 0.89* (0.83, 0.98) <u>% agency</u> RN 1.09* (1.02, 1.14) LPN 1.01* (1.00, 1.10) NA 1.05 (0.99, 1.18) Staff mix 0.92*** (0.88, 0.98) * <i>P</i> < .05; ** <i>P</i> < .01; *** <i>P</i> < .001
Castle, 2011 <sup>25</sup> ; Moderate; Longitudinal; 2839 free-standing NH, ≥30 beds, national sample	NHA survey (2003–2007); FTE per 100 residents (not including agency staff), mean (SD): RN 11.7 (9.3), LPN 14.6 (8.4), NA 30.4 (9.5) % FTE filled by agency staff, mean (SD): RN 9.7% (3.3), LPN 11.2% (3.5), NA 12.1% (4.2) Skill mix—RN/(LPN+NA), mean (SD): 0.25 (0.4)	NH Compare (2003–2007); GMM with Arellano-Bond estimator (change in % residents with outcome, case-adjusted measure), coefficients (SE)	Residents (long-stay) with moderate-severe pain: <u>FTE (per increase of 1)</u> RN -0.53*(0.28) LPN -0.15** (0.05) NA -0.46** (0.17) <u>% agency (per decrease of 1%)</u> RN -0.31*** (0.11) LPN -0.19 (0.08) NA -0.32*(0.02) Skill mix, per increase of 1% -0.15*** (0.03) Significant at: * 0.05; ** 0.01; ***0.001
Castle, 2010 <sup>28</sup> ; Moderate; Cross-sectional; 2840 free-standing NH, ≥30 beds, national sample	NHA survey (2005); FTE per 100 residents (not including agency staff), mean (SD): RN 12.2 (8.2), LPN 12.5 (6.5), NA 25.8 (7.0) Agency staff FTE per 100 beds, mean (SD): RN 1.6 (1.2), LPN 2.9 (1.9), NA 6.9 (3.4)	NH Compare (2005); SEM path analysis (% residents with outcome, case-adjusted for pain but not functioning), path coefficients <i>P</i> ≤ .05 were reported (otherwise NR)	Residents with moderate-severe pain: <b>Long-stay Short-stay</b> <u>FTE</u> RN -0.17 -0.06 LPN -0.14 -0.06 NA -0.06 -0.01 <u>Agency FTE</u> RN NR NR LPN NR NR NA 0.55 0.10

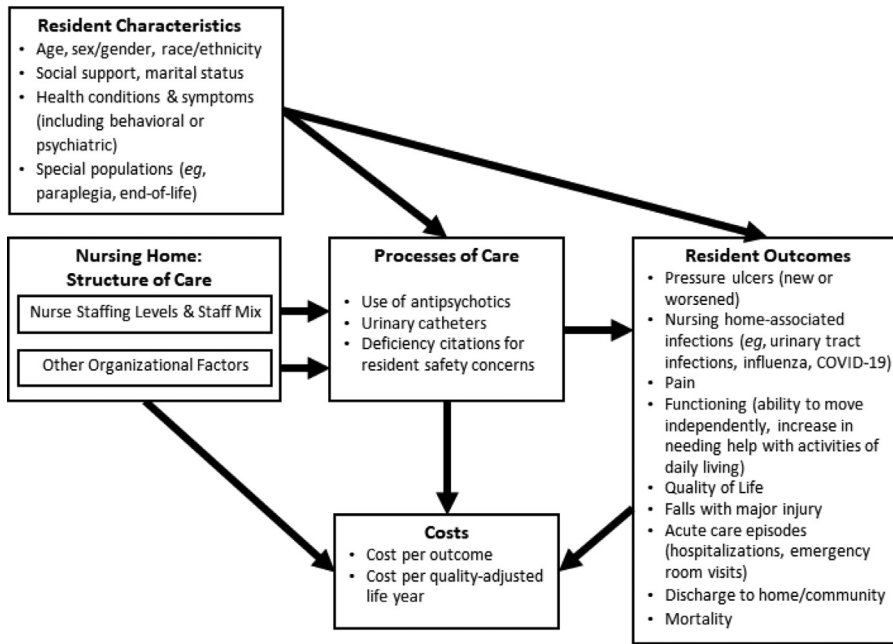
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## Supplementary Appendix 7 (continued)

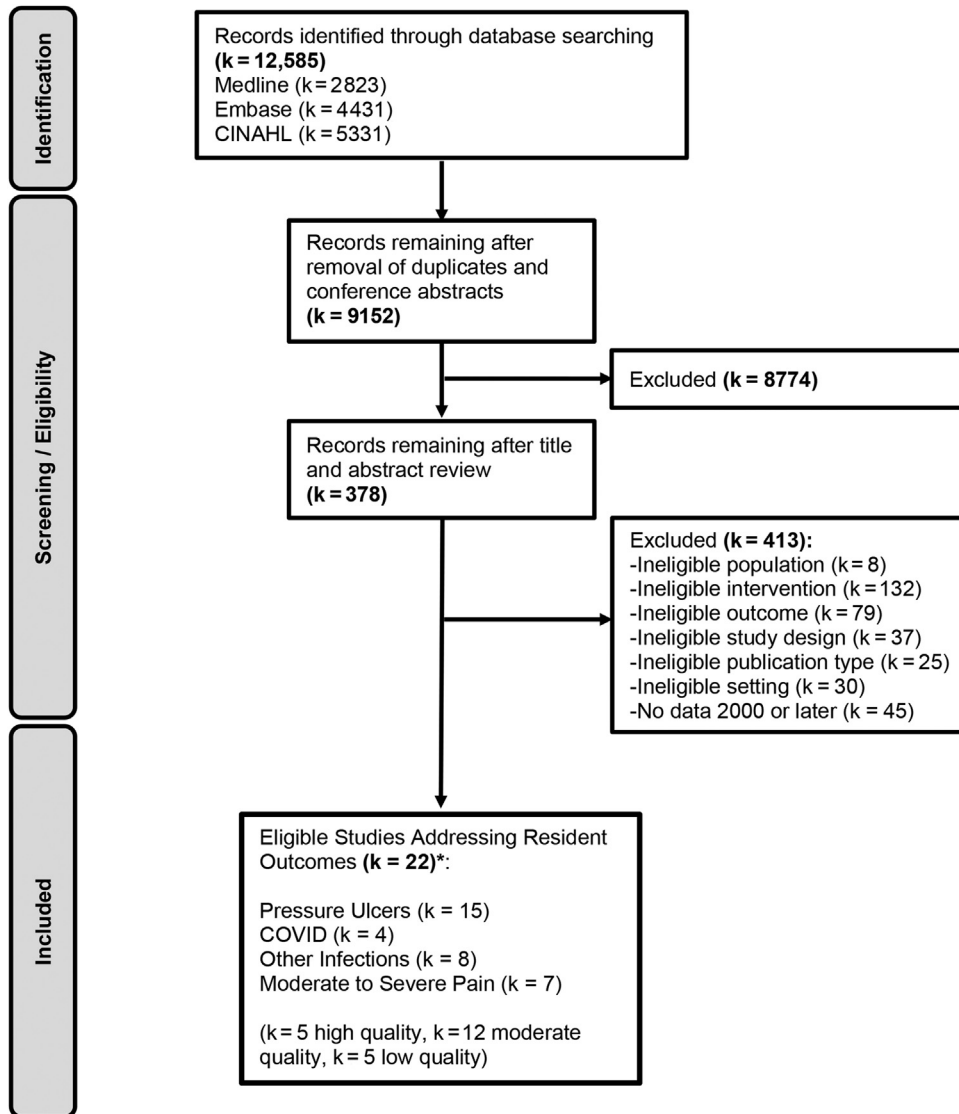
Author, Year; Quality Study Design; Sample	Nurse Staffing: Data Sources (Year); Definition and Descriptives	Outcome Data Sources (Year); Analytic Strategy	Moderate to Severe Pain
Castle, 2008 <sup>29</sup> ; Moderate; Cross-sectional; 6005 free-standing NH, ≥30 beds, national sample	NHA survey (2005–2006), staffing data for 2004; FTE per 100 residents (not including agency staff), mean (SD): RN 11.7 (9.5), LPN 15.6 (8.6), NA 31.4 (9.9) % FTE filled by agency staff, mean (SD): RN 8.7% (3.1), LPN 10.2% (3.4), NA 11.1% (4.6) Skill mix—RN/(LPN+NA), mean (SD): 0.25 (0.4)	NH Compare (2004); Negative binomial regression (count of events per NH), case adjustment NR, coefficients (SE)	Residents with moderate-severe pain: <b>Long-stay Short-stay</b> <u>Log FTE</u> RN 0.771** (0.083) 0.844*** (0.052) LPN 1.121 (0.099) 0.867** (0.049) NA 0.954*** (0.012) 0.478*** (0.106) <u>Log agency %</u> RN 1.184* (0.114) 1.012 (0.030) LPN 0.920 (0.149) 1.019 (0.192) NA 1.081*** (0.030) 1.055*** (0.021) Log skill mix 0.773** (0.082) 0.958 (0.040) *P < .05; **P < .01; ***P < .001.
Castle, 2007 <sup>27</sup> ; Moderate; Cross-sectional; 1071 NH in Missouri, Texas, Pennsylvania, New York, Connecticut, and New Jersey (2 states from each tertile for staff turnover)	NHA survey (2003); FTE per 100 residents (not including agency staff), mean (SD): RN 14.7 (9.3), LPN 16.6 (8.1), NA 33.4 (10.1) % FTE filled by agency staff, mean (SD): RN 7.7% (12.7), LPN 1.9% (3.9), NA 20.2% (18.9)	NH Compare (2003); Negative binomial regression (% residents with outcome, case-adjusted for pain and mobility but not ADL), coefficients (SE)	Residents with moderate-severe pain: <b>Long-stay Short-stay</b> <u>Log FTE</u> RN 0.960 (0.136) 1.247 (0.191) LPN 0.987 (0.152) 0.827 (0.143) NA 1.131 (0.253) 0.798 (0.333) <u>Log agency %</u> RN 1.077* (0.033) 1.004 (0.046) LPN 1.034 (0.028) 0.914* (0.038) NA 1.055 (0.059) 1.260** (0.079) Significant at: * 0.05; ** 0.01
Trinkoff, 2013 <sup>23</sup> ; Moderate; Cross-sectional; 1142 NH, national sample	National NH Survey (2004, by CDC); Total staffing (RN+LPN+NA) HPRD, dichotomized at < 5.0 or ≥5.0, 88% NH had <5.0 Skill mix—(RN+LPN)/(RN+LPN+NA), mean 34% (SD NR)	MDS (2004); Logistic regression (NH >75 <sup>th</sup> percentile in outcome rate), separate models for NA or licensed nurse (RN+LPN) turnover as main predictor, OR (95% CI)	Residents with moderate-severe pain (whether long-stay and/or short-stay NR): <u>NA turnover model</u> Total staffing 0.74 (0.37, 1.48) Skill mix 1.00 (0.98, 1.02) <u>Licensed nurse turnover model</u> Total staffing 0.57 (0.29, 1.11) Skill mix 1.00 (0.98, 1.02)

ADL, activities of daily living; CI, confidence interval; GLM, generalized linear model; GMM, generalized method of moments; IRR, incident rate ratio; MDS, Minimum Data Set; NH, nursing homes; NHA, nursing home administrator; NR, not reported; OSCAR, Online Survey Certification and Reporting; SD, standard deviation; SE, standard error; SEM, structural equations model.





Supplementary Fig. 1. Analytical framework.



\*Some studies addressed multiple outcomes

**Supplementary Fig. 2.** Literature flow diagram. \*Some studies addressed multiple outcomes.