Quantification of nursing workload and the need for nursing staff in intensive care

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Quantification of nursing workload and the need for nursing staff in Intensive Care

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CONTENTS

CHAPTER 1

General introduction

1.1 INTRODUCTION

The Intensive Care Unit (ICU) in a hospital delivers labor-intensive services to critically ill patients requiring a high amount of care. Due to their critical illness, the ICU patient is in need for monitoring and use of modalities for organ support, and therefore specialized nursing care[1,2].

The Dutch Quality Standard Organization of Intensive Care defines an ICU patient as "a patient with one or more critically endangered or impaired vital signs, where continuous monitoring is necessary, and treatment of a potentially reversible condition can lead to recovery of vital signs'[3]. This complex ICU patient requires special nursing care. Due to the complex care the ICU nurses provide they can take care for only a limited number of patients. The number of patients per nurse on an ICU does generally not exceed the number of three, or as usually stated the patients per nurse ratio is not exceeding 3 : 1[2-4]. On top of that, the ICU nurse has a higher autonomy in decision making and action, compared to the general ward nurse[5-8]. Due to the complex and specific care the nursing staff consists mainly of certified ICU nurses.

The resulting high need for specialized nursing capacity is also the main reason why ICU care is expensive[9]. The costs for nursing staff comprise about 40% of the total ICU costs[10,11]. In most West European countries, there exist currently a shortage of specialized ICU nurses[12,13]. Given the shortage of ICU nurses it is important to keep nurses motivated and satisfied with their job. Both understaffing and overstaffing is an undesirable situation which can lead to job dissatisfaction. Understaffing increases the risk for burn-out and overstaffing the risk for bore-out[14,15]. Therefore, nursing resources should be deployed as efficiently as possible. From a managerial as well as financial point of view, it is important to have access to valid and reliable instruments to quantify the need for nursing staff to avoid understaffing as well as overstaffing.

1.2 NURSING WORKLOAD

A common way to quantify the need for nursing staff is by quantifying the amount of work that is to be done by the nurses. The most used method to quantify the amount of work is to determine the number of patients a nurse has to take care of[16]. However, this is a crude measure and more important than the number of patients per nurse is the amount of work those patients actually require. The amount of time needed to perform those patient care activities is dependent on several factors, e.g. the degree of patient dependency, the complexity of the illness of the patient or the skills of the ICU nurse[17-19]. The sum of all those factors determines how much is asked from the nurse and is commonly translated in the term nursing workload. The definition of nursing workload is however complex[20,21]. Morris and his colleagues defines nursing workload as the amount of direct and indirect patient care activities carried out by nurses during their shift[21]. In this definition the nursing workload has different aspects, which can roughly divided into two dimensions; the amount of work for patient care and the impact of this work for the nurse[21,22]. The first dimension, the amount of work, is the time the nurse needed to perform the nursing activities, an objective and measurable parameter. In this thesis we therefore use the term 'objective workload' for this dimension of workload.

The second dimension of the nursing workload could be described as the cognitive or the mental demand[22-24]. Taking care for a critical ill dying young patient and his or her family can weigh much more in terms of nursing workload than taking care for a planned postoperative cardiac surgery patient. The workload can also be different for a graduated ICU nurse with a lot of experience than for a student ICU nurse. This dimension of nursing workload represents the experienced, subjective workload for the nurse. In this thesis we use the term 'perceived workload' for this dimension of nursing workload.

Over the last decades there has been a wide interest in the substantiation and weighing of nursing workload. A high workload in combination with a shortage of certified ICU nurses increases the risk of burn-out in ICU nurses[25,26]. Nursing workload has therefore been shown to be associated with the nurse's well-being and satisfaction, and equally important associated with patient outcome, ICU costs, hospital costs and ICU bed availability[27-29]. Giving the importance of nursing workload it is clear that one needs a reliable validated tool to quantify this workload.

1.2.1 Quantification of the objective nursing workload

Over the years, many systems have been developed to measure the objective nursing workload[30]. The way in which those models classify the need for nursing staff varies widely. The first model used for measuring nursing workload was the Therapeutic Intervention Scoring System (TISS)[31]. Although originally developed as early as in 1974 to classify the severity of illness, this system is still used to measure the nursing workload[23,32-34]. Because the TISS focusses on medical interventions and not on nursing activities it is not representing the actual nursing time. Therefore, Reis Miranda and his colleagues developed the Nursing Activity Score[35]. This system represents a total of 23 nursing activities in direct and indirect patient care with a score representing a mean time per activity. The sum score of the activities can be translated to the need for nursing staff. The developers validated the NAS and concluded that 81% of the total nursing time can be explained with the NAS, whereas the TISS was only representing 43% of the total nursing time[35]. The NAS was originally developed to measure the nursing workload per day but it has also been validated for the use per shift[36]. More than 15 years after development, the NAS is used all over the world for measuring nursing workload[37]. However, some studies showed that scoring NAS is subject to differences in interpretation of the scoring rules which can ultimately lead to differences in the NAS-score and subsequently lead to differences in the calculated need for nursing staff[38-40]. Given these considerations, the increasing use of the NAS and the importance of the results for ICU management it is relevant to re-evaluate the validity of this instrument in the current ICU practice in the Dutch ICU setting.

1.2.2 Quantification of the perceived nursing workload

Beside the time needed for the interventions, it is also important to quantify the perceived impact of this time on the nurse. Thirty minutes support and care for the patient and his or her family can weight more in terms of perceived workload than thirty minutes of administrative tasks surrounding discharge of a patient to the ward. The NASA-Task Load Index (TLX) is a questionnaire originally developed to measure the perceived workload in the National Aeronautics and Space Administration (NASA) but also validated in other settings, including health care systems[41,42]. It is commonly used to measure the perceived workload in health care[23,43,44]. Earlier research has shown that a perceived high workload is associated with job (dis)satisfaction and nurse burnout[27,45]. It is therefore important to focus on this aspect of the nursing workload. This final impact of nursing workload on a nurse is determined by both the objective and the perceived workload. The relation between objective and perceived workload is unclear, as is also the perception of this workload for the nurse. When is a nurse satisfied with his or her workload? When is it high? Or low? To our knowledge, it is unknown what nurses themselves consider a high or low workload, how this is related to nurses' satisfaction and which factors influence satisfaction. To keep the nurse motivated and satisfied and prevent nurses from developing a burnout, we feel that we also have to take their perception on an optimal workload into account[46,47].

1.3 NATIONAL INTENSIVE CARE EVALUATION

Managers should be able to benchmark the workload of their ICU with other ICUs, to support the process of decision making on capacity planning. For this thesis, we used data on workload gathered and processed by the National Intensive Care Evaluation (NICE) quality registry. NICE was founded in 1996 by a group of intensivists in the Netherlands for the purpose of benchmarking ICU data in order to monitor and improve quality of Dutch ICU care[48,49]. The minimal dataset of this registry contains among others demographic, physiological and diagnostic data, ICU, and hospital length of stay and mortality of all patients admitted to a Dutch ICU. Since 2016, all Dutch ICUs participate in the NICE registry. This year, 2021, we celebrate the 25th anniversary of NICE.

Besides participating with the minimal dataset, an ICU can choose to participate in other optional data modules. One of these optional modules is the capacity module, available since 2017, in which data about workload are processed. Since the start in 2017, eleven hospitals currently collect data for the capacity module and the number of participants is growing. The capacity module contains specific nursing information and was therefore developed in cooperation with the Dutch Society of ICU nurses, the V&VN-IC[50]. This dataset contains among others, NAS data. All separate interventions of the NAS, with the corresponding score, are collected and from these the total NAS score per patient is calculated. The capacity module also contains the number of ICU nurses per shift and per unit, classified as student or graduated ICU nurse. The NAS data are collected by ICU nurses at the end of each shift. The NICE registry provides both an online monitoring and analyses tool as well as annual benchmark reports with data of individual hospitals compared to the other participating hospitals. For this thesis, we used data from both the minimal dataset and the capacity module.

1.4 IMPACT OF COVID

Doing research on nursing workload in a period when the COVID-19 pandemic imposed a global burden on healthcare resources gave a unique opportunity to assess the effects of this problem on nursing workload. During this pandemic it became soon apparent that the COVID-19 patients had a huge impact on the ICU nursing workload. Also in the Netherlands the ICU nursing workload was considered high by ICU nurses as indicated in a survey among ICU nurses[51]. During this COVID-19 pandemic, the impact of a persistent high workload on the work satisfaction and mental health of ICU nurses became clear[52]. The experience of a new patient category with an unknown disease and the complexity of the nursing care in a setting with a high risk of infection caused overall a high nursing workload[53,54]. On top of the increase of nursing workload per patient, nurses were also confronted with an increase in the number of patients they had to take care for[55].

1.5 OBJECTIVES

The aim of this thesis was to evaluate existing scoring systems to quantify ICU nursing workload and to relate this objective nursing workload to the perceived nursing workload. To fulfil this aim we addressed the following research questions:

1. Which scoring systems to measure the amount of ICU nursing workload do exist and can they be applied to measure workload in the Dutch ICU setting?
2. To what extent are the objective nursing workload and the perceived nursing workload correlated and are they associated with the satisfaction of nurses with their workload?
3. What is the impact of COVID-19 on the ICU nursing workload?

1.6 THESIS OUTLINE

Research question one is answered in chapter 2 and 3. Chapter 2 of this thesis describes the results of a systematic literature review on scoring systems used to measure the amount of nursing care needed for ICU patients. We evaluated the validity and reliability of those systems and evaluated which system is most useful in daily practice in terms of quantification of the required nursing capacity. Chapter 3 describes a validation study of the Nursing Activities Score in the Dutch ICU setting, according to the literature review in chapter 2 the most used and best performing system, to measure nursing workload. We performed this validation study with time-motion techniques to find out if this system needs a revision after 15 years of use.

Research question two is answered in chapter 4 and 5. In chapter 4 we describe the association between the objective nursing workload, based on the NAS, and the perceived nursing workload, based on the NASA-TLX. In chapter 5 we describe the association of both the objective nursing workload and the perceived workload with the satisfaction of nurses on their nursing workload.

In chapter 6 we assessed our third research question. In this chapter we describe the impact of the COVID-19 pandemic on the nursing workload and compared it to a recent non-COVID period.

Finally, chapter 7 contains the overall findings and discussion of our findings, the strengths and limitations of this research project, the implications for practice and suggestions for further research.

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CHAPTER 2

Workload scoring systems in Intensive Care and their ability to quantify the need for nursing workload: A systematic literature review

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ABSTRACT

Introduction. The Intensive Care Unit is a resource intense service with a high nursing workload per patient resulting in a low ratio of patients per nurse. This review aims to identify existing scoring systems for measuring nursing workload in Intensive Care and assess their validity and reliability to quantify the needed nursing time.

Methods. We conducted a systematic review of the literature indexed before 01/Mar/2018 in the bibliographic databases MEDLINE, Embase, and Cinahl. Full-text articles were selected and data on systems measuring nursing workload in Intensive Care and translation of this workload into the amount of nursing time needed was extracted.

Results. We included 71 articles identifying 34 different scoring systems of which 27 were included for further analysis as these described a translation of workload into nursing time needed. Almost all systems were developed with nurses. The validity of most scoring systems was evaluated by comparing them with another system (59%) or by using time measurements (26%). The most common way to translate workload-scores into nursing time needed was by categorizing the Nurse:Patient-ratios. Validation of the Nurse:Patient-ratios was mostly evaluated by comparing the results with other systems or with the actual planning and not with objective time measurements.

Conclusion. Despite the large attention given to nursing workload systems for Intensive Care, only a few systems objectively evaluated the validity and reliability of measuring nursing workload with moderate results. The Nursing Activity Score system performed best. Poor methodology for the translation of workload scores into Nurse:Patient-ratio weakens the value of nursing workload scoring systems in daily Intensive Care practice.

INTRODUCTION

The Intensive Care Unit in a hospital is a labour-intense service due to its highly complex patients and the consequently high amount of care they require. Therefore, nurses can care for only a limited number of patients. A high workload and a low Nurse:Patient-ratio have shown to be associated with an increased risk for nosocomial infections in Intensive Care-patients, unplanned extubations, and an increased risk of mortality[1-5]. Although there is evidently a high need for nursing capacity, there are also constraints on the healthcare budget and the availability of educated Intensive Care nurses. It is clear that resources should be used as efficiently as possible, which means avoiding understaffing as well as overstaffing. Therefore, for managerial as well as financial reasons, quantification of the Nurse:Patient-ratio is an important issue as the costs for nursing staff comprise about 40% of total Intensive Care costs[6, 7]. Application of scoring systems to measure the amount of nursing time needed per patient, mostly translated into a Nurse:Patient-ratio, could provide insight into the required nursing capacity. This is increasingly important for Intensive Care management who has to focus on both quality and cost, including the implementation of guidelines on Nurse:Patient-ratios[8, 9]. The application of a reliable nursing workload classification system might optimize both Intensive Care and hospital costs, availability of Intensive Care beds and improve patient outcome. Due to this importance, many systems have been developed for this purpose over the years. However, the validation and application of those systems in daily practice varies strongly. The objective of this study is to systematically review the literature to identify existing scoring systems used to measure the amount of nursing care needed for Intensive Care patients, evaluate the validity and reliability and evaluate which system is most useful in daily practice in terms of quantification of the required nursing capacity.

METHODS

Search strategy

We searched the databases MEDLINE, Cinahl, and Embase for original studies with the primary aim to develop or validate a scoring system to quantify the nursing time needed for Intensive Care patients. We checked the references of the included publications for relevant publications. We searched all literature up till 01/Mar/2018. As the earliest publications on workload scoring systems, of which some are still in use, date from the early seventies we did not restrict the commencing date.

We also checked the Cochrane-database for published reviews on this topic. The search strategy included MeSH terms and keywords for 'nursing', 'Intensive Care', 'scoring system', 'classification' and 'workload'. The exact search queries are presented in appendix 1. The results were first independently assessed by two reviewers (MH and CM) based on title and abstract. If there was no abstract available, but the title indicated potential relevance, the article was selected for full-text reading. The full text of the selected articles was independently judged by the same two reviewers on the inclusion criteria. Differences in selection of articles were solved by discussion and in case of disagreement resolved by a third reviewer (NdK). We used a PRISMA flow chart for reporting the results of the search (www.equator-network.org/reporting-guidelines/prisma/)[88].

Selection criteria

Papers were selected when they adhered to all of the following inclusion criteria:

- It concerned an original study on either:
    - the development of a new scoring system to measure nursing workload or
    - the update of an existing scoring system to measure nursing workload or
    - the validation or evaluation of an existing scoring system to measure nursing workload
- The scoring system quantified the workload into the needed amount of nursing time based on points, classes, levels of care or absolute amount of time
- The setting was an adult Intensive Care Unit
- The language of the articles was English, German or Dutch

We excluded articles about scoring systems without a quantification of the nursing time needed. We also excluded articles with Intensive Care Units situated in a burn centre because the nursing care in a burn centre is not comparable with other Intensive Care Units. References from reviews and included articles were checked on relevance and included if they met the inclusion criteria.

Data extraction from selected articles

The two reviewers (MH and CM) extracted all relevant information from the selected articles by filling in a data extraction form. This form contained the following items: name of the scoring system, study aim, country, setting and number of participants (Intensive Care Units, patients and nurses), kind of nursing interventions or activities measured by the scoring system, methods used to select nursing interventions or activities in case of development of a scoring system, methods used to measure reliability and validity of the system, results regarding reliability and validity and methods used to translate the workload measurement in needed nursing time.

Assessment of validity and reliability of scoring systems

For all included full papers the validity and reliability of the scoring systems were assessed using the following criteria.

Content validity: we considered a scoring system content-valid when nursing professionals participated in the selection of interventions and activities included in the scoring system, and when expert-consensus in focus groups or Delphi rounds were used or when a Content Validity Index for the overall system was at least 0.9[10, 11].

Reliability: we assessed data on inter-rater reliability (level of agreement between the scores of different nurses scoring the nursing interventions of the same patient) and intra-rater reliability (level of agreement between assessment and reassessment of the nursing intervention scores of a patient by the same nurse). The following statistical tests and cut-off values were used for the assessment of the reliability: Cohen's Kappa and the Intra-Class Coefficient (ICC). For the Kappa we used the ranges of kappa according to Landis and Koch meaning a value of 0.41–0.60 as moderate; 0.61–0.80 as substantial, and 0.81–1 as almost perfect agreement[12]. For evaluation of the ICC we used the Cronbach's alpha with a cut-off point of 0.70 for an acceptable reliability[13].

Validity: we defined the validity as to which extent interventions or activities of a scoring system actually measured the true outcome i.e. needed nursing time. We distinguished two methods to assess the validity:

1. By comparing the results of a scoring system with the 'gold standard' observed time-measurements.
2. By comparing a newly developed scoring system with an already existing system.

We considered method 2 a weaker method for validation. The following statistical methods were used for the assessment of the validity: linear regression equation (r^2) and the Correlation Coefficient (Pearson's r or Spearman's r_s). For interpretation of the results we did categorize the results as a weak ($r/r^2<0.25$), moderate ($0.25\leq r/r^2<0.75$) or strong ($r/r^2\geq 0.75$) correlation[14].

We used the same methods to assess the validity of the translation of the measurement of nursing time into the need for nursing staff, often translated into a Nurse:Patient-ratio.

Results search strategy

Figure 1 shows a PRISMA flow chart with the results of the literature search strategy. Starting with 1840 unique articles we finally we included 71 articles for analysis. Among these 71 included articles, 30 articles reported on the development of a scoring system to measure the amount of nursing care. Nineteen articles (also) reported on reliability of an existing scoring system. Fourty four articles reported (also) on validation of a scoring system. In total 17 articles reported (also) on the validation of the translation of the measured nursing time into a Nurse:Patient-ratio for calculation of the need for nursing staff.

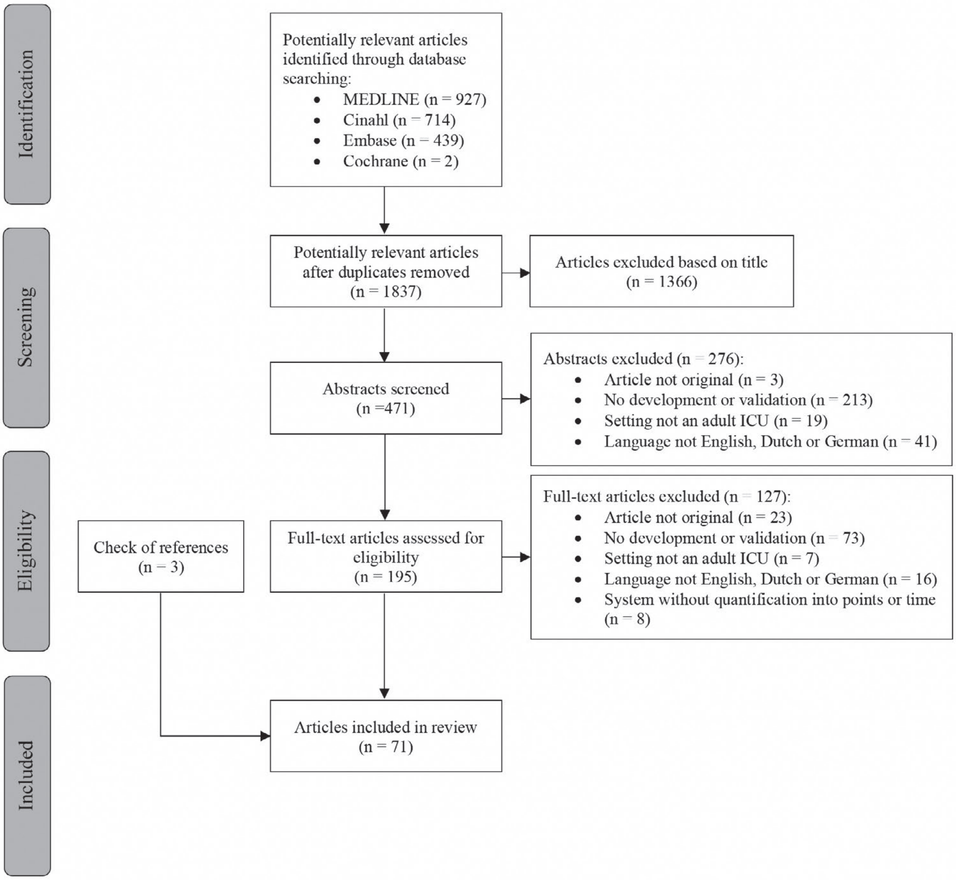

Figure 1. Flow chart of included and excluded articles

Methods used for classification of needed nursing time

From the 71 included articles, we identified 27 different scoring systems with a translation of workload into nursing time needed. Table 1 provides an overview of these 27 systems with the name and the abbreviation as used in daily practice and in this article, a description of their main content and the year of development. This table also shows that the way in which the needed nursing capacity is classified varies largely. There are differences in both content (nursing or medical interventions) and way of categorizing the care (points, time or Nurse:Patient-ratio). Twelve systems (44%) were based on a list of nursing interventions or a combination of nursing and medical interventions with either a description of minutes per intervention (n=3), or points per intervention (n=9). Those points were translated into minutes per point (n=4) or translated into (a categorization of) expected nursing time per shift or an expected Nurse:Patient-ratio (n=5).

Nine systems (33%) were based on the level of dependency of the patient or a category of nursing care (i.e. preventive or minimal care to compensatory or intensive care), with a description of time in minutes or hours per category (n=2), or points per category (n=7). The points were translated either into minutes per point (n=1) or translated into (a categorization of) expected nursing time per shift or an expected Nurse:Patient-ratio (n=6). One system (4%) was based on a computerized calculation of activities from a care-plan with points per activity and a translation from points to minutes. In five systems (19%) the classification was based on the expected Nurse:Patient-ratio with a description of the patient category per Nurse:Patient-ratio.

Validity and reliability of the scoring systems

Content validity

Information on the content validity was reported for 20 out of 27 (74%) scoring systems. A summary of the results of the content validity of the scoring systems is presented in Table 2.

In 17 of these 20 systems (85%), nurses participated in the selection and weighing of the interventions. For the TISS-76, the interventions were selected by physicians, but the actual weighing of the points was done by a team of physicians and nurses. The interventions included in the PINI were based on nineteen other scoring systems. The interventions included in the SGI-Grading System were based on a retrospective dataset without involvement of nurses. The Content Validity Index was only described for the Acuity-tool with a value of 0.85, which was lower than the considered threshold index of 0.9.

Table 1. Scoring systems.

Scoring system (Year 1st publication)	Score per shift or per 24h	Main content	Scoring method
Systems measuring nursing and/or therapeutic interventions			
1. TISS-76 (1974)[15] Therapeutic Intervention Scoring System	Per 24h	Classification of medical interventions	- 76 medical interventions - 1-4 points per intervention - Total score categorized into four levels of care with expected Nurse:Patient-ratio.
2. PRN-system (1978)[16] Project Research in Nursing	Per 24h	Classification of nursing interventions	- 8 categories of nursing interventions - 35 tasks per category - 1 - 20 points per nursing task - 1 point is 5 minutes.
3. NISS (1978) [17] Nursing Intervention Scoring System	Per shift	Classification of nursing interventions	- 15 categories of nursing interventions - 1-4 points scale of nursing care (preventive till compensatory nursing) - 1 point is 6.75 minutes
4. Classification system of Jackson Memorial Medical Centre (1979)[18]	Per shift	Classification of nursing interventions	- 44 nursing interventions - 1-6 points score per intervention. - 1 point is 4 minutes
5. NDS (1983)[19] Nurse Dependency Scoring System	Per shift	Classification of nurse dependency	- 6 categories of nurse-dependency - Score of 0-4 per category - Total score categorized to different Nurse:Patient-ratios.
6. Computerized Acuity System (1986) [20]	Per shift	Classification of nursing activities	- Software program calculating direct and indirect nursing activities from a care plan - Calculation of points representing the nursing time per activity - 1 point is 1 minute
7. PINI (1988)[21] Patient Intensity for Nursing Index	Per shift	Classification of nursing intensity	- 12 dimensions of nursing care (i.e. complexity tasks, complications, mobility) - Level I – V per dimension, representing the complexity of nursing care (basic till intense/high or complex)
8. TOSS (1991)[22] Time Oriented Score System	Per 24h	Classification of nursing activities	- List of nursing 14 activities - Categories of estimated time per activity.
9. NCR-11 (1992)[23] Nursing Care Recording System	Per shift	Classification of nursing activities	- Description of nursing contribution to 11 categories of nursing and medical procedures - 1-3 points per category, points representing intensity - Total oints categorized to estimated nursing time

Table 1. Continued.

Scoring system (Year 1st publication)	Score per shift or per 24h	Main content	Scoring method
10. WICSS (1993)[24] Weezenlanden IC Scoring System	Per shift	Classification of nursing activities	- 111 nursing activities in direct and indirect nursing patient care - 1-20 points per activity - 1 point is 6 minutes
11. Acuity tool (1995)[25]	Per 24h	Classification of nursing intensity	- Five categories of nursing care intensity; minimal till life-support - Estimated hours of nursing time per category
12. CCPD (1996)[26] Critical Care Dependency System	Per shift	Classification of nursing intensity	- 7 nursing activity related groups - 1 – 4 points of nursing intensity per activity, 1 is low and 4 is high intensity - Total points categorized to estimated nursing time
13. TISS-28 (1996)[27] Therapeutic Intervention Scoring System	Per 24h	Classification of medical interventions	- Simplified version of the TISS-76 with 28 therapeutic medical interventions - 1-4 points per intervention. - Total score categorized into four levels of care with expected Nurse:Patient-ratio
14. CritScore (1996)[28]	Per 24h	Classification of medical interventions	- 70 therapeutic medical interventions - 1-4 points per intervention - Total score categorized into four levels of care with expected Nurse:Patient-ratio
15. NEMS (1997)[29] Nine Equivalents of Nursing Manpower	Per shift or per 24h	Classification of medical interventions	- Simplified version of the TISS-28 with 9 activities performed on an IC - 1-8 points per activity - Total score categorized into four levels of care with expected Nurse:Patient-ratio
16. Acuity System (1999)[30]	Per 24h	Classification of estimated nursing time	- Assignment of patient to level I-V description of the expected nursing time for level V
17. ICNSS (2001)[31] Intensive Care Nursing Scoring System	Per shift	Classification of nursing intensity	- 16 different health problems of patients - 1 point (preventive) - 4 points (compensatory) - Points representing intensity of nursing care - Total score categorized to different Nurse:Patient-ratios.
18. Perroca's instrument (2002)[32]	Per 24h	Classification of nursing intensity	- Nine areas of the care process - Complexity of care per area graded from 1- 4. - Total score categorized to levels of care with a description of expected nursing time for an ICU patient.

Table 1. Continued.

Scoring system (Year 1st publication)	Score per shift or per 24h	Main content	Scoring method
19. NAS (2003)[33] Nursing Activity Score	Per shift or per 24h	Classification of nursing activities	- 23 nursing activities - A score 1.2 – 32 points per nursing activity - Points representing the required nursing time per activity.
20. Nurse Workload (NWL)-Patient Category Scoring System (2003)[34]	Per 24h	Classification of nursing and medical interventions	- Score based on the TISS with additional scores for therapeutic and nursing interventions. - Total score categorized to different N:P-ratios.
21. CNIS (2003)[35] Comprehensive Nursing Intervention Score	Per 24h	Classification of nursing interventions	- List of 73 nursing interventions - 4-grade workload score in 6 aspects per intervention: nursing time needed, number of nurses, muscular extension, mental stress, skill, job intensity.
22. Workload indicator for Nursing (WiN)-score (2009)[36]	Per 24h	Classification of nursing interventions	- A list of nursing interventions based on the Nursing Interventions Classification - Points representing estimated time per intervention. - 1 point is 1 minute
Scoring systems based on an expected N:P-ratio			
23. [No name] (1980)[37]	Per shift and per 24h	Classification of Nurse:Patient-ratio	- Categorization of patients according the expected N:P-ratio based on nursing time.
24. SGI-Grading system of the Swiss Society of Intensive Care (1997)[38]	Per shift	Classification of Nurse:Patient-ratio	- Categorization of patients according to the estimated number of patients per nurse
25. American Association of Critical Care Nurses Synergy Model (1998)[39]	Per 24h	Classification of Nurse:Patient-ratio	- Description of indicators for nursing time divided under 8 dimensions of patient care. - Categorization according Nurse:Patient-ratio - Description of patient care for 1:1-ratio
26. Time weighted nursing demand (2000) [40]	Per shift	Classification of Nurse:Patient-ratio	- Description of needed time for patient categories based on a N:P-ratio.
27. Association of UK university hospitals (AUKUH) acuity tool (2008)[41]	Per 24h	Classification of Nurse:Patient-ratio	- Description of patient criteria, based on patient dependency and nursing activities - Classification in four levels of care - Expected nursing time and Nurse-Patient ratio per level of care

Table 2. Results on the validity and reliability of the scoring systems

		Content Validity		Reliability		Validity		
Scoring system	Nr. of articles	Score	Explanation	Score	Results	Score	Compared with	Results
TISS-76	5	+/-	Selection interventions without nurses, weighting interventions with nurses[15, 49]	+	-	**NS**	Time observations[46] TISS[49] Non-ICU system: Oulu patient classification system[50]	r = 0.89 r = 0.57
PRN-system	3	+	Selection interventions with nurses[16]	**NS**	-	+/-	Actual staff ICU[16] Non-ICU system[51] GRASP Medicus	r^2 = 0.77-0.90 r^2 = 0.80-0.84
NISS	2	+	Selection interventions with nurses[17]	**NS**	-	+/-	Non-ICU system[52]	r^2 = 0.61
Classification system of Jackson Memorial Medical Centre	2	+	Selection interventions with nurses[18]	**NS**	-	+/-	Time observations[47]	r not stated
NDS	1	**NS**	-	**NS**	-	+/-	TISS[19]	r = 0.33
Computerized Acuity System	1	+	Selection interventions with nurses[20]	**NS**	-	-	Non-ICU system for nursing diagnosis[20]	No correlation, r not stated
PINI	4	-	Selection interventions based on 19 other systems, without nurses[21]	+/-	Kappa 0.29-0.86[21, 42-44]	+/-	Time measurements[42] Non-ICU systems[43] Medicus GRASP	r=0.75 r=0.54-70
TOSS	1	+	Selection interventions with nurses[22]	**NS**	-	+/-	TISS[22]	r = 0.79

Table 2. Continued

Scoring system	Nr. of articles	Content Validity		Reliability		Validity		
		Score	Explanation	Score	Results	Score	Compared with:	Results
NCR-11	2	+	Selection interventions with nurses[23]	+	Coefficient of variation 5.9-10.4%[53]	+/-	TISS[23] NEMS[53]	r = 0.60 r not stated
WICSS	1	+	Selection interventions with nurses[24]	**NS**	-	**NS**	-	-
Acuity tool	1	+/-	Selection interventions with nurses, Content Validity Index 0.85[25]	+	Pearson's $r^2 = 0.84$[25]	**NS**	-	-
CCPD	1	**NS**	-	+	Interrater reliability 74% Test-retest reliability 85%[26]	+/-	Comparing old and new system[26]	NS
TISS-28	9	+	Selection interventions with nurse [27, 54]	+	ICC: 0.93 – 1.00[54, 55]	+/-	Time observations[56] TISS-76[27, 54, 55] NEMS[48, 57, 58] SGI-Grading System[48] NDS[19] NAS[57] SAPS[54] Between ICUs and shifts[59]	Significant difference r=0.78-0.96 r=0.78 Good agreement r=0.33 NAS>TISS, p=0.001 R=0.68 Kruskal Willis: H=133.57
CritScore	1	+	Selection interventions with nurses[28]	**NS**	-	**NS**	-	-

Table 2. Continued

Scoring system	Nr. of articles	Content Validity		Reliability		Validity		
		Score	Explanation	Score	Results	Score	Compared with:	Results
NEMS	11	+	Selection interventions from TISS with nurses[29]	+	ICC: 0.73-0.99[29, 60-62]	+/-	TISS-28[29, 48, 58] NAS[63-65] NCR-11[53] Case vignettes[66]	r=0.78-0.88, r^2 =0.59-0.76 r=0.16-0.93, r^2 =0.45-0.87 r not stated Accuracy 63.7-99.1%
Acuity System	1	**NS**	-	**NS**	-	+/-	Actual staff ICU[30]	r = 0.95
ICNSS	4	+	Selection interventions with nurses[31, 67]	+	Kappa 0.81, Cronbach's alpha 0.91[68]	+/-	TISS[68, 69]	r^2 =0.07-0.24
Perroca's instrument	3	**NS**	-	+	Cronbach's alpha 0.75-0.94[70, 71]	+/-	1st and 2nd version[72] NAS[70] Non-ICU system: Beakta[71]	r=0.60 r=0.65 r=0.60-0.83
NAS	12	+	Selection interventions with nurses[33, 73]	+/-	Kappa 0.02-0.69[45, 74] Cronbach's alpha 0.71[75]	+	Time observations[33] Prospective/retrospective[57] NAS/shift[75, 76] TISS[33, 63] NEMS[57, 64, 65, 77] Perroca's instrument[71]	r=0,81 r=0.65 not stated r=0.56 r=0.16-0.93 r=0.65
NWL- Patient Category Scoring System	1	**NS**	-	**NS**	-	+/-	Time observations[34]	NWL does not reflect nursing time, r not stated
CNIS	1	+	Selection interventions with nurses[35]	+	Kappa 0.65[35]	+/-	NEMS[35]	r=0.75

Table 2. Continued

Scoring system	Nr. of articles	Content Validity		Reliability		Validity		
		Score	**Explanation**	**Score**	**Results**	**Score**	**Compared with:**	**Results**
WiN-score	2	+	Selection interventions with nurses[36]	**NS**	-	+/-	TISS[36] B-NMDS[78]	r=0.74 r=0.89
[No name]	1	+	Selection interventions with nurses[37]	**NS**	-	+/-	Time observations[37]	No significant differences, results not stated
SGI – Grading system	2	-	Based on dataset, no nurses involved[38]	**NS**	-	+/-	TISS, NEMS[48]	r=0.78, r^2=0.62
AACN Synergy Model	4	+	Description ratio by nursing experts[9, 39, 79, 80]	**NS**	-	+/-	Patient acuity-indicators[81]	r=0.30-0.60
Time weighted nursing demand	1	**NS**	-	**NS**	-	+/-	Actual staff[40]	r^2=0.83
AUKUH-dependency tool	1	**NS**	-	+	Cronbach's alpha 0.99[41]	-	Non-ICU Leeds system[41]	r=0.77

Reliability

Information about the inter- or intra-rater reliability was reported for 12 out of 27 (44%) scoring systems. A summary of the results of the reliability of the scoring systems is presented in Table 2. For 10 systems (37%) the inter-rater reliability and the intra-rater reliability were considered substantial to almost perfect (Cronbach's alpha 0.71 – 1.00, Kappa > 0.65). The results of the remaining 2 systems (PINI and NAS) showed varying results from slight to substantial agreement[21, 42-45]. The interventions which include categories of a subjective estimation of time by the nurse (e.g. the hygienic procedures took more than 2 hours per shift in NAS) showed lower reliability (Kappa of 0.02-0.12)[45].

Validity

Information about the validity was reported for 24 of the 27 (89%) scoring systems. A summary of the results of the validity of the scoring systems is presented in Table 2. The 'gold standard', observed time-measurement, was used in only 7 (26%) scoring systems. Although the TISS was originally (in 1974) developed without the use of continuous time-measurements, we found one study, published in1992, in which the TISS was retrospectively evaluated using continuous time-measurements[46]. A strong correlation was shown between the time for nursing interventions and the TISS-76 (r=0.89, p<0.0001). The Classification System of the Jackson Memorial Medical Centre was developed and evaluated with continuous time-observations. It was concluded that the point-system was a good indicator of the actual care received[47]. The PINI was validated with an observational time measurement study[42]. A strong correlation was found between the observed time and the rated hours of care (r=0.75, p<0.001). In 70% of the disagreements, nurses overestimated the hours of care. The NAS was validated with Multi Moment Recordings; 81% of the total time spent by nurses was explained by the NAS[33]. The NWL-Patient Category Scoring System was validated by comparing the results of the scoring system with time-measurements by video-observation. They concluded that this scoring system did not give an accurate reflection of the amount of nursing time[34]. The system described by Evans et al (No name) was validated with time-observations; the expected needed hours per shift was compared with the observed hours per shift per category[37]. They concluded that the expected and observed nursing care hours were equal, except for category II patients. This category expected 8 hours nursing care per shift where 5.3 hours nursing care were observed.

The weaker method for validation, i.e. comparing the newly developed scoring system with an existing scoring system, was described for 16 scoring systems (59%). As we can see in table 2, most studies (n=10) used the TISS for this comparison. One study used case-vignettes for the evaluation of the validity[66].

Validity of the quantification of the nursing time needed

The way in which the workload systems quantify the needed nursing time and the validity of this quantification is described in table 3. The most common way is classification of care into different categories of Nurse:Patient-ratios. Any evaluation of the validity of these categories of Nurse:Patient-ratios was described for 15 out of 27 systems (56%).

In three cases (11%) the number of nurses needed according to the calculated Nurse:Patient-ratio was compared with actual time measurements. The calculated need for nursing staff according to TISS or PINI was higher than the measured nursing time[42, 46]. Comparing the Nurse:Patient-ratio according to the NWL Patient Category Scoring System with the observed time-measurements, showed substantial differences. The time spent with a patient in the category with an expected Nurse:Patient-ratio of 0.5:1 was more than the time spent with a patient in the category with an expected Nurse:Patient-ratio of 1:1. The researchers concluded that the categorization according the NWL Patient Category Scoring System was not accurate[34].

In five systems (19%) the translation of scores into a N:P-ratio was evaluated by comparing different systems applied to the same patients. A good agreement was reported between the Nurse:Patient-ratio according to the TISS and NEMS; which is not surprising because the NEMS was developed based on the TISS[46]. The need for nursing staff according to TOSS was up to 52% higher than with TISS. Where TISS indicated a Nurse:Patient-ratio of 2:1 TOSS indicated in the same patient a Nurse:Patient-ratio of 3:1[22]. Also in ICNSS the need for nurses was higher than in TISS for the same patients[69]. The need for nurses according to NAS was higher than the need for nurses according to NEMS[65].

Table 3 shows a retrospective comparison of the Nurse:Patient-ratio with the actual or planned number of nurses in 11 systems (41%) [18, 23, 30, 40, 52, 57, 60, 82-84]. The ‘midnight census’ on planning the actual number of nurses per unit was also described as a method for classification of care[40, 85]. For five systems it was concluded that the need for nurses according to the system was higher than the actual present staff[18, 22, 34, 42, 83]. However, none of these articles mentioned how the actual or planned number of nurses was calculated and on which assumptions these numbers were based.

Table 3. Validation of quantification of the need for nursing time

Scoring system	Quantification need for nursing time	Validation method	Results validation
TISS-76	1 Nurse/shift= 40-50 TISS points/shift Class I: < 10 TISS points – Nurse:Patient-ratio = 1:4 Class II: 10-19 TISS points – Nurse:Patient-ratio = 1:2 Class III: 20-39 TISS points – Nurse:Patient-ratio = 1:1+1 Class IV: >39 points – Nurse:Patient-ratio = 1:1	Compared with time measurements[46]	Need for nursing staff with TISS-76 < measured time[46]
PRN-system	1 point = 5 minutes	Compared with planned nursing staff[82]	PRN-system: good correlation with planned staff[82]
NISS	1 nurse = 480 minutes 1 NISS-point = 6.75 minutes of care	Compared with actual nursing staff[52]	NISS: reasonable estimate of time[52]
Jackson MMC Scoring system	1 point =4 minutes nursing time, 1 nurse=195 points Class I-serious: £12h care/24 h = Nurse:Patient-ratio 2:1 Class II-critical: 12-24h care/24h = Nurse:Patient-ratio 1:0.75 Class III-Crisis: ³ 24h care/24h = Nurse:Patient-ratio 1:1.2	Compared with actual and planned nursing staff[18]	Need for nursing time according scoring system in 57-92% of the patients more than actual staff[18]
NDS	Score 1-6 = Nurse:Patient-ratio 0.5:1 Score 7-13 = Nurse:Patient-ratio 1:1 Score 13-20 = Nurse:Patient-ratio 1.5:1 Score 21-28 = Nurse:Patient-ratio 2:1	Not described	
PINI	Level 1: 0.5 – 1h nursing care Level 2: 1-1.5h nursing care Level 3: 1.5 – 2.5h nursing care Level 4: 2.5 – 4h nursing care Level 5: > 4h nursing care	Compared with time measurements[42]	Overall agreement of 69% Level 1: 92%. Level 2: 64%, Level 3: 38%, Level 4: 60%. In 70% of the disagreements overestimation with PINI[42]
TOSS	TOSS £ 360 minutes = Nurse:Patient-ratio 1:4 TOSS 361-480 minutes = Nurse:Patient-ratio 1:3 TOSS 481-720 minutes = Nurse:Patient-ratio 1:2 TOSS 721-1170 minutes = Nurse:Patient-ratio 1:1+1 TOSS ³ 1171 minutes = Nurse:Patient-ratio 1:1	Compared with other system; TISS[22]	Nurse:Patient-ratio with TISS 2:1, Nurse:Patient-ratio with TOSS 3:1 in the same patients[22]

Table 3. Continued

Scoring system	Quantification need for nursing time	Validation method	Results validation
NCR-11	Category A: 10-15 = 6h nursing care/shift Category B: 16-23 points = 12h nursing care/shift Category C: 24-30 points = 16h nursing care/shift	Compared with actual or planned nursing staff[23]	Nursing intensity according NCR-11 higher than actual staffing[23]
Acuity tool	Category I: Minimal care = 4 hours care Category II: Intermediate care = 6 hours care Category III: Modified Intensive care = 10 hours care Category IV: Intensive Care = 14 hours care Category V: Life support = 24 hours care	Compared with actual or planned nursing staff[30]	Underestimation of 0.65 registered nurse per shift according acuity tool[30]
CCPD	Category A: < 10 points = < 8 nursing hours Category B: 11-15 points = 8 nursing hours Category C: 16-21 points = >8 < 16 nursing hours Category D: ≤ 22 points = ≥16 hours nursing time	Not described	
TISS-28	1 Nurse= 46 TISS points, 1 point = 10.6 minutes Class I: 1-14 points – Nurse:Patient-ratio = 1:4 Class II: 14–24 points - Nurse:Patient-ratio = 1:2 Class III: 25–34 points -Nurse:Patient-ratio = 1:1+1(cat 2) Class IV: > 35 points – Nurse:Patient-ratio = 1:1	Compared with actual nursing staff[57] Compared with other system; NEMS, NAS[65]	Nurse:Patient-ratio TISS-28 (0.8:1) < actual staff (1.2:1)[57] Nursing staff according TISS-28 higher than with NEMS but lower than with NAS[65]
CritScore	Class I: < 10 points – Nurse:Patient-ratio = 1:4 Class II: 10-19 points – Nurse:Patient-ratio = 1:2 Class III: 20-39 points – Nurse:Patient-ratio = 1:1 Class IV: ≥ 40 points – Nurse:Patient-ratio = 1:2	Compared with actual or planning nursing staff[83]	Actual number of nurses consequently lower than specified by CritScore[83]
NEMS	Level 1 = NEMS < 21 = Nurse:Patient-ratio 1:4 Level 2 = NEMS 21-30 = Nurse:Patient-ratio 1:2.5 Level 3 = NEMS > 30 = Nurse:Patient-ratio 1:1	Compared with actual nursing staff[57, 60, 65] Compared with other system; TISS[48, 57]	Nurse:Patient-ratio with NEMS (0,8:1) < actual staff (1.2:1)[57, 65], Nurse:Patient-ratio with NEMS > planned staff[60], Mismatch in 76% of the ICUs, Good agreement between Nurse:Patient-ratio TISS and NEMS[48, 57]

Table 3. Continued

Scoring system	Quantification need for nursing time	Validation method	Results validation
ICNSS	Class I = 16 – 22 points = Nurse:Patient-ratio 1:2 Class II = 23-32 points = Nurse:Patient-ratio 1:1 Class III = 33 – 40 points = Nurse:Patient-ratio 3:2 Class IV = > 40 points = Nurse:Patient-ratio 2:1	Compared with actual nursing staff[84] Compared with other system; TISS[68]	Need for nurses higher than actual staff. Nurses satisfied ICNSS[84]. Nurse:Patient-ratio with TISS 1:1–1:2, with ICNSS 1.5:1–2:1[68]
Perroca's instrument	9-12 points: minimum care 13-18 points: intermediate care 19-24 points: semi-intensive care 25-36 points: intensive care = 17.9 hours care/24h	Not described	
NAS	100 NAS points = 1 FTE Nursing time 1 NAS point = 4.8 min/shift or 14.4 minutes/24h	Compared with actual nursing staff[57, 65] Compared with other system; TISS, NEMS[65]	Need for nurses with NAS (1:1) < actual staff (1.2:1)[57, 65] Nursing staff according NAS (1:1) > TISS-28 and NEMS (0.8:1)[65]
NWL- Patient Category Scoring System	Category 1 = 10 points = Nurse:Patient-ratio 0.5:1 Category 2 = 20 points = Nurse:Patient-ratio 1:1 Category 3 = 30 points = Nurse:Patient-ratio 1.5:1 Category 4 = 40 points = Nurse:Patient-ratio 2:1	Time measurements[34]	Time spend with a category 1 patient, Nurse:Patient-ratio 0.5:1 is more than a patient in category 2, Nurse:Patient-ratio 1:1[34]
CNIS	Classification time per intervention: 0=0-9 minutes, 1=10-29 minutes, 2=30-59 minutes, 3=>1 hour	Not described	
No name	Category I = Nurse:Patient-ratio 1:1 Category II = Nurse:Patient-ratio 1.33:1 Category III = Nurse:Patient-ratio 2:1 Category IV = Nurse:Patient-ratio 3:1	Not described	
SGI – Grading system	Category I = Nurse:Patient-ratio 1:1 Category Ia = Nurse:Patient-ratio 1.3:1 Category II = Nurse:Patient-ratio 2:1 Category III = Nurse:Patient-ratio 3:1	Compared with other system; TISS and NEMS[48]	Good agreement between systems, but large variability at individual patient level[48]
AACN Model	Description of criteria for a patient with Nurse:Patient-ratio1:1	Not described	

Table 3. Continued

Scoring system	Quantification need for nursing time	Validation method	Results validation
Time weighted nursing demand	Acutely ill patients: Nurse:Patient-ratio 1:1 Less acutely ill patients: Nurse:Patient-ratio 2:1	Compared with planned nursing staff[40]	Time-weighted nursing demand better predictor than midnight census[40]
AUKUH-dependency tool	Level 0 = 0.79 FTE nurse per bed Level la = 1.70 FTE nurse per bed Level 1b = 1.86 FTE nurse per bed Level 2 = 2.44 FTE nurse per bed Level 3 = 6.51 FTE nurse per bed	Not described	

DISCUSSION

This review shows that over the years classification of nursing workload on an Intensive Care has been a topic of continuous attention. Our aim was to identify the existing scoring systems in literature. A high number of scoring systems has been developed and used for planning of care since the first system was published in 1974. In total we included 27 different systems for measuring nursing workload on an Intensive Care in this review. Remarkable is the continuous use of this first developed system, the TISS. Although developed in 1974, the TISS is still used in daily Intensive Care practice as well as for development and validation of other scoring systems. Table 1 shows an increasing number of new systems between 1980 and 2000. The continuous use of those systems since their development shows that quantification of nursing care is still actual and considered important.

The next important part of this review was the evaluation of the validity and the reliability of the scoring systems. Although we found many articles about validation and reliability of the different systems, none of the finally included 27 systems that claimed to quantify needed nursing staff satisfied all our pre-set validity and reliability criteria. Only a few satisfied a majority of our pre-set criteria. The content validity of almost all 27 included systems was good; most systems were developed by nurses or a multidisciplinary team of nurses and physicians. Only the items of the TISS concerned mainly medical interventions exclusively selected by physicians, which can be explained by the fact that the original aim of this system was to classify severity of illness and not nursing workload[15]. It is therefore remarkable that the TISS has become one of the most commonly used scoring systems to measure nursing workload. Moreover the TISS itself or items of the TISS have also been used in the development of six other systems for measuring nursing workload, namely the NISS, TISS-28, CritScore, NEMS, NAS, and the NWL Patient Category Scoring System.

The inter- and/or intra-rater reliability was tested in less than half of the systems (44%). If described, the results were generally moderate to good. Only the results on the inter-rater reliability of the NAS evaluated in several different studies showed a large variability with weak to good results[45]. In particular the inter-rater reliability of nursing activities which included an estimate of the duration of that activity, such as monitoring and titration, hygiene procedures, support and care of patient and relatives, administrative tasks and mobilization, showed a large variability. For example, the inter-rater reliability of the item "Mobilization and positioning" resulted in an agreement of 49% (Kappa 0.16) if rated by a nurse and a manager. If rated by a nurse and a physician, the agreement was 39,6% (Kappa 0.020)[45]. On the other hand, a medical intervention like oxygen showed a 100%

agreement. Because the duration of the activity has to be estimated, the assessment is partly subjective. This subjective estimation can lead to differences in NAS-scores and subsequently to differences in the calculated need for nursing staff.

We indicated the use of time-measurements or Multi Moment Recordings as the gold-standard for the development and validation of a system to quantify nursing time needed. This method was, however, only used in six of the 27 (22%) scoring systems. For all those systems the results showed a good validity. The most common method used for validation of a new system was the comparison with an already existing system. TISS was most frequently used for this purpose. Although the TISS-76 was developed without time measurements, a later version of TISS-76 was in fact validated with the gold standard (i.e. time-measurements), but not before 1992[15, 46]. Despite the lack of formal validation, the TISS-76 was already used as a reference in validation studies of other systems before 1992.

Overall, the NAS performed best as it was developed by nurses, validated with time-measurements and explaining 80% of the nursing activities. The reliability varied between low to good. The studies which reported low reliability explicitly evaluated the reliability of scoring systems with categories of estimated time per intervention. This can be explained by the psychometric properties of these questions. The answers on subjective questions are more influenced by external factors as the involved observer self and knowledge of the definitions of those questions. Education and training in the use of the NAS is therefore necessary for a better use of this system. Furthermore, as more and more Intensive Cares are equipped with electronic patient records or patient data management systems, automatic bedside registration in an electronic patient record could also lead to more unambiguous scoring and improved reliability of the NAS.

Translation of a scoring system into another language is also known to influence the reliability[86]. This is important for the NAS, because the NAS is widely used, among others, in countries with Portuguese language. We found one study reporting about the psychometric properties of a translated Portuguese version of the NAS. This study concluded that the Portuguese version of the NAS was found to be a valid instrument[74]. One study in 7 different countries in Europe and Brazil showed a large variation in NAS scores, ranging from a mean NAS per patient of 101.8 in a Norwegian Intensive Care to 44.5 in a Spanish Intensive Care[87]. We recognize this variation also in other studies included in our review. This could partly be explained by the fact that the studies are conducted in different countries with different organization structures of the Intensive

Cares and different patient characteristics. Although all studies used the standardized NAS-scoring system, these differences still make reliable comparisons between the studies more difficult.

Finally we evaluated the ability of the workload scoring systems to quantify the nursing capacity in daily practice, mostly translated into a Nurse:Patient-ratio. The Nurse:Patient-ratio is important because this is the translation of 'abstract' points into nursing capacity in daily practice, and can so be helpful for Intensive Care management. It enables to plan the needed numbers of nurses per shift and it enables a nurse to know at the beginning of his/her shift how many patients are under his/her responsibility. The Nurse:Patient-ratio was validated for only half of the systems (56%), of which only three systems used objective time-measurements (11%). Given the fact that the ultimate aim of a scoring system should be supporting the planning of nursing capacity, it is disappointing that the accuracy of translating the scores of a system into needed nursing time was only assessed to a limited extent and even then often in an inadequate way. Comparison with time-measurements is only described for the TISS, the PINI and the NWL Patient Category Scoring System. In all three studies the categorization to a Nurse:Patient-ratio led to an overestimation of needed time[34, 42, 46]. Comparison among different scoring systems also gave disappointing results with large differences in the reported Nurse:Patient-ratio, with examples of doubling the needed nursing staff[69]. In a number of articles, the calculated Nurse:Patient-ratio from a scoring system was compared to the actual available or planned number of nurses. However, a description of how the actual or planned number of nurses was determined was lacking. This information is crucial to interpret the results of the comparisons made. Without a validation by time-measurements it is impossible to assess the accuracy of both the actual planned staff as well as the planned staff according to a scoring system.

Implications for research

Regarding the validation of the systems, the low number of systems that were validated with the gold standard, i.e. time-measurements, is striking. The implications of the absence of the gold standard becomes clear when interpreting the results of the second-best method for validation; comparing two different systems often show large variation [22, 33, 48, 57, 58]. In these cases it is hard to tell which scoring system agrees with reality, due to the absence of time-measurements. Studies in which the systems-based nursing capacity was compared with the actual nursing staff show the same weakness. A higher indication for needed nursing staff by a system compared to the actual present staff would suggest that the workload of the nurses is too high and should be lowered. However, without information on the accuracy of both the actual planned and system-based calculated nursing staff, this conclusion cannot be made with certainty. Therefore, studies with time-measurements for both the systems and the Nurse:Patient-ratio should be performed before any implications for practice and actions to improve the practice can be made. New time-measurements should also be done for systems still in use but without any update in the last decades, i.e. the TISS, because daily care and treatment may have changed considerably over the years. Finally, another way of assessing the accuracy of the planned staff is comparing the calculated workload with the subjective workload as experienced by nurses. Future studies should focus on how an objectively calculated workload with a workload-system correlates with the subjective workload as experienced by nurses.

Implications for practice

It is clear that the variety in calculated and overestimation of needed nursing staff could have large consequences for the actual planning of nursing staff. A scoring system should be able to quantify the need for nursing time as accurately as possible to be of any use as a tool for planning nursing staff. The conflicting results and lack of thorough validation make the scoring systems less useful for management decisions. Considering the results of the evaluation of the Nurse:Patient-ratio, the added value of a categorization into a Nurse:Patient-ratio with a system is debatable. If a system is able to measure the actual time needed for nursing care the needed number of nurses can be determined without such a calculated Nurse:Patient-ratio. An accurate calculation of the nursing time needed for certain patient categories should make it possible, on average, to plan the correct number of nurses. It could be that not the Nurse:Patient-ratio, but the workload per patient and therefor per nurse is important for management decisions. This adds to the value of the NAS; with the NAS-points it is possible to calculate the need for nursing time in minutes. The NAS is not calculating an Nurse:Patient-ratio. From a management perspective the balance between needed nursing time according NAS-points and available nursing time in NAS-points is sufficient to measure the workload and calculate the need for nursing staff.

Strengths and limitations

This study has some strengths and weaknesses. A strength of this study is that we used all relevant literature databases over a long period of time. The titles, abstracts and articles were independently assessed by two different reviewers and inclusion was based on consensus of both reviewers.

The included articles cover a period of more than 40 years. It is quite unusual for systematic reviews to include articles over such a long period as the relevance of this literature might become debatable. During a period of 40 years the nursing care on an

Intensive Care is changed due to a changing patient population, development of new techniques and organisational changes. However, the first system developed in 1974, the TISS, including the translation of points into a Nurse:Patient-ratio, is still used in current practice. Therefore, it is important to update or validate systems, if still in use after such a period of time.

Because the limitation to articles in English, German or Dutch, we did exclude a relatively high number of articles for further analysis (n=57). Among these excluded articles are a substantial number of articles on the NAS which were written in the Portuguese or Spanish language. Despite this high number of excluded NAS studies, the NAS is still well represented in the results of our review (n=12). Therefore, we believe that the most important systems are represented in our review.

CONCLUSION

Scoring systems for measuring nursing workload and calculating the needed nursing staff on an Intensive Care received a lot of attention over the years. A range of systems has been developed and is still in use in daily practice of Intensive Care management. Overall, NAS performed best; it is the only system with good content-validity and Multi Moment Recordings showed that 81% of total time spent by nurses could actually be explained. The results of this review showed that the NAS is the most used system for measuring nursing workload. However, the intra- and inter-rater reliability evaluation of NAS showed a need for improvement.

Given the insufficient evaluation methods and results regarding the validity and reliability of most scoring systems we conclude that the value of these systems to plan nursing capacity in practice is debatable. Due to the important role of workload scoring systems for Intensive Care management, further research is needed to improve the reliability of scoring and the accuracy of the translation of the scores into the actual needed nursing time.

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CHAPTER 3

Validation of the Nursing Activities Score (NAS) using time- and-motion measurements in Dutch intensive care units

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ABSTRACT

Background. The Nursing Activities Score (NAS) is widely used for measuring the workload of intensive care unit (ICU) nurses. However, the performance of the NAS to measure actual nursing time has not been comprehensively and externally validated. The aim of this study is to validate the NAS using time-and-motion measurements in Dutch ICUs.

Methods. We measured nursing time for patients admitted to seven Dutch ICUs, between November 2016 and October 2017. The patient(s) that were under the care of a chosen nurse were followed by the observers during the entire shift and measurements were performed using an in-house developed web application. To validate the reliability of the NAS, we first converted NAS points per activity into minutes. Next, we compared the converted time per NAS item and the converted total nursing time per patient with the actual observed time. We used Wilcoxon signed-rank tests at nursing activity level and Pearson's R and R^2 at patient level for these comparisons.

Results. A Pearson's correlation of R=0.59 (R^2=0.35) was found between the total converted NAS time and the total observed time per patient. The median converted NAS time per patient (202.6 minutes) was higher compared with the observed time per patient (114.3 minutes). At NAS item level, we found significant differences between the converted NAS time and the observed time for all separate NAS items.

Conclusions. The NAS overestimates the nursing time needed for patients in Dutch ICUs. Therefore, we advise revisions of the time weighting assigned to each NAS item to obtain better insight into the true nursing workload so that this information can be used for more effective nursing capacity planning.

INTRODUCTION

There are concerns regarding excessively high nursing workload, both in general and ICU wards[1]. An excessively high nursing workload can lead to burnout and job dissatisfaction among nurses[2] and have a deleterious effect on patients[3]. Workload has risen due to an increased turnover of patients, increased complexity of patients, together with nursing shortages[4]. All this makes planning of nursing capacity important. In the last 30 years different instruments have been developed to measure the nursing workload to give insight into the nursing staff needed per shift and provide much needed input for capacity planning[5].

To assess nursing workload in the ICU, Cullen et al.[6] created the Therapeutic Intervention Scoring System (TISS). The TISS was originally developed to classify nursing workload in relation to the severity of illness of ICU patients. The TISS consists of 76 therapeutic interventions that receive 1-4 points based on the severity of illness. It appeared that nursing workload is only partly related to severity of illness, since less severely ill patients could also generate a high nursing workload. For instance, a patient recovering from a serious illness with agitated delirium would not score high in severity of illness, but could demand very intensive nursing care, up to continuous bedside care throughout the day. This made the TISS less effective in assessing nursing workload. Therefore, the Nursing Activities Score (NAS) was developed by Miranda et al. in 2003[7]. The NAS describes activities that largely represent the work actually performed by nurses at the bedside in caring for patients and was developed to measure the nursing workload for each individual patient. The points assigned to nursing activities provide an average time consumption in caring for the patients instead of representing the severity of illness. The NAS was created by using the work-sampling approach: at random moments per shift the nurse was asked what he or she was doing at that specific moment. The researchers applied a weighting for each activity. The total NAS for an individual patient is the sum of NAS points for all activities, varying between 0 to 177 points (appendix 2). A score of 100 NAS points is equivalent to the amount of care that can be provided by one full-time equivalent nurse during either one shift or one day. A score above 100 points indicates that the care needed can only be provided by more than one nurse[7]. The NAS is considered a valuable tool and is widely used for workload measurement in ICUs[8, 9]. However, the performance of the NAS has not been comprehensively validated. One study showed that the NAS might either underestimate or overestimate the actual nursing time required by patients and therefore recommended revision of the original NAS because of inadequate measurement of nursing activities[4]. The study by Stafseth et al. suggests that the reliability and validity of the NAS are good. However, this study strongly suggests more research in other countries and larger groups of patients[10].

Furthermore, research has demonstrated that the work- sampling approach, as used for the development of the NAS, does not lead to an accurate representation of the true nursing workload. This is due to the fact that the weighting of nursing activities is based on the probability that a particular nursing activity occurred[11]. The total amount of time in a shift is divided over the nursing activities that were carried out. When nursing activities frequently occur or take a lot of time, they would also occur more frequently in the work-sampling approach. However, this approach will not lead to precise measurements, but will only approximate the time of the different activities. Thus, in contrast to time-and-motion techniques in which every minute of a nursing shift is measured, the work-sampling approach does not measure the real amount of time spent on nursing activities, which could lead to less accurate results[12]. Therefore, the time-and-motion technique is considered the best technique for time measurement[13].

The aim of this study is to validate the NAS in the Dutch ICU setting using the time-and-motion technique, and to identify which nursing activities are underestimated or overestimated in the NAS.

METHODS

Setting

We conducted an observational study. All 82 Dutch ICUs participate in the National Intensive Care Evaluation (NICE) quality registry. Fifteen of these ICUs are participating in the newly implemented voluntary nursing capacity module[14], seven of which voluntarily took part in this study. Data on characteristics of the ICUs (such as number of ICU beds) and data on patient characteristics (such as age, BMI, admission type, and mortality) were extracted from the NICE registry.

Time-and-motion

The study involved time-and-motion measurements for patients admitted to the ICU. We included different types of hospitals (academic, teaching and non-teaching hospitals) and different shifts (day, evening and night). We performed an equal number of measurements in all types of hospitals and shifts. At the start of a shift, one nurse was chosen by the observer. The patient(s) that were under the responsibility of this nurse were followed by the observer during the entire shift. A longer-term patient could theoretically be observed on different dates during different shifts and therefore could possibly be followed during more than one measured shift. The measurements took place on different days of ICU admission (e.g. first ICU admission day through to last ICU admission day) and with different types of nurses (registered and student nurses). We randomly selected nurses who took care of patients that were expected to stay during the whole shift in order to measure as many nursing activities as possible.

Observers were researchers CM and MH and ten student nurses. The students were trained in performing time-and-motion measurements by oral and written instructions and one day of measuring together with one of the researchers. The observers used an in-house developed web application to record start and stop times of each performed nursing activity. The application included all activities occurring in the NAS (appendix 3). If two nurses were simultaneously performing nursing activities for the same patient, this was also registered by pressing the 'two nurses button' and multiplying this time by two in the analysis. When two different activities were carried out by two nurses, these activities could be measured simultaneously. Measurements were conducted between 1 November 2016 and 1 October 2017. Participation of the hospitals was on a voluntary basis. Seven hospitals were willing to participate. Data were processed anonymously.

Ethical approval

The Institutional Research Board of the Amsterdam University Medical Centre reviewed the research proposal and waived the need for informed consent (IRB protocol W17_366).

Data analysis

Nursing activities that occurred less than ten times in the total dataset were excluded from the analysis. Most NAS items have a fixed number of NAS points, but some items have different categories corresponding to different numbers of NAS points depending on the duration of that activity (e.g. bedside with hourly vital signs, bedside for two hours or more, or four hours or more). For these duration-dependent activities, we first used the measured time for that activity to assign the correct number of points. For example, a nurse performed hygiene procedures on a patient for 1.2 hours during a shift, according to our time measurements. This NAS item has three categories: performing hygiene procedures for less than two hours, for more than two hours, or for more than four hours. In the above-mentioned example, the activity took 1.2 hours and would therefore be assigned to the category for less than two hours, which corresponds to 4.1 NAS points. To validate the NAS, we first converted the originally assigned NAS points per activity into time. Based on Miranda et al[7]. 100 NAS points correspond to 100% of care time provided by one nurse during a shift and hence 1 NAS point corresponds to 1% of care time provided by one nurse. As stated by the author of the NAS, a nurse is productive in 80% of the 8-hour shift; this means that one NAS point corresponds to 3.84 minutes of nursing care during an 8-hour shift ((8 hours * 60 mins)/100)*0.8)[7, 15]. With this information, we were able to convert the NAS scores into an estimated nursing time per patient and per nursing activity (from now on referred to as 'converted NAS time'. Next we compared the time per NAS item and the total nursing time per patient, based on NAS scores according to the model, with observed times from the time-and-motion measurements. For the observed time, we took the sum of the times of all performed nursing activities per patient per shift in minutes (from now on referred to as 'observed time'. The median and interquartile ranges (IQR) of the converted NAS times and the observed times were calculated. First, the difference between the total converted NAS times and the total observed times per patient were visualized by scatterplots. Second, the correlation between the total converted NAS times and the total observed times per patient were assessed with the Pearson's correlation test. In addition, we also assessed the R2, a measure for the proportion of the variance. For each nursing activity separately, medians and interquartile ranges (IQR) of the converted NAS times and observed times were calculated and differences were tested with the Wilcoxon signed-rank test. All statistical analyses were performed using R statistical software, version 3.3.2[16].

RESULTS

Baseline results

Table 1 shows the ICU characteristics of the seven included ICUs compared with all Dutch ICUs; no significant differences were found between the included ICUs and all Dutch ICUs. During our study, a total of 287 unique patients were observed during 371 different shifts with time-and-motion measurements. In these patients, 46,319 nursing activities were measured. In 45% of the measurements, nurses took care of two patients per shift. In 15% nurses took care of three patients per shift. For the remaining 40%, nurses cared for one patient per shift.

The patients in our study had a significantly higher in-hospital mortality rate (22.3% versus 13.0%) and length of ICU stay (3.2 days versus 1.0 day) compared with all Dutch patients in the same period (table 2). Furthermore, acute renal failure, chronic respiratory insufficiency, and cirrhosis differed between the groups, with a higher percentage in the patients in our study. For the other patient characteristics, the included patients and all Dutch ICU patients in this period were comparable.

Table 1. ICU characteristics

Variable	Included ICUs (n=7)	All Dutch ICUs (n=84)
Number of university hospitals (%)	1 (14%)	9 (11%)
Number of teaching hospitals (%)	4 (57%)	23 (27%)
Number of non-teaching hospitals (%)	2 (29%)	52 (62%)
Median number of ICU beds per ICU (IQR)	13.0 [9.0, 17.0]	12.0 [8.0, 16.0]

Table 2. Patient characteristics

Variable	Included patients in measurements	All Dutch ICU patients
Number of unique patients, N	287	100.145
Age, median [IQR]	66.0 [56.0-76.0]	66.0 [55.0-75.0]
BMI, median [IQR]	26.0 [23.6-28.7]	25.9 [23.1-28.4]
Admission type		
Medical, N (%)	121 (42.2)	51,290 (52.7)
Surgical: urgent and elective, N (%)	151 (52.6)	45,905 (47.2)
In-hospital mortality, N (%)*	85 (22.3)	13,017 (13.0)
ICU LOS (in days), median [IQR]*	3.2 [0.9, 14.8]	1 [0.7-4.0]
Comorbidities		
Acute renal failure, N (%)*	37 (12.9)	9211 (9.2)
Cardiovascular insufficiency, N (%)	16 (4.2)	4257 (4.3)
Chronic renal failure1, N (%)	25 (6.7)	7976 (7.9)
Chronic respiratory insufficiency, N (%)*	7 (2.4)	4620 (4.6)
Cirrhosis, N (%)*	1 (3.5)	1751 (1.7)
COPD, N (%)	36 (12.5)	13,304 (13.3)
Diabetes, N (%)	68 (17.8)	16,273 (16.2)
Gastrointestinal bleeding, N (%)	2 (0.7)	2263 (2.3)
Haematological malignancy, N (%)	6 (2.1)	2143 (2.1)
Immunological insufficiency, N (%)	16 (5.6)	8290 (8.3)
Neoplasm, N (%)	9 (3.1)	4506 (4.5)

** Indicates a significant P value of <0.05. COPD = chronic obstructive pulmonary disease; IQR = interquartile range; LOS length of stay; [1] Chronic renal failure consists of chronic renal insufficiency and chronic dialysis*

Excluded nursing activities

The following three NAS nursing activities occurred less than 10 times in all measurements and were therefore excluded from the analysis at activity level: care of a pulmonary or left atrial catheter, cardiopulmonary resuscitation and specific interventions in the ICU (endotracheal intubation, insertion of a pacemaker, cardioversion, endoscopy, emergency surgery in the previous 24 hours, gastric lavage). Furthermore, we did not specifically measure intravenous replacement of large fluid losses and treatment of metabolic acidosis/alkalosis, since these two nursing activities usually fall under the category bedside activities.

Total patient time and times per NAS item

The median converted NAS time per patient (202.6 minutes; IQR 155.0-241.2 minutes) was significantly higher ($p<0.001$) compared with the observed time per patient (144.3 minutes; IQR 81.3 – 168.4 minutes), see *figure 1.* A Pearson's correlation of R=0.59 ($R^2=0.35$) was found between the total converted NAS time and the total observed time per patient *(table 3).*

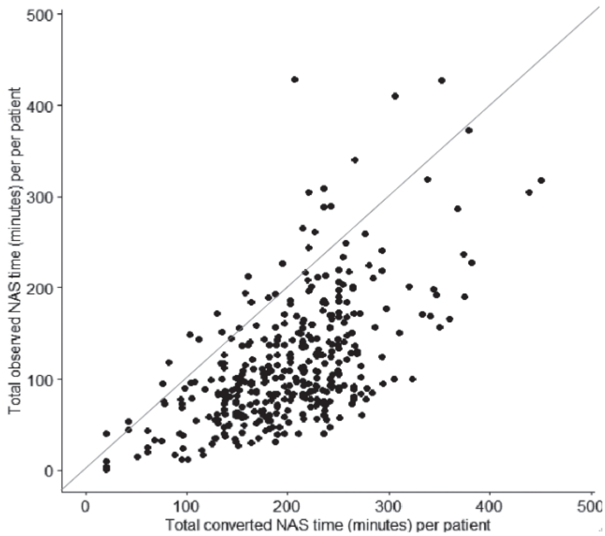

Figure 1. The correlation between the total converted NAS time in minutes and the total observed time in minutes per patient.
A full nursing shift is 480 minutes. Blue diagonal shows equal converted and observed time per patient

At the NAS item level, we found significant differences between the converted NAS times and observed times for all items. These differences ranged from -54.6 minutes (support or care of patient or relatives for about 1 hour) to 79.2 minutes (mobilization and positioning with three nurses). For most (86%) nursing activities the median converted NAS overestimated the observed time. For four activities (support or care of patient for about 1 hour, administrative tasks for less than 2 hours, administrative tasks for about 2 hours and specific interventions outside the ICU) the converted NAS underestimated the observed time *(table 3)*.

Table 3. NAS activities with their points according to Miranda et al. (2003)[7], and the median converted NAS times and observed times per NAS item

NAS activity	NAS points per activity	Median converted NAS time (minutes)	Median observed time, minutes [IQR]	Difference in minutes, median [IQR]
1a. Present at bedside and continuous observation or active for <2 hrs.[1]	4.5	21.6	14.22 [7.26-26.17	7.38 [-4.57-14.35]*
1b. Present at bedside and continuous observation or active for ≥2 hrs.	12.1	NA	NA	NA
1c. Present at bedside and continuous observation or active for ≥4 hrs.	19.6	NA	NA	NA
2. Laboratory, biochemical and microbiological investigations	4.3	20.64	5.45 [3.13-8.81]	15.19 [11.83-17.51]*
3. Medication, vasoactive drugs excluded	5.6	26.88	2.24 [0.90-4.91]	24.64 [21.97-25.98]*
4a. Performing hygiene procedures ≤2 hrs.	4.1	19.68	11.58 [3.95-27.8]	8.1 [-8.12-15.73]*
4b. Performing hygiene procedures >2 hrs.	16.5	NA	NA	NA
4c. Performing hygiene procedures >4 hrs.	20.0	NA	NA	NA
5. Care of drains	1.8	8.64	2.41 [0.92-4.64]	6.23 [4.0-7.72]*
6a. Mobilization and positioning, performing procedure(s) up to 3 times per 24 hrs.	5.5	26.4	2.46 [0.91-4.88]	23.94 [21.52-25.49]*
6b. Mobilization and positioning, performing procedure(s) >3 times per 24 hrs., or with two nurses	12.4	59.52	4.82 [2.17-9.33]	54.69 [50.19-59.49]*
6c. Mobilization and positioning, performing procedure(s) with 3 nurses	17.0	81.6	2.4 [0.89-6.16]	79.2 [75.44-80.71]*
7a. Support or care for patient or relatives for about 1 hrs.	4.0	19.2	73.8 [68.46-84.36]	-54.6 [-49.3 - -65.16]*

Table 3. Continued

NAS activity	NAS points per activity	Median converted NAS time (minutes)	Median observed time, minutes [IQR]	Difference in minutes, median [IQR]
7b. Support or care for patient or relatives for about 3 hrs.	32.0	NA	NA	NA
8a. Administrative or managerial tasks for <2 hrs.	4.2	20.16	40.91 [28.53-60.33]	-20.74 [-40.17- -8.37]*
8b. Administrative or managerial tasks for about 2 hrs.	23.2	111.4	130.0 [126.3-157.4]	-18.67 [-46.02- -14.92]*
8c. Administrative or managerial tasks for about 4 hrs.	30.0	NA	NA	NA
9. Respiratory support	1.4	6.72	2.99 [1.42-5.9]	3.73 [0.82-5.30]*
10. Care of artificial airways	1.8	8.64	1.43 [0.5-4.77]	7.21 [3.87-8.14]*
11. Treatment for improving lung function	4.4	21.12	1.32 [0.64-2.79]	19.80 [18.33-20.48]*
12. Vasoactive medication	1.2	5.76	1.99 [0.95-4.99]	3.78 [-0.77-4.81]*
13. Intravenous replacement of large fluid losses	2.5	NA	NA	NA
14. Left atrium monitoring	1.7	NA	NA	NA
15. Cardiopulmonary resuscitation after arrest	7.1	NA	NA	NA
16. Hemofiltration techniques	7.7	36.96	18.76 [7.83-36.66]	18.20 [-1.67-28.78]*
17. Qualitative urine output measurement	7.0	33.6	1.35 [0.66-2.45]	32.25 [31.15-32.96]*
18. Measurement of intracranial pressure	1.6	7.68	0.91 [0.28-2.62]	6.77 [5.07-7.4]*
19. Treatment of complicated metabolic acidosis	1.3	NA	NA	NA
20. Intravenous hyperalimentation	2.8	13.44	2.64 [0.79-4.1]	10.80 [9.41-12.65]*
21. Enteral feeding through gastric tube	1.3	6.24	1.87 [0.81-4.64]	4.37 [1.6-5.43]*

Table 3. Continued

NAS activity	NAS points per activity	Median converted NAS time (minutes)	Median observed time, minutes [IQR]	Difference in minutes, median [IQR]
22. Specific interventions in the ICU	2.8	NA	NA	NA
23. Specific interventions outside the ICU	1.9	9.12	18.18 [5.69-27.46]	-9.06 [-18.34- 3.43]*
		202.56 [155.04-241.2]	98.52 [71.86-127.72]	84.7 [50.31-127.72]*

*N = 371 patients and 46,319 measured nursing activities. * Indicates a significant P-value of <0.05 (Wilcoxon signed-rank test); NA: not measured during measurement. This is a shortened version of the NAS; the full version can be found on appendix 2*

DISCUSSION

Our analysis showed that the NAS overestimates the nursing time needed for patients in the Dutch ICU setting. Times of most NAS items were overestimated by the NAS, except for four activities (support or care of patient for about 1 hour, administrative tasks for less than 2 hours, administrative tasks for about 2 hours, and specific interventions outside the ICU), we used in this study to calculate the converted time per NAS point. Using this approximation, the converted time would have changed from 3.84 to 3.62 minutes per NAS point. This change does not affect the results and we therefore conclude that non-nursing duties do not significantly influence the performance of the NAS.

A strength of our study is that we validated the NAS with time-and-motion measurements, which is considered to be the best technique for measuring nursing workload[13]. To our knowledge, this has not been performed before in the context of NAS validation. Measurements for nursing activities by using time-and-motion measurements are more accurate compared with the work-sampling approach, as used for the development of the NAS[24]. Furthermore, since measurements took place in all types of ICUs, we believe that results of this study are generalizable to all Dutch ICUs.

One of the limitations of our study is the fact that we excluded NAS activities because they did not occur or occurred less than ten times. Two of these activities are usually scored in other categories: the activity ‘intravenous replacement of large fluid losses’ is mostly scored under NAS item 1 ‘bedside’. The activity ‘treatment of complicated metabolic acidosis/alkalosis’ is mostly scored in NAS item 3 ‘medication’. Since these activities could be scored in other categories, we did not include them in our study. Three NAS activities (left atrial monitoring, cardiopulmonary resuscitation after arrest, and specific interventions in the ICU, respectively) and six subcategories 1b, 1c, 4b, 4c, 7b, and 8c (the nursing activities that required more than 2, 3 or 4 hours of the nurses' time) did not happen often enough (so, ten times or more) during the measurements, which makes the validation of the NAS incomplete. Given the fact that the median time of nursing care per patient is 2.4 hours (144.3 minutes), nursing activities taking more than 2, 3 or 4 hours rarely occur in daily ICU practice, so it is not likely that our results have been affected by this situation. Nurses took care of two or three patients in 60% of our measurements; we assume that nurses taking care of only one patient can perform nursing activities in a shorter amount of time. We did not specifically study this, but further research could eventually point out what is the optimum time per nursing activity.

Furthermore, the observed patients seem to have been more severely ill and consequently had a longer length of stay compared with all Dutch patients in the same time period, which is likely caused by our selection mechanism. In order to measure as many nursing activities as possible we probably more often choose nurses who took care of patients that were expected to stay the whole shift and these patients were probably more severely ill. This may have biased our results since our aim was to validate the NAS and check for underestimations or overestimations compared with time-and- motion measurements and it is possible that observed times in where the NAS gives an underestimation of the observed time. This study showed that 35% of nursing time is explained by the NAS model (R^2 = 0.35). The converted NAS time per patient (202.6 minutes per shift) in our study was comparable with the converted NAS times per patient in other studies. Bernet et al[17]. found 150 to 156 minutes per shift and Deberg et al[18]. found 180 to 228 minutes per shift. The different articles on the NAS give variable NAS times per shift. A full shift of work equals 480 minutes of nursing time.

The low correlation of Pearson's R and R^2 (0.59 and 0.35) implicates that the NAS is not accurate enough to estimate the nursing time at patient level. However, it is currently still the best nursing workload model for quantifying nursing workload in ICUs[5]. There is no clear cut-off point from which the model can be identified as 'good enough' based on the R^2. However, since the NAS is used for capacity planning, an R^2 closer to 1 would be more desirable.

Since ICU nurses also spend time on non-nursing duties in almost every shift, such as coaching a student or participating in an emergency team within the hospital, we performed a sensitivity analysis to determine whether these non-nursing duties were affecting the correlation. According to several studies nurses spend approximately 3 to 6% of their shift on non- nursing duties[19,23]. We therefore took the average of 4.5% and subtracted this from the 80% of productive nursing time, which sicker patients differ from those in less sick patients. However, according to Armstrong et al. NAS scores in intermediate care patients did not differ from those in ICU patients[25].

Finally, our study does not correct for the nurses years of experience on the ICU or level of education. In the analysis we included student and registered ICU nurses but further research in larger groups should investigate whether different groups need different weighting of NAS points. Based on our results we believe there is room for improvement in the measurement of nursing workload. The NAS could be improved by adjusting the NAS points given to the different items. The developers of the NAS did not report the Pearson's R or R^2, but stated that the NAS is reflecting 81% of total nursing time. About 11% of the nurses' time is spent on personal activities. The remaining 8% comes from nursing activities derived from medical interventions, related exclusively to the severity of illness of the patient not measured by the NAS[7]. The TISS takes these medical interventions into account, such as induced hypothermia, cardiac assist device, pacemaker monitoring or ECG monitoring. For this reason, we suggest additional research towards the merging of the TISS-28 and the NAS. The models could be partly combined which could possibly improve the estimation of nursing workload. Our results on observed time per patient and per nursing activity could be taken into consideration when assigning weighting to the activities in this new model. Moreover, we think that expressing nursing activities in minutes or hours would be more informative compared with points, since it is more straight forward for ICU managers to work with.

CONCLUSION

The NAS was developed more than 15 years ago and significantly overestimates the nursing time needed for ICU patients in the current daily ICU practice. Therefore, we recommend a revision of the time weighting assigned to each nursing activity to gain better insight into the true nursing workload and to enable a more effective nursing capacity planning.

DISCLOSURES

The data that support the findings of this study are available from the National Intensive Care Evaluation (NICE) but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the NICE registry. The department of medical informatics (with C.C. Margadant, S. Brinkman, and N.F. de Keizer as employees) receives funding for data processing of the

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CHAPTER 4

The objective nursing workload and perceived nursing workload; analysis of association

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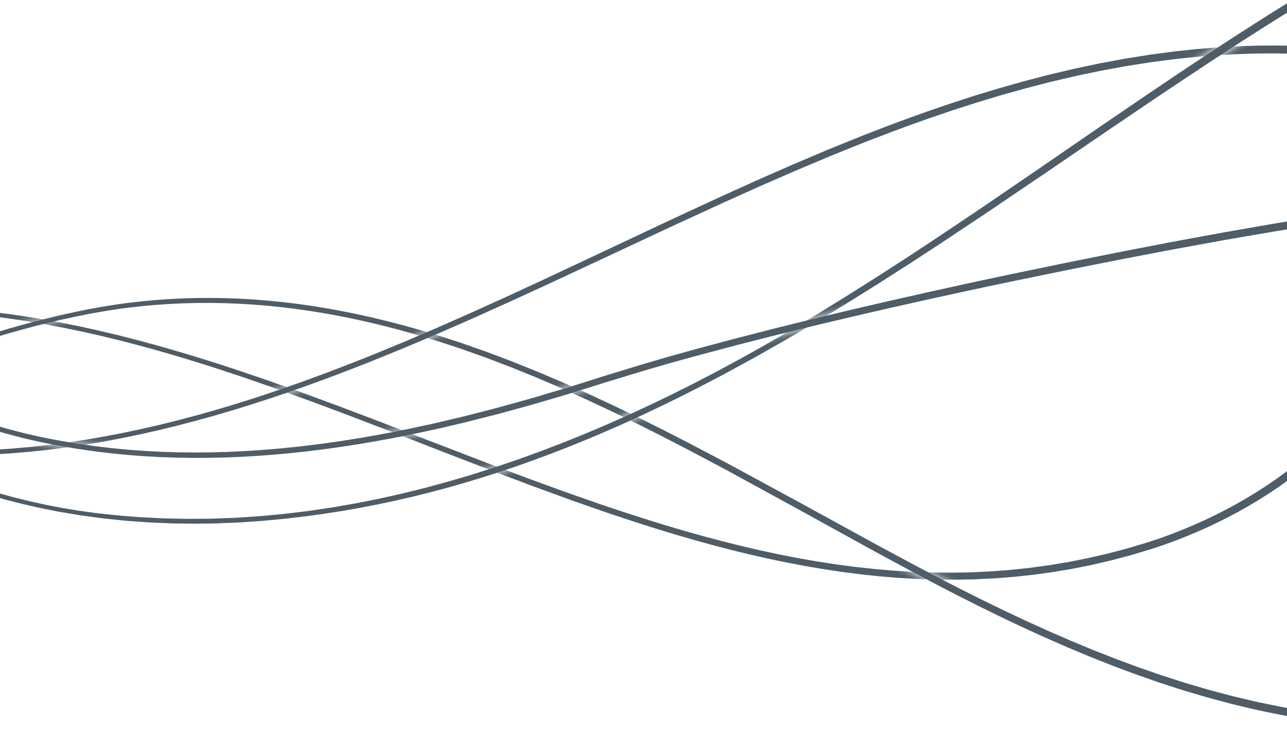

ABSTRACT

Background. A range of classification systems are in use for the measurement of nursing workload in Intensive Care Units. However, it is unknown to what extent the measured (objective) nursing workload, usually in terms of the amount of nursing activities, is related to the workload actually experienced (perceived) by nurses.

Objectives. The aim of this study was to assess the association between the objective nursing workload and the perceived nursing workload and to identify other factors associated with the perceived nursing workload.

Methods. We measured the objective nursing workload with the Nursing Activities Score and the perceived nursing workload with the NASA-Task Load Index during 228 shifts in eight different Intensive Care Units. We used linear mixed-effect regression models to analyze the association between the objective and perceived nursing workload. Furthermore, we investigated the association of patient characteristics (severity of illness, comorbidities, age, body mass index, and planned or unplanned admission), education level of the nurse, and contextual factors (numbers of patients per nurse, the type of shift (day, evening, night) and day of admission or discharge) with perceived nursing workload. We adjusted for confounders.

Results. We did not find a significant association between the observed workload per nurse and perceived nursing workload (p=0.06). The APACHE-IV Acute Physiology Score of a patient was significantly associated with the perceived nursing workload, also after adjustment for confounders (p=0.02). None of the other patient characteristics was significantly associated with perceived nursing workload. Being a certified nurse or a student nurse was the only nursing or contextual factor significantly associated with the perceived nursing workload, also after adjustment for confounders (p=0.03).

Conclusion. Workload is perceived differently by nurses compared to the objectively measured workload by the Nursing Activities Score. Both the severity of illness of the patient and being a student nurse are factors that increase the perceived nursing workload. To keep the workload of nurses in balance, planning nursing capacity should be based on the Nursing Activities Score, on the severity of patient illness and the graduation level of the nurse.

INTRODUCTION

High levels of workload with a low number of patients per nurse are common in the Intensive Care Unit , due to a high complexity and intensity of patient care. The high workload in combination with a shortage of highly educated Intensive Care nurses increases the risk of burn-out in Intensive Care nurses[1]. The number of patients per nurses, defined as the Nurse : Patient ratio has proven to be associated with quality of care and the outcome of critically ill patients[2,3]. A low Nurse : Patient-ratio is related to an increase in both patient morbidity and mortality[4,5]. However, recent research showed that workload per nurse, and not the number of patients per nurse, was associated with in-hospital mortality [6]. Therefore, it is more important to focus on the workload per nurse than the number of patients per nurse.

Several systems have been developed to measure nursing workload in Intensive Care Units[7]. One of the most accepted and widely used systems is the Nursing Activities Score (appendix 2). The Nursing Activities Score was developed in 2003 as an instrument to categorize the nursing activities in patient care in Intensive Care and the average time consumption of those activities[8]. It has been used in different countries all over the world as a tool for planning nursing capacity in daily practice[9]. Because of the use of a fixed number of points representing the needed time per activity, we use the term 'objective workload' for the workload measured by Nursing Activities Score.

Although Nursing Activities Score objectively measures the nursing time needed to take care for each Intensive Care patient, e.g. one hour bedside care, it does not take the emotional or perceived workload into account. This is, however, an important factor of the nursing workload[10]. One hour bedside care for a dying young patient with a sepsis and hemodynamic instability due to multi-organ failure will weigh more in terms of perceived workload for a nurse than one hour bedside care for a patient after planned cardiac surgery with hemodynamic instability. The impact of taking care for these complex patients can also be different depending on the expertise of a nurse. Research has shown that a perceived high workload is associated with nurse burnout and job (dis)satisfaction[11,12]. Therefore, in capacity planning it seems to be important to use the objective workload, but also the workload as perceived by the nurse. The NASA-Task Load Index is a validated questionnaire originally developed to measure the perceived workload in the National Aeronautics and Space Administration (NASA) [13] (appendix 4). This six-item scale represents six aspects of workload: mental, physical, and temporal demand, effort, performance and frustration. The NASA Task Load Index has been shown to be reliable and is also the most commonly used system for the measurement of the perceived workload in different settings, including health care[10,14-16]. Because of the use of a scale representing the experienced impact of work on the nurses, we use from now on the term 'perceived workload' for the workload as measured with NASA-Task Load Index.

Although it is increasingly common to use the Nursing Activities Score in Intensive Cares for measuring nursing workload and planning nursing resources, less is known about to what extent this objective workload is related to perceived workload, and which other factors are potentially of influence on the perceived workload. We found one study from Hoonakker et al. (2015) [10] that analyzed the association between NASA-Task Load Index and factors such as kind of shift and Nurse to Patient ratio but not for patient factors. The aim of our study is to assess the association between the objective nursing workload measured by Nursing Activities Score and the perceived nursing workload measured with NASA-Task Load Index, and identify patient, nurse, and contextual factors (e.g. kind of shift) associated with the perceived nursing workload.

METHODS

Study design

We measured the objective nursing workload and the perceived workload in a prospective cohort study between October 1st 2016 and November 30th 2017. Dutch Intensive Cares with an existing workload registry or an intention to participate in a workload registry were approached to participate in this study on a voluntary basis.

Objective nursing workload

The Nursing Activities Score, used for the objective nursing workload, represents a total of 23 nursing activities in direct and indirect patient care (e.g. hygiene procedures, mobilization and positioning, care of artificial airways, administration tasks) (appendix 2). Each activity is translated into a score, between 1.2 and 32.0 points, representing the time needed to fulfill this activity. A total score of 100 Nursing Activities Score -points has been defined equally to the time spend by 1 Fulltime-equivalent nurse per shift[8]. Research has shown that the Nursing Activities Score explains 59 - 81% of the actual nursing time[8,17]. The interrater reliability of the Nursing Activities Score showed variable results (Kappa 0.02 – 0.69), with low results for the items with an estimated time by nurses (i.e. two hours for administration), to substantial results for the other items[24]. The Nursing Activities Score is collected by nurses at the end of the shift. For this study we used the total sum score of the Nursing Activities Score per nurse per shift. If a nurse took care of more than one patient, we calculated the total sum score of the Nursing Activities Score of all the patients under that nurse's responsibility during that shift.

Perceived nursing workload

For the perceived nursing workload we asked the nurses to fill in the NASA-Task Load Index Task Load Index in a web based digital form at the end of each shift. The score of the NASA- Task Load Index is a total sum score of six subscales representing the mental demand, physical demand, temporal demand, the overall performance, frustration level and effort (appendix 4). Every subscale is rated on a scale of 0 to 10 points. For this study we used the total sum score of the six subscales of the NASA-Task Load Index with 60 points as a maximum score; representing a maximum demand on all subscales.

Factors influencing perceived workload

We identified various factors that may influence the perceived workload, based on literature and availability of data in a Dutch national quality registry for Intensive Care [18,19,20]. Two health scientists with nursing background, two intensivists, and a clinical data scientist summarized the factors into three categories: patient factors, nursing factors, and contextual factors. We used the following patient factors with potential impact on perceived nursing workload: severity of illness expressed as the APACHE-IV Acute Physiology Score[21], comorbidities (chronic renal insufficiency, diabetes mellitus, respiratory insufficiency, cardiovascular insufficiency), age, body mass index, and type of admission (planned or unplanned). As nursing factors we included information about educational level (student; i.e. certified nurse in specialization for Intensive Care nurse or certified Intensive Care nurse) and years of experience as a certified Intensive Care nurse (less than two years or two or more years of experience). The contextual factors consisted of the number of patients the nurse had to take care for during the shift, type of shift (day, evening, or night shift), and day of admission or discharge versus in-between days.

Data collection

We used data from the Dutch quality registry National Intensive Care Evaluation [18]. Currently all Dutch Intensive Cares participate in this registry and upload data regarding among others demographic, physiological and diagnostic data, and in-hospital mortality of all admitted Intensive Care patients. One of the optional modules of the National Intensive Care Evaluation is the nursing capacity-module including the number of Fulltime-equivalent nurses and Nursing Activities Score data per patient per shift. The Nursing Activities Score data in the registry consists of all nursing activities within the

Nursing Activities Score with a data definition according the updated guidelines[25], and the sum-score of the Nursing Activities Score per patient as collected by the Intensive Care nurse at the end of the shift.

From the eight hospitals participating in our study, five hospitals participated in the optional nursing capacity-module of the National Intensive Care Evaluation. For the three hospitals not participating in the nursing capacity-module, the nurses were trained in the Nursing Activities Score and collected Nursing Activities Score data at the end of the shift on a paper form. Data about type of shift, number of nurses per patient, education level, and years of experience of the nurse were collected on the same digital form as the NASA-Task Load Index.

Data preparation

For the analysis of the Nursing Activities Score we included the total score per nurse per shift. We used the cumulative Nursing Activities Score in case of more than one patient per nurse. For the analysis of t patient factors, we included the APACHE-IV Acute Physiology Score, in case of more than one patient per nurse we used a cumulative APACHE-IV Acute Physiology Score of all the patients the nurse took care for during that shift. We believe that a younger age can affect the perceived nursing workload as treating young severely ill people might be emotionally stressful, therefore we indicated whether the treated patient was younger than 45 years. We also indicated whether the treated patient was 80 years or older. In case of more than one patient per nurse we used the cumulative number of patients younger than 45 years and the cumulative number of patients of 80 years or older.

The number of comorbidities per patient was evaluated in the analysis. In case of more than one patient per nurse we used the cumulative score of the comorbidities of all the patients the nurse had to take care for during that shift.

For the analysis of the body mass index as a patient factor we categorized the results in an index of < 30 (not obese) or ^{3} 30 (obese) according to the categorization of the World Health Organization[22]. In case of more than one patient per nurse we used the cumulative number of patients with a body mass index of 30 or higher.

For the analysis of type of admission as a patient factor we categorized type of admission in two categories: planned or unplanned admission. We added a category ‘both planned and unplanned admissions’ for nurses with more than one patient covering both types of admissions. We also adjusted our model for day of admission or discharge versus days in between.

Statistical analysis

We used linear mixed models to analyze the association between the Nursing Activities Score per nurse and NASA-Task Load Index, using the perceived workload with NASA-Task Load Index as the outcome measure. To correct for clustering within type of hospital we included type of hospital (academic or teaching versus non-teaching) as a random intercept in our models. We identified confounding factors for the association between Nursing Activities Score per nurse and NASA-Task Load Index based on expert opinion of a nursing scientist of the Intensive Care, an intensivist, and a data scientist. We used association frameworks to identify variables in the same causal pathway and variables not in the same causal pathway (appendix 5). We analyzed each possible interaction between the different factors per model (see appendix 5 Figure 1.1 till Figure 1.10).

Next, we analyzed the association between the different patient-, nurse-, and contextual factors and the NASA-Task Load Index. In every model we adjusted for possible confounding factors determined in the association frameworks. Patient-, nurse-, and contextual factors were considered statistically significant when they had a p-value of < 0.05 after adjustment for possible confounders. All statistical analyses were performed using R version 3.3.3. We used STROBE[27] as a reference to report on this study.

Ethical approval

The Institutional Research Board of the Amsterdam University Medical Centre reviewed the research proposal and waived the need for informed consent (IRB protocol W17_366).

RESULTS

We included NASA-Task Load Index data from 228 nurses in 226 different shifts of 8 different hospitals. During these shifts, nurses took care of 389 patients. From the 389 patients we had to exclude 8 patients due to missing Nursing Activities Score -data.

Table 1 shows characteristics of the hospitals, as well as patient-, nurse-, and contextual factors.

Due to the low number of nurses with 3 or 4 patients per nurse (N = 6) we categorized the results of this contextual factor in two different categories: 1 patient per nurse or > 1 patient per nurse. Due to the low number of nurses with < 2 years' experience (N = 9) we categorized the results of this nursing factor in two categories: student nurse or certified Intensive Care nurse.

Table 1. Baseline characteristics

Patient factors (N=389):	Included ICUs, nurses, and patients
ICU admission type: Unplanned patients – n (%)	245 (68)
Planned patients – n (%)	117 (32)
Comorbidities: Diabetes Mellitus – n (%)	68 (17.8)
Renal insufficiency – n (%)	24 (6.3)
Cardiovascular insufficiency – n (%)	16 (4.2)
Respiratory insufficiency – n (%)	7 (2.4)
APS – Median (IQR)	68 [47.25 – 96.5]
Age – Median (IQR)	66 [56 – 76]
BMI – Median (IQR)	25.95 [23.6 – 28.7]
In hospital mortality – n (%)	85 (22.3)
Length of ICU stay in days– Median (IQR)	3.2 [0.9 – 14.8]
Nurse factors:	
Numbers of patients per nurse	
1 patient per nurse – n (%)	95 (40.4)
>1 patients per nurse – n (%)	140 (59.6)
Education level and level of experience nurses (N=228)	
Student nurse – n (%)	20 (8.8)
Certified ICU nurse – n (%)	207 (91.2)
Contextual factors:	
Type of hospital (N=8)	
Academic or teaching hospital – n (%)	6 (75.0)
Non-teaching hospital– n (%)	2 (25.0)
Kind of shift (N=226)	
Day – n (%)	84 (37.2)
Evening – n (%)	77 (34.0)
Night – n (%)	65 (28.8)

Table 2 presents the mean Nursing Activities Scores and the NASA-Task Load Index scores per nurse. The Nursing Activities Score -score per patient was on average 41.3 points (SD 12.9), the mean score per nurse 67.8 points (SD 21.5). The perceived NASA-Task Load Index workload was on average 24.3 points per nurse (SD 9.1). In our models we used the mean Nursing Activities Score per nurse. If the nurse took care for more than one patient the mean score per nurse is the Nursing Activities Score of all the patients the nurse took care of during his or her shift. The mean Nursing Activities Score per nurse for

Table 2. Mean NAS and NASA-TLX

	Mean (SD) NAS	Mean (SD) NASA-TLX / nurse
All patients		
Per nurse	67.8 (21.5)	24.3 (9.1)
Per patient	41.3 (12.9)	-*
Patient factors:	**Mean (SD) NAS / patient**	
Admission type:		
a. unplanned admissions	42.9 (13.1)	-*
b. planned admissions	36.7 (9.7)	
Comorbidities:		
Patients with 1 comorbidity	39.6 (10.6)	-*
Patients with >1 comorbidity	43.1 (15.0)	
Age:		
a. Young patients (< 45 years)	40.1 (12.6)	-*
b. Old patients (>80 years)	44.9 (15.0)	
BMI:		
≤ 30	40.9 (12.3)	-*
>30	41.8 (11.0)	
Nursing factors:	**Mean (SD) NAS / nurse**	**Mean (SD) NASA-TLX / nurse**
Education level and level of experience nurses:		
Student nurse	66.2 (21.0)	27.6 (7.5)
Certified ICU nurse	68.0 (21.7)	24.0 (9.2)
Contextual factors:	**Mean (SD) NAS / nurse**	**Mean (SD) NASA-TLX / nurse**
Hospital type:		
Academic or teaching hospital	70.5 (21.1)	32.1 (9.5)
non-teaching hospital	58.7 (21.0)	27.3 (9.5)
Numbers of patients per nurse:		
1 patient per nurse	54.2 (19.6)	28.0 (10.5)
>1 patient per nurse	77.8 (17.2)	32.7 (9.0)
Kind of shift:		
Day	69.2 (24.7)	25.3 (8.9)
Evening	68.6 (20.1)	24.2 (9.0)
Night	65.7 (19.4)	23.4 (9.4)

**No NASA-TLX/Nurse because patient factors can differ per patient in case of more than one patient per nurse*

one patient per nurse was 54.2 points (SD 19.6), the mean score per nurse if taking care for more than one patient was 77.8 points (SD17.2), with a mean score per patient of 38.6 points (SD 9.4).

Table 3 gives an overview of both the unadjusted and adjusted beta coefficients and standard errors of the analyzed factors. We adjusted a factor for other factors if these were identified as a confounding factor in the association frameworks (see appendix 5 Figure 1.1 till 1.10).

Table 3. Results association NASA-TLX per nurse

	Unadjusted			Adjusted		
Variable	**Intercept**	**Beta (CI)**	**p-value**	**Intercept**	**Beta (CI)**	**p-value**
Objective NAS score per nurse	**18.94**	0.07 (0.03-0.13)	0.01	17.66	0.07 (0.00-0.13) [a]	0.06
Patient factors						
Admission type:						
a. Planned admissions	24.05	-2.00 (-4.85-0.97)	0.18	23.99	-1.94 (-4.81-0.99) [e]	0.19
b. Unplanned admissions	23.62	0.13 (-2.58-2.41)	0.92	23.53	0.17 (-2.40-2.46) [e]	0.89
c. Both planned and unplanned admissions	23.42	1.85 (-0.77-5.02)	0.19	23.45	1.72 (-0.93-4.83) [e]	0.23
Number of comorbidities	22.76	1.16 (-0.45-2.56)	0.12	22.25	1.26 (-0.51-2.70) [c]	0.78
APS	**20.52**	0.04 (0.02-0.06)	<0.001	20.00	0.03 (0.01-0.06) [b]	0.02
Age:						
a. Patients with younger age (< 45 years)	23.54	1.32 (-2.01-4.97)	0.45		NA	
b. Patients with older age (³ 80 years)	23.93	-0.80 (-3.65-2.00)	0.58			
Patients with BMI >30	23.29	1.81 (-0.77-4.64)	0.18	23.26	1.93 (-0.62-4.86) [d]	0.16
Contextual factors						
Kind of shift:						
Day shift	23.18	1.40 (-1.08-3.80)	0.26		NA	
Evening shift	23.74	-0.11 (-2.50-2.38)	0.93			
Night shift	24.12	-1.41 (-3.97-1.13)	0.28			
Number of patients per nurse:						
1 patient per nurse		Ref	Ref		Ref	Ref
>1 patient per nurse	22.23	**3.80 (1.47-6.12)**	**<0.001**	18.51	2.50 (-0.55-6.02) [g]	0.15
Day of admission	23.76	-1.64 (-5.02-2.12)	0.36	24.62	-1.72 (-5.11-2.03) [f]	0.34
Day of discharge	23.53	1.24 (-1.80-4.36)	0.43	24.45	0.61 (-2.63-3.97) [f]	0.72

Table 3. Continued

	Unadjusted			Adjusted		
Variable	**Intercept**	**Beta (CI)**	**p-value**	**Intercept**	**Beta (CI)**	**p-value**
Nursing factors						
Certified ICU nurse		Ref	Ref		Ref	Ref
Student nurse	23.08	**4.36 (0.23-8.17)**	**0.03**	16.86	**4.56 (0.33-8.36)**[h]	0.03

a; Adjusted for APACHE IV APS, number of comorbidities, age <45 and >80, BMI>30, unplanned or planned admission, day of admission/discharge, kind of shift

b; Adjusted for number of comorbidities, age <45 and >80, BMI>30, unplanned or planned admission, day of admission/discharge

c; Adjusted for age <45 and >80, BMI>30

d; Adjusted for age <45 and >80

e: Adjusted for kind of shift, number of comorbidities

f; Adjusted for kind of shift

g; Adjusted for NAS, APS, number of comorbidities, BMI>30, unplanned or planned admission, day of admission/discharge, kind of shift, student/certified ICU nurse

h; Adjusted for NAS, APS, number of comorbidities, unplanned or planned admission, day of admission/discharge

The beta coefficient represents the increase of NASA-Task Load Index when the factor increases with 1 point, thus a beta of 0.07 in the association between Nursing Activities Score and NASA-Task Load Index means that with every increase of 1 Nursing Activities Score point the NASA-Task Load Index increases with 0.07 points. The negative beta of -2.00 in the association between planned admission and NASA-Task Load Index means that in case of a planned admission the NASA-Task Load Index decreases with 2.0 points. We found a significant crude association between the objective workload with the Nursing Activities Score and perceived nursing workload with the NASA-Task Load Index (beta=0.07, p=0.01). However, after adjustment for confounders this association did not remain significant (beta=0.07, p=0.06).

In our next models we analyzed the association between the different patient-, nurse-, and contextual factors and the NASA-Task Load Index. In the analysis of the association between the patient factors and the NASA-Task Load Index we found that the APACHE-IV Acute Physiology Score was significantly associated with the perceived workload, also after adjustment for confounders (beta= 0.03, p=0.02). Among the contextual factors, only the number of patients per nurse was associated with the perceived nursing workload (p<0.001), but after adjustment for confounders this association did not remain significant. Among the nursing factors, the type of nurse (certified or student nurse) was significantly associated with the perceived nursing workload, also after adjustment of confounders (beta= 4.56, p=0.03). Being a student nurse gives an increase of the NASA-Task Load Index with 4.56 points. This remained significant, even after adjustment for the fact that in practice student nurses were assigned to less complex patients than certified Intensive Care nurses. We found that student nurses have a lower mean Nursing Activities Score per nurse compared to certified Intensive Care nurses (66.2 versus 68.0). Also the maximum of Nursing Activities Score points per nurse was lower; 102 points for student nurses versus 158 points for certified Intensive Care nurses.

DISCUSSION

This study showed that the objective nursing workload measured by the Nursing Activities Score is not significantly associated with the perceived nursing workload of nurses. This result confirms the expectation that the time that is needed for patient care does not significantly influence the perceived nursing workload. Also the association between the number of patients per nurse and the perceived nursing workload remained not significant after analysis for confounding factors, i.e. the Nursing Activities Score. The results showed a lower mean Nursing Activities Score per patient in case of more than one patient per nurse compared to the mean score per patient in case of one patient per nurse. This confirms our expectation that in daily Dutch practice the objective workload is taken into account in the allocation of patients to nurses in case of more than one patient is allocated to nurse. This is also in line with a recent publication in Belgium where they suggested that differences in Nursing Activities Score could be explained by the organization of the ICU, i.e. the Nurse to Patient ratio[28].

However, the patients' severity of illness (measured by the APACHE-IV Acute Physiology Score) is significantly associated with the experienced nursing workload. Every increase of the APACHE-IV Acute Physiology Score with 1 point gives an increase of 0,03 on the NASA-Task Load Index scale. This means that the workload of a complex severely ill patient has a bigger impact on the perceived nursing workload of the Intensive Care nurse compared to the less-complex patient. Also the graduation level of the nurse appeared to be associated with the perceived workload: student nurses experience higher workload compared to certified nurses. The lower maximum Nursing Activities Score points per student nurse also has shown that in practice less complex and intensive patients are assigned to student nurses because these nurses are in an educational situation and are not as competent as certified nurses. Student nurses do not yet have all skills to take care for the more complex patients in clinical practice. The impact of graduation level is an important factor for perceived nursing workload and a risk for distress or even a burn-out[23]. So being a student nurse on the Intensive Care, taking care for severely ill patients is an indication for a higher perceived nursing workload. The higher perceived nursing workload in student nurses can also occur in less experienced certified nurses. Due to the low number of nurses with < 2 years' experience (N=9) we were not able to analyze the impact of this factor on the perceived nursing workload. However, research has shown that a short work experience is significantly related to emotional distress[26]. Due to the lack of skills the cognitive workload is not only higher for student nurses but also for nurses with a lack of experience. This finding must be taken into account by those responsible for planning nursing capacity, those who assign patients to nurses at the start of the shift, and the certified nurse counseling those students.

A strength of this study is the multifactorial analysis of different potential factors influencing the perceived nursing workload. As far as we know this has not been investigated before in Intensive Care. Another strength of this study is the completeness of data about the Nursing Activities Score, NASA-Task Load Index, and data about patient-, nursing-, or contextual factors. The NASA-Task Load Index was filled in by all the nurses included in our study. We had to exclude only 8 patients due to missing Nursing Activities Score data. Those patients did not appear to be different with respect to the baseline characteristics, compared to the included patients.

The collection of data in the different hospitals was carried out over a period of 13 months. Because of this we think our results are not affected by seasonal influences and therefore representative for nursing workload all over the year. We included data from different hospitals with a digital nursing capacity-module and data from hospitals with manual registration of the Nursing Activities Score. No differences between the distribution of the Nursing Activities Score results of both types of hospital were found.

There are also some limitations of this study. We included data from only eight Intensive Cares out of the 84 hospitals in the Netherlands. However, the included Intensive Cares were diverse in size (7 beds – 33 beds) and representative to Dutch Intensive Cares regarding hospital type (teaching, non-teaching) and geographical locations. We used data of 228 nurses in 226 different shifts, any future work might look at a (smaller) number of nurses over several shifts or comparing a number of nurses caring for the same patient over time for a clearer comparison. Another limitation is that registration burden of filling in Nursing Activities Score and NASA-Task Load Index might have influenced perceived workload. We measured the time for filling in the Nursing Activities Score for different nurses. The time for registration of Nursing Activities Score for a complex patient never reached more than 2 minutes. Nurses in hospitals using a digital registry needed about 1 minute per Nursing Activities Score registration. We do not expect a significant effect of this time on the perceived nursing workload. The time for recording the NASA-Task Load Index did not influence the Nursing Activities Score, because the timing of the NASA-Task Load Index was at the end of the shift after registration of Nursing Activities Score.

Although our study is one of the larger studies in adult Intensive Cares comparing the NASA-Task Load Index with Nursing Activities Score, the number of observations is relatively low and this might cause lack of power to prove an association between the Nursing Activities Score and NASA-Task Load Index. In the study of Hoonakker et al. (2015) they measured the NASA-Task Load Index in 700 nurses in 7 hospitals in 17 Intensive Cares[10]. However, they analyzed only the association between NASA-Task Load Index and factors as kind of shift and nurse-patient ratio but not with patient factors. Therefore, further research with a larger study population is needed to confirm the generalizability of the results of our study.

In our study we used the 6-scale NASA-Task Load Index. Recent research of Tubbs et al. showed that four of the six items (mental demand, physical demand, temporal demand, and effort) are strong and significant indicators for the overall nursing workload in Intensive Care nurses[16]. The study of Tubbs et al. was published after the data collection in our study, but we suggest that in a next study also the 4-scale version of the NASA-Task Load Index can be used for measuring nursing workload.

The varying results of the interrater reliability are also a limitation of this study. We did not analyze the impact of different kinds of nursing interventions on the perceived nursing workload due to the lack of power. The low interrater reliability of the items with a subjective estimation of time can influence the results of the NASA-Task Load Index as a high experienced workload can lead to an overestimation of the time needed for a patient. The impact of the time needed to take care for a dying patient and his or her relatives, can also be higher than the impact of the time needed for administration on the perceived nursing workload by a nurse. In our sample none of the patients died during that shift. Furthermore, perceived workload might be influenced by events in the nurses' personal life but also other organizational factors like a change in management. Further research is recommended on these aspects of nursing workload.

CONCLUSION

This study showed that workload is differently perceived by nurses compared to the objectively measured workload by the Nursing Activities Score. Both the severity of patient illness and being a student nurse are factors that increase the perceived nursing workload. To keep the workload of nurses in balance, planning nursing capacity should be based on the Nursing Activities Score, the severity of patient illness and the graduation level of the nurse.

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CHAPTER 5

A bell-shaped association between both the objective and perceived nursing workload and workload satisfaction of Intensive Care nurses

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ABSTRACT

Background. Nursing workload is an important issue in ICU management. However, not much is known about the association between nursing workload and satisfaction of nurses with their workload.

Objective. The aim of this study is to assess the association of the objective, time and activity-based nursing workload and the perceived nursing workload with the satisfaction of nurses about their workload in Intensive Care.

Methods. We measured the objective nursing workload with the Nursing Activities Score and the perceived nursing workload measured with the NASA-TLX during 226 shifts in eight different Intensive Cares Units (ICUs). Nurses were asked to rate their satisfaction about the nursing workload during that shift on a scale from 0 (not satisfied at all) till 10 (maximum satisfaction). We used logistic regression models to analyze the association between both the Nursing Activities Score and the NASA-TLX with workload satisfaction (satisfied (>=6) or not (<6)) of nurses about the workload.

Results. In our study we showed that a Nursing Activities Score between 73.9 - < 83.7 points per nurse leads to a significant higher chance of a nurse being satisfied about his/her nursing workload (OR = 2.92 (1.01 – 8.45)). An increase of the overall workload with a NASA-TLX score of ^{3} 27 is leading to a significant higher chance of a nurse being satisfied about the nursing workload (NASA-TLX 27 - <32: OR(CI)=3.26 (1.23 – 8.64); NASA-TLX ^{3} 32: OR(CI) = 3.04 (1.11-7.98). Analyzing the subcategories of the NASA-TLX showed a significant higher chance of a nurse being satisfied about the workload in case of a high demand in the subcategories 'mental demand', 'physical demand' and 'effort'.

Conclusion. Our study showed that nurses are most satisfied on their objective workload when the Nursing Activity Score is around 80, and when the perceived overall workload as measured with the NASA-TLX is high (above 27). Especially a perceived high mental demand, physical demand or effort contribute to a higher chance of the nurse being satisfied. A further increase of the objective or perceived nursing workload to a very high demand or a low objective or perceived nursing workload diminish these positive associations. Managers responsible for capacity planning should take these results into consideration to avoid burn-out and bore-out of ICU nurses.

INTRODUCTION

The Intensive Care is a labor-intensive environment for nurses. The care for ICU patients is demanding due to the severity of illness of ICU patients and the often technical complexity of the treatment[1,2] . The support and care for the patient and his or her relatives, confronted with a critical and life-threatening situation, can be emotionally burdensome. Because of the relatively high mortality risk of ICU patients, ICU nurses are regularly confronted with end-of-life care which also can have a high impact on their mental workload.

The physical care can be demanding because most ICU patients are completely dependent of the nursing care, but also because of specific ICU nursing care as mobilization of ventilated patients or turning patients into prone position. That this work often has to be done in limited space and in ergonomic uncomfortable positions add to this physical demand[3]. Therefore, the mental and physical demand on ICU nurses is high[4,5].

Research has shown that all those factors: intensity of nursing activities, severity of illness, complexity of care and mental demand, attribute to the nursing workload[6-11]. This becomes particularly important as it has been shown that nursing workload is related to job satisfaction, burn-out and an intention to leave the current job[12,13]. Given the shortage of ICU nurses in Netherlands but also in many other western countries[14,15], it is important to keep nurses motivated and satisfied with their job. In an earlier study we assessed the association of time and activity based (objective) workload with the perceived nursing workload and concluded that it is important to take both the number of patients and the nursing workload into consideration when planning nursing capacity[11]. However, both the objective and the perceived workload did not give insight in the workload satisfaction of nurses. We therefore extended on our previous research with the aim to gain insight in the workload satisfaction of ICU nurses. To the best of our knowledge there are no studies published on the association of nurses' workload satisfaction with the objective or perceived nursing workload.

OBJECTIVE

The aim of this study is to assess the association of workload satisfaction with both the objective nursing workload, measured with Nursing Activities Score, and the perceived nursing workload, measured with the NASA-TLX. We hypothesized that both a too low and too high workload could lead to dissatisfaction of the nurse. To further understand the association between nursing satisfaction with the perceived nursing workload we also assessed the association of nursing workload satisfaction with the different subcategories of the perceived nursing workload as measured with the NASA-TLX.

METHODS

Study design and setting

We invited 15 Dutch ICUs already recording workload scores or with an intention to participate in the capacity module of the NICE quality registry[16] that includes a workload registration, to participate in this study on a voluntary basis. The nurses of the participating hospitals were informed about the study in a newsletter. From October 1st, 2016, and November 30th, 2017, we prospectively measured the objective nursing workload, the perceived nursing workload, and the satisfaction of the ICU nurses with the workload during their shift. Nurses were approached by the researcher to participate in this study on a voluntary basis.

Variables

Objective nursing workload

For the measurement of the objective nursing workload we used the Nursing Activities Score (appendix 2). The Nursing Activities Score represents a total of 23 nursing activities in direct and indirect care (e.g. hygiene procedures, mobilization and positioning or administration tasks) with a translation into a score, representing the mean nursing time needed for this activity[17,18]. A total Nursing Activities Score of 100 has been defined equally to the time spend by 1 Full Time Equivalent (FTE) nurse per shift. The Nursing Activities Score is validated with time measurements[17,18]. Research has shown that the Nursing Activities Score explains 59 - 81% of the actual nursing time[17,19]. The interrater reliability of the Nursing Activities Score showed variable results (Kappa 0.02 – 0.69)[20,21,22]. The Nursing Activities Score is the most common system for measuring nursing workload all over the world[18,23].

Perceived nursing workload

For the perceived nursing workload we used the NASA-Task Load Index (NASA-TLX). The NASA-TLX is a validated questionnaire originally developed to measure the perceived workload in aviation[24] (appendix 4). The NASA TLX has been shown to be reliable for the measurement of the perceived workload in different settings, including health care[25,26]. It is a commonly used system to assess the perceived nursing workload on the ICU[27,28]. The NASA-TLX is a six-item scale representing six aspects of perceived workload: mental demand, physical demand, temporal demand, effort, performance, and frustration. Every subscale of the NASA-TLX is rated on a scale of zero to ten points with zero as a minimal perceived workload and ten as a maximum perceived workload in that subcategory. For this study we used both the total NASA-TLX score and the NASA-TLX score per subscale. The subscales of the NASA-TLX represents a score from 0 till 100 points, with 0 points representing a minimum demand and 100 points representing a maximum demand on the workload in that specific subcategory. The total NASA-TLX score represents a mean score of the cumulative score of all six subscales with a score from 0 till 100; with 100 points representing a maximum overall workload.

Satisfaction with nursing workload

To measure how satisfied the nurses were with the work they had performed we asked the ICU nurses to grade their satisfaction with the workload during that shift on a scale from zero till ten (zero for not satisfied at all and ten for maximal satisfied) at the end of the shift.

Ethical approval

All data were collected and analyzed anonymously. The Institutional Research Board of the Amsterdam University Medical Centre reviewed the research proposal and waived the need for informed consent (IRB protocol W17_366).

Data collection

We used the Nursing Activities Score data of the capacity module in the Dutch National Intensive Care Evaluation (NICE) registry. The nursing workload data in the capacity module of the NICE registry consists of all nursing activities within the Nursing Activities Score with updated data definitions[18], and the sum-score of the Nursing Activities Score per patient. Nurses using the capacity module are trained in the use of the Nursing Activities Score and the data definitions. The Nursing Activities Score data are collected by the ICU nurse in the Electronic Health Record, at the end of each shift. In our study we used the Nursing Activities Score per nurse. In case of two or more patients the Nursing Activities Score per nurse is the sum score of the Nursing Activities Score of all patients the nurse had to take care for during that shift. For the purpose of the study, we asked the ICU nurses to fill in the NASA-TLX subscales at the end of the shift on a web-based digital form, after the handover of the patient(s) to the colleague of the next shift. We also asked the ICU nurses to rate their workload satisfaction in that shift from zero (not satisfied) till ten (maximal satisfied) in the same web-based digital form. The nurses also had the opportunity to comment on the workload or the questionnaire in a free text field. During and after the shift the researcher was available for questions about the Nursing Activities Score and the questionnaires.

STATISTICAL ANALYSES

We used univariate logistic regression analysis with nursing workload satisfaction divided into two categories: not satisfied (0 – 5) and satisfied (6 – 10) as the outcome variable. The independent variables, the Nursing Activities Score and the overall workload NASA-TLX score, were divided into quintiles, using the first quintile as the reference value. For our secondary analyses we used as independent variables each of the six subscales of the NASA-TLX divided into four categories: very low (<40), low (40 – 50), high (60 - 70) and very high (≥ 70) with very low as the reference value. We used the Odds Ratio (OR) and the 95%-Confidence Interval (CI) to determine if the association between workload satisfaction and objective or perceived workload is statistically significant (confidence interval does not include 1) or not significant (confidence interval does include 1). All analyses were performed using the R statistical environment (version 3.6.1) (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

During the study period we collected NASA-TLX data from 229 nurses in 226 different shifts of 8 different hospitals. During these shifts, the ICU nurses were taking car for 389 different patients. Eight patients missed NAS-data and were excluded. The data of two nurses were excluded because of a missing satisfaction rate. Therefore, finally we included 381 patients, 227 nurses and 226 shifts. Table 1 shows the baseline characteristics of the included patients, nurses, type of hospitals and type of shifts.

The median Nursing Activities Score per nurse, the objective nursing workload, was 69.6 (IQR 49.3 – 80.5) with a minimum of 20.6 points per nurse and a maximum of 134 points per nurse. The overall perceived workload based on NASA-TLX per nurse was 43.3 (IQR 30-50) with a minimum sum-score of 33 and a maximum score of 75. Overall, the nurses were satisfied with the workload with a median satisfaction rate of 8 on a scale of 0 till 10 (IQR 6 – 8) (see Table 2). Thirteen nurses took the opportunity to leave free text in the questionnaire. Those comments can be found in the last row in table 2.

Table 1. Baseline characteristics

Patient factors:	Included ICUs, nurses, and patients
ICU admission type:	
Unplanned patients – n (%)	245 (68)
Planned patients – n (%)	117 (32)
Comorbidities:	
Diabetes Mellitus – n (%)	68 (17.8)
Renal insufficiency – n (%)	24 (6.3)
Cardiovascular insufficiency – n (%)	16 (4.2)
Respiratory insufficiency – n (%)	7 (2.4)
APACHE IV Acute Physiology Score – Median (IQR)	68 [47.25 – 96.5]
Age – Median (IQR)	66 [56 – 76]
BMI – Median (IQR)	25.95 [23.6 – 28.7]
In hospital mortality – n (%)	85 (22.3)
Length of ICU stay in days– Median (IQR)	3.2 [0.9 – 14.8]
Nursing Activities Score per patient (IQR)	31 [25.5 – 38.9]
Numbers of patients per nurse	
1 patient per nurse – n (%)	95 (41.4)
>1 patients per nurse – n (%)	134 (58.5)
Education level and level of experience nurses	
Student nurse – n (%)	20 (8.7)
Certified ICU nurse – n (%)	209 (91.3)
Type of hospital	
Academic or teaching hospital – n (%)	6 (75.0)
Non-teaching hospital– n (%)	2 (25.0)
Type of shift	
Day – n (%)	84 (37.2)
Evening – n (%)	77 (34.0)
Night – n (%)	65 (28.8)

Table 3 shows the Odds Ratios of the objective nursing workload (Nursing Activities Score) and the perceived nursing workload (NASA-TLX). Only the fourth quintile of the Nursing Activities Score (73.9 - < 83.7) showed a significant higher workload satisfaction compared to the reference category (OR = 2.92 (1.01 – 8.45)). The two highest quintiles of the overall NASA-TLX score (≥ 27) were both significantly associated with a higher workload satisfaction (NASA-TLX 27 - <32: OR = 3.26 (1.23 – 8.64); NASA-TLX ≥ 32: OR = 3.04 (1.11-7.98)).

Table 2. results nursing workload per nurse and satisfaction

	Median (IQR)
Nursing Activities Score per nurse – Median (IQR)	69.9 (50.0 – 80.5)
NASA-TLX Overall workload - Median (IQR)	43.3 (30 – 50)
NASA-TLX Mental demand- Median (IQR)	50 (30 – 70)
NASA-TLX Physical demand- Median (IQR)	50 (20 – 70)
NASA-TLX Temporal demand- Median (IQR)	30 (10 – 50)
NASA-TLX Overall performance- Median (IQR)	20 (20 – 30)
NASA-TLX Frustration level- Median (IQR)	30 (20 – 70)
NASA-TLX Effort- Median (IQR)	40 (20 – 70)
Satisfaction with workload – Median (IQR)	8 (6 – 8)
Satisfaction < 6 - N (%)	49 (21.6%)
Satisfaction ≥ 6 - N (%)	178 (78.4%)
workload satisfaction score	**Comments of nurses**
9	1. Peak was in the first half of the shift, manageable and very easy to do
10	2. Just got back from vacation, had to get going
10	3. Was a very quiet service
8	4. Because of my own fatigue (breastfeeding at night) I feel broke, so I have difficulty thinking and so on
3	5. The workload is too low for me to experience this shift? as pleasant
3	6. Not a challenging shift?
3	7. Very quiet shift. Not very challenging. 1 patient who was very stable.
7	8. The shift started very restlessly, 1 nurse too few, who was brought in from the other unit, which made me switch patients. Which made it a troubled start-up. In addition, physically demanding because of an obese / troubled patient.
3	9. Too quiet rather than too busy
7	10. Quiet shift, where I was able to do everything I had to do and what I wanted to do. But it could be a bit busier.
2	11. Only 1 stable patient to take care of, especially attention to basic care, mobilization, etc.
8	12. Very quiet shift
9	13. Workload is subjective, sometimes it feels more pleasant to have a busier shift

Table 3. Odds Ratios of Nursing Activities Score and NASA-TLX, including the subscales, on workload satisfaction

Variable	Odds	95% CI
Nursing Activities Score per nurse		
Q1: < 47.10	(ref)	(ref)
Q2: 47.10 - < 65.08	1.35	0.54-3.41
Q3: 65.08 - < 73.90	1.75	0.67-4.59
Q4: 73.90 - < 83.74	2.92	1.01-8.45
Q5: ≥ 83.74	1.80	0.69-4.71
NASA-TLX - Overall workload per nurse		
Q1: < 16	(ref)	(ref)
Q2: 16 - < 23	2.67	1.0 – 7.14
Q3: 23 - < 27	2.54	0.91 – 7.11
Q4: 27 - < 32	3.26	1.23 – 8.64
Q5: ≥ 32	3.04	1.11 – 7.89
NASA-TLX - Mental demand		
< 40, very low	(ref)	(ref)
40 – 50, low	0.66	0.3 – 1.47
60 – 70, high	2.72	1.05 – 7.06
≥ 70, very high	2.07	0.79 – 5.43
NASA-TLX – Physical demand		
< 40, very low	(ref)	(ref)
40 – 50, low	1.16	0.54 – 2.46
60 – 70, high	5.40	1.53 – 19.15
≥ 70, very high	1.32	0.53 – 3.31
NASA-TLX – Temporal demand		
< 40, very low	(ref)	(ref)
40 – 50, low	0.72	0.33 – 1.55
60 – 70, high	1.47	0.56 – 3.88
≥ 70, very high	1.04	0.21 – 5.19
NASA-TLX – Overall performance		
< 40, very low	(ref)	(ref)
40 – 50, low	1.23	0.44 – 3.44
60 – 70, high	0.15	0.04 – 0.67
≥ 70, very high	0.77	0.08 – 7.61
NASA-TLX – Frustration level		
< 40, very low	(ref)	(ref)
40 – 50, low	6.27	0.81 – 48.55
60 – 70, high	0.41	0.15 – 1.10
≥ 70, very high	0.92	0.44 – 1.96
NASA-TLX – Effort		
< 40, very low	(ref)	(ref)
40 – 50, low	1.52	0.69 – 3.35
60 – 70, high	2.73	1.03 – 7.24
≥ 70, very high	1.52	0.55 – 4.19

Analyzing the subcategories of the NASA-TLX showed a significant increase of the chance of a nurse being satisfied with the workload in the highest quartiles of subcategories 'mental demand', 'physical demand' and 'effort'. If the nurse scored a high mental demand (quartile 3) the odds ratio was 2.72 (CI 1.05 – 7.06). If the nurse scored a high physical demand the odds ratio was 5.40 (CI 1.53 – 19.15). In case of a high effort the OR was 2.73 (CI 1.03 – 7.24).

DISCUSSION

With this study we showed an association between workload satisfaction and the objective and perceived workload of ICU nurses. The fourth quintile of the objective workload, measured by the Nursing Activities Score (between 74-84), was significantly associated with a higher workload satisfaction, this effect was absent in the other and hence also the fifth quintile. This confirms our hypothesis that regarding workload satisfaction there is an optimum in the Nursing Activities Score per nurse. However, the Nursing Activities Score is developed with the suggestion that 1 FTE ICU nurse corresponds with a Nursing Activities Score of 100[17]. This score per nurse was never validated as an optimum score per nurse. In most studies the mean Nursing Activities Score per nurse is lower than the 100 NAS-points per nurse. Moghadam et al. (2020) reported a mean Nursing Activities Score per nurse of 72,84[5]. Earlier research of our research group comparing the COVID-19 ICU patients with non-COVID ICU patients showed a mean Nursing Activities Score per nurse of 46.6[29]. In an observational study about the updated guidelines of the Nursing Activities Score from Padilha et al (2015) in 19 ICUs in seven different countries they found a mean Nursing Activities Score of 72.8 with the lowest mean Nursing Activities Score of 44.5 in Spain and the highest mean Nursing Activities Score of 101.8 in Norway[18]. Our research shows that regarding the workload satisfaction of ICU nurses an optimal Nursing Activities Score per nurse would be around 80. In an earlier study of our group we showed a significant increase in hospital mortality if the Nursing Activities Score per nurse exceeded 78 per nurse[30]. Based on those results we already suggested that one registered ICU nurse should provide no more than a Nursing Activities Score of 78 per shift. Our present results seem to fit with these observations.

We also investigated the association of workload satisfaction with the perceived workload. The two highest quintiles of the perceived nursing workload measured by the NASA-TLX were associated with a higher workload satisfaction. This is also represented in 3 of the 6 subscales of the NASA-TLX; the mental and physical demand and the effort. In all three subcategories we found a higher workload satisfaction in the highest but one quintile (score 60 - 70). This implicates that both a perceived under- and over-prestation has an influence on how satisfied nurses are about the workload. Comparing the mean NASA-TLX in our study (NASA-TLX 43.3) with the results of other studies, the overall perceived workload with the NASA-TLX was relatively low. A study of Hoonakker et al (2011) in 757 ICU nurses in 7 hospitals and 17 different ICUs showed a mean overall workload of 70.4[27]. Those ICUs included however also workload of nurses on a burn-unit, pediatric or neonatal unit. But also other studies showed NASA-TLX scores between 59.95 and 70.2[4,5]. A possible explanation for our lower NASA-TLX score is the high number of postoperative patients in our study group (32%); the workload of a planned postoperative ICU patient is relatively low compared to unplanned surgical or medical patients[11]. The low nursing workload and the negative impact of this workload on nurses is also confirmed in different remarks we found in the free text comments. Nine out of the thirteen nurses left a comment about a quiet shift stating: 'very quiet' or 'too quiet', 'little or no challenge', 'workload too low to be pleasant', 'sometimes it feels more pleasant to have a busier shift'. Only one nurse left a comment about a busy (restless) shift with too few nurses for the work to be done. The results of the satisfaction about workload of the nine nurses with comments due to a quiet shift showed a wide range in the satisfaction rate (2 till 10). this shows that there is dissatisfaction with the workload at both a very high and very low workload. These qualitative results seem to support that there is an optimal point in the nursing workload. This optimal point is important because of the impact of nursing workload on job satisfaction, burn-out or intention to leave[12,13]. Planning the nursing staff should not be based on the number of patients per nurse, but on both the objective and perceived nursing workload.

Strength and limitations

To the best of our knowledge this study is the first one that assessed the relationship between workload satisfaction and both the objective as well as the perceived nursing workload. Many studies described nursing workload or job satisfaction, but none of those studies analyzed the association between these concepts. Therefore, this study contributes to a better understanding of nursing workload and how to use the concept of workload as a human resource tool. A strength of this study is the completeness of data. During this study both the Nursing Activities Score and the NASA-TLX was filled in by almost all the nurses. We included data in a period of 13 months and therefore the data are representative for workload all over the year. Because we asked the nurse to fill in the questionnaire at the end of the shift and after the handover the study itself did not affect the measured nursing workload.

Some limitations of our study need to be taken into consideration. Whereas workload satisfaction is a very complex concept we used a simple one-dimensional question for the satisfaction of nurses about workload. As the Nursing Activity Score and the NASA-TLX questionnaire already contain many items to be scored we opted for the simple one-dimensional question to avoid adding more registration load. This question was unambiguous in asking for the satisfaction rate on the nursing workload during the last shift and it simply used a scale between zero and ten that nurses are used to in all kinds of daily life varying from school grades as well as review rates of consumer products and travel services.

Although our study is one of the larger studies in adult ICUs comparing workload data with both the Nursing Activities Score and the NASA-TLX, the number of observations is still relatively low and this might cause lack of power to prove an association between workload satisfaction and Nursing Activities Score or NASA-TLX, especially on the subscales of NASA-TLX. To generalize the results of our study a larger study population and studies in different ICUs and in different countries are needed. It seems to be important to focus on a further validation of the optimal Nursing Activities Score per nurse.

CONCLUSION

We showed that both the objective nursing workload as measured with Nursing Activities Score and the perceived nursing workload as measured with the NASA-TLX are associated with the satisfaction with nursing workload. A Nursing Activities Score per nurse between 74 and 84 points per nurse and a total NASA-TLX of > 27 points are significantly associated with a higher workload satisfaction. This indicates that there is an optimum in the nursing workload. Further research is needed to validate the optimum Nursing Activities Score per nurse.

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CHAPTER 6

The impact of COVID-19 on nursing workload and planning of nursing staff in Intensive Care; A prospective descriptive multicenter study

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ABSTRACT

Introduction. The impact of the care for COVID-19 patients on nursing workload and planning nursing staff in the Intensive Care Unit has been huge. Nurses were confronted with a high workload and an increase in the number of patients per nurse they had to take care of.

Objective. The primary aim of this study is to describe differences in the planning of nursing staff in Intensive Care in the COVID period versus a recent non-COVID period. The secondary aim was to describe differences in nursing workload in COVID-19 patients, pneumonia patients and other patients in Intensive Care. We finally wanted to assess the cause of possible differences in Nursing Activities Scores between the different groups.

Methods. We analyzed data on nursing staff and nursing workload as measured by the Nursing Activities Score of 3,994 patients and 36,827 different shifts in 6 different hospitals in the Netherlands. We compared data from the COVID-19 period, March 1st, 2020, till July 1st, 2020, with data in a non-COVID period, March 1st, 2019, till July 1st, 2019. We analyzed the Nursing Activities Score per patient, the number of patients per nurse and the Nursing Activities Score per nurse in the different cohorts and time periods. Differences were tested by a Chi-square, non-parametric Wilcoxon or Student's t-test dependent on the distribution of the data.

Results. Our results showed both a significant higher number of patients per nurse (1.1 versus 1.0, $p<0.001$) and a significant higher Nursing Activities Score per Intensive Care nurse (76.5 versus 50.0, $p<0.001$) in the COVID-19 period compared to the non-COVID period. The Nursing Activities Score was significantly higher in COVID-19 patients compared to both the pneumonia patients (55.2 versus 50.0, $p<0.001$) and the non-COVID patients (55.2 versus 42.6, $p<0.001$), mainly due to more intense hygienic procedures, mobilization and positioning, support and care for relatives and respiratory care.

Conclusion. With this study we showed the impact of COVID-19 patients on the planning of nursing care in Intensive Care. The COVID-19 patients caused a high nursing workload, both in number of patients per nurse and in Nursing Activities Score per nurse.

INTRODUCTION

It is generally recognized that the COVID-19 pandemic had a huge impact on nursing workload and the planning of the nursing staff in the Intensive Care Unit (ICU). Also in the Netherlands the COVID-pandemic hit hard. The ICUs were confronted with an increase in patients admitted, in an already existing situation of shortage of ICU nurses. The ICU bed capacity expanded from around 1100 beds in the normal situation to up to 1700 beds in April 2020 with the associated need for nursing staff[1] . In the Netherlands the nursing workload on the ICU was also considered high by ICU nurses as indicated in a survey among 700 ICU nurses by the Dutch professional Association for ICU nurses[2] Firstly, because they were confronted with an increase in numbers of patients per nurse. The high number of unplanned ICU admissions due to the COVID-pandemic caused an extreme pressure on the bed capacity on the ICU and therefore on the nursing staff[1]. The ICU management was forced to alter normal nursing staff planning, and to bypass the Dutch Guidelines for Intensive Care which states that an ICU nurse in the Netherlands takes care for one or two patients per shift[3]. During the peak of the COVID-19 crisis ICU nurses frequently had to take care for more than two patients per nurse. A study from Arabi et al described different methods to expand the ICU staffing pool during the COVID-pandemic, e.g. optimizing ICÜ-nursing capacity by increasing the number of patients per nurse and the use of non-ICU staff to reinforce the ICU staff[4]. Also in the Netherlands the ICU nurses were supported by non-ICU nurses for basic care, but the ICU nurses were still responsible for the wellbeing of a higher number of patients during their shift. This is relevant as earlier research showed that the number of patients per nurse on an ICU is related to the patient outcome[5,6].

Secondly, in addition to an increased number of patients, the ICU nurses were also confronted with a new patient category with a complex care demand. The nursing workload of patients with COVID-19 pneumonia was perceived high compared to the average patient admitted to the ICU. Recent research showed that in Italy and Belgium the nursing workload as expressed with the Nursing Activities Score was higher in patients with COVID-19 compared to other ICU patients[7,8]. Moreover, due to the pressure on ICU beds there was no capacity left for planned surgical patients with a need for postoperative care on the ICU[1]. This resulted in a decrease of planned admissions of less complex postoperative ICU patients; the available beds were mainly used for emergency medicine and surgery admissions. The combination of the potentially high nursing workload of both the COVID-19 patients and the other ICU patients could result in a higher workload per patient, and consequently a higher workload per nurse. Especially because the nurses had to take care of more than the normal number of patients. Recent research of

Margadant et al (2020) stated the importance of the nursing workload per ICU nurse; a higher Nursing Activities Score per nurse ratio was associated with a higher in-hospital mortality[9]. Therefore, it is important to look both at the number of patients per nurse and the nursing workload per nurse.

The primary aim of this study was to describe differences in the planning of nursing staff, expressed as the patient per nurse ratio on the ICU, and the impact of those differences on nursing workload in the COVID-period versus a recent non-COVID-period. The secondary aim of this study was to describe differences in ICU nursing workload according to the Nursing Activities Score of COVID-19 ICU patients and other ICU patients. We compared the workload of COVID-19 ICU patients with the workload of pneumonia patients from a recent non-COVID period. We also compared the workload of non-COVID patients during the COVID-period versus non-pneumonia patients in a recent non-COVID period. Lastly, we compared the workload of COVID-19 ICU patients with other ICU patients during the COVID-period. We finally wanted to assess the cause of possible differences in Nursing Activities Score between the different groups.

METHODS

Setting

We used data from the Dutch National Intensive Care Evaluation (NICE) quality registry. Since 2016 all 80 Dutch ICUs participate in NICE[10]. The NICE quality registry contains a minimal dataset with demographic, physiological and diagnostic patient data, and in-hospital mortality of all admitted ICU patients in all Dutch hospitals. One of the optional modules in the NICE registry is the nursing capacity module with data about nursing workload and the number of fulltime-equivalent nurses per shift. This capacity module is available since 2017. Among the 80 Dutch ICUs participating in the NICE quality registry, eleven Dutch ICUs of eleven distinct hospitals participate in the nursing capacity module since the start in 2017. From the eleven participating ICUs in the capacity module, we included the data of six ICUs as we had to exclude five ICUs due to missing Nursing Activities Score; the nurses in those five ICUs were not able to collect the Nursing Activities Score during the COVID-19 period due to the high workload.

Participants and period definition

All patients with a date of admission between March 2020 and July 1st, 2020, to the six ICUs participating in the nursing capacity module were included for the COVID-19 period. All patients with a date of admission between March 1st, 2019, and July 1st, 2019, on those ICUs were included for the non-COVID period.

Variables

We defined four ICU patient cohorts: (1) patients admitted with a confirmed COVID-19 infection [positive polymerase chain reaction (PCR) test and/or confirmed COVID-19 on CT-Thorax i.e. a COVID-19 Reporting and Data System score (CO-RADS) of ≥4 in combination with the lack of an alternative diagnosis[11]] during the COVID-period, (2) patients admitted with a pneumonia [aspiration, bacterial, fungal, parasitic of viral pneumonia or pulmonary sepsis] during the non-COVID period; (3) all non-COVID patients admitted to the ICU during the COVID period; and (4) all non-pneumonia patients admitted to the ICU during the non-COVID period.

We used the Nursing Activities Score to measure the nursing workload on the ICU[12]. The Nursing Activities Score represents a total of 23 nursing activities in direct and indirect ICU patient care (e.g., hygiene procedures, mobilization and positioning, care of artificial airways, administration tasks) with a score representing the average time consumption per activity (appendix 2). A total score of 100 points has been defined equal to the time spent by one fulltime-equivalent nurse per shift. Validation with time measurements has shown that Nursing Activities Score explains 59-81% of the actual nursing time[12,13]. The interrater reliability of the Nursing Activities Score showed variable results (Kappa 0.02 – 0.69). The results are low for the items with categories of an estimated time by nurses (e.g. present at bedside and observation for two hours or more)[14]. This subjective estimation can lead to differences in NAS-scores and subsequently to differences in the calculated need for nursing staff[15,16]. Despite this consideration the Nursing Activities Score is widely used in different countries all over the world as a tool for planning nursing staff in daily practice[17,18]. The use of NAS in Intensive Care is described in e.g. Belgium, Italy, the Netherlands, Norway, Spain, Portugal, Poland, Egypt, Greece and Brazil[19,20,21,22].

The nursing workload data in the capacity module of the NICE registry consists of all nursing activities within the Nursing Activities Score with updated data definitions and the sum-score per patient. The Nursing Activities Score is collected in the Electronic Health Record by the ICU nurse, at the end of each shift. Nurses of the hospitals using the capacity module are trained in the use of NAS and the data definitions.

The nursing staff data in the capacity module of the NICE registry consists of both the number of certified ICU nurses and trainee-ICU nurses actual present per shift and the number of operational beds per shift. The actual nursing staff data are retrospectively collected by the ICU management or ICU secretary. This staff is also trained in the use of the capacity module and the data definitions. Data quality is assessed with a feedback system in the software on missing and extreme or abnormal data, both in the hospital Electronic Health System and within the NICE-registry database.

Statistical analysis

Depending on the variable distribution we used mean and standard deviation (SD) to describe normally distributed continuous variables and median and interquartile range (IQR) for non-normally distributed variables. Categorical variables were described by numbers and percentages. Differences between the cohorts were tested with a Chi-square test for categorical variables, a non-parametric Wilcoxon for non-normally distributed continuous variables and Student's t-test in case of normally distributed variables. Differences were considered statistically significant when they had a p-value of < 0.05. All statistical analyses were performed using R version 3.3.3.

RESULTS

Baseline characteristics

We included data of 36,754 shifts (day, evening, night) of 3,994 ICU patients: 218 patients with COVID-19 and 1,367 non-COVID ICU patients in the COVID-19 period; 147 patients with pneumonia and 2,262 non-pneumonia ICU patients in the non-COVID period. Table 1 shows the baseline characteristics of the four patient cohorts.

Comparing the COVID-19 patients with the pneumonia patients, the COVID-19 patients showed a significant lower number of patients with chronic respiratory insufficiency (11.9% versus 37.4%, p<0.001), a higher BMI (Median BMI 27.7 versus 25.7, p = 0.001), higher number of patients requiring mechanical ventilation in the first 24 hours on the ICU (83.0% versus 55.8 %, p < 0.001), longer length of stay on the ICU (median LOS 14 days versus 3.9 days, p<0.001), a higher ICU mortality (28.9% versus 19,0%, p=0.048) and in-hospital mortality (39.0% versus 26.5%, p=0.017). The group of non-COVID patients during the COVID period showed a significant higher number of urgent surgery patients (17.5% versus 10.8%, p<0.001) compared to the non-pneumonia patients and also a higher number of patients requiring mechanical ventilation in the first 24 hours on the ICU (57% versus 60.7%, p = 0.03).

Table 1. Baseline characteristics

Patient factors:	COVID-patients versus pneumonia patients			Non-COVID patients versus non-pneumonia patients		
	COVID-19 patients	Pneumonia patients	Significance p-value	Non-COVID patients	Non-pneumonia patients	Significance p-value
Number of patients – N (%)	218 (13.8 %)	147 (6.1%)		1,367 (86.2 %)	2,262 (93.9%)	
ICU admission type:						
Medical patients – N (%)	217 (99.5)	147 (100)	1	447 (32.8)*	828 (36.6)*	0.019
Elective surgical patients – N (%)	1 (0.5)	0 (0)	1	678 (49.6)*	1,188 (52.5)*	0.100
Urgent surgery patients – N (%)	0 (0)	0 (0)	-	239 (17.5)*	245 (10.8)*	<0.001
Comorbidities:						
Diabetes Mellitus – N (%)	53 (24.3)	28 (19.0)	0.263	251 (18.4)	411 (18.2)*	0.890
Renal insufficiency – N (%)	7 (3.2)	16 (10.9)	0.002	57 (4.2)	147 (6.5)*	0.005
Cardiovascular insufficiency – N (%)	6 (2.8)	7 (4.8)	0.404	76 (5.6)	97 (4.3)	0.098
Respiratory insufficiency – N (%)	26 (11.9)	55 (37.4)	<0.001	145 (10.6)*	277 (12.2)*	0.151
Apache-APS score – Median (IQR)	50 (42 - 64)*	54 (44 – 68)	0.079	37 (27 - 51)	38 (27 - 55)*	0.079
Age – Median (IQR)	66 (58 - 74)	68 (59 - 76)	0.219	67 (58 - 73)	66 (56 – 73)	0.105
BMI – Median (IQR)	27.7 (25.2 - 30.2)	25.7 (23.0 – 29.8)	0.001	26.0 (23.2 - 29.4)	26.2 (23.5 – 29.6)	0.262
Mechanical ventilation in first 24 hours-N (%)	181 (83.0)	82 (55.8)	<0.001	779 (57.0)	1,373 (60.7)	0.026
Mortality						
ICU-mortality - N (%	63 (28.9)*	28 (19.0)	0.031	83 (6.1)	160 (7.1)*	0.240
In hospital mortality – N (%)	85 (39.0)*	39 (26.5)	0.017	133 (9.7)	201 (8.9)*	0.405
Length of ICU stay in days – Median (IQR)	14.0 (8.0 – 27.0)	3.9 (1.5 – 6.8)	<0.001	0.9 (0.8 - 1.8)	0.9 (0.8 – 2.0)*	0.457
Nursing Activities Scores – Median (IQR)	55.2 (44.9 – 64.8)	50 (40.4 – 55.6)	<0.001	42.6 (38.5 – 46.9)	42.9 (29.5 – 51.0)	0.037

** Statistically significant difference compared to baseline characteristics of other hospitals in the NICE database*

We also compared the baseline characteristics of the included patients from the six hospitals in our study with the patients of all other hospitals in the NICE database (appendix 6) We found a difference in the distribution of patients between the groups. We found a significant lower number of medical patients (32.8% versus 51.8%, p<0.001), a higher number of elective surgery patients (49.6% versus 35.0%, p<0.001) and emergency surgical patients (17.5% versus 12.6%, p<0.001) in our study group compared to the patients in all hospitals. Also the Apache Acute Physiology Score (APS)-score and both the ICU and in-hospital mortality were higher in COVID-19 patients in our study group compared to COVID-19 patients in all other hospitals in the NICE database.

Results workload per nurse

We found a significant higher number of patients per nurse in the COVID-period compared to the non-COVID period (Median (IQR) 1.1 (0.8 – 1.5) versus 1.0 (0.7 – 1.3), p<0.001). Figure 1 shows the differences in number of patients per ICU nurse per month of the COVID and the non-COVID periods. The number of patients per ICU nurse was significant higher in the months April and May in the COVID-period compared to the non-COVID-period, with an increase of 30% in April 2020 compared to 2019 (Median (IQR) 1.3 (0.9 – 1.8) versus 1.0 (0.6 – 1.2), p<0.001) (Table 3). In April 2020 some ICU nurses took care for up to 5 patients per shift. This is more than double the maximum of two patients per nurse as stated by the Dutch Guidelines for Intensive Care.

We further found a higher Nursing Activities Score per ICU nurse in the COVID-period compared to the non-COVID-period (Median (IQR) 69.8 (50.1 – 90) versus 46.6 (26.4 – 70.7), p<0.001). Figure 2 shows the differences in Nursing Activities Score per ICU nurse per month of the COVID and the non-COVID periods. The mean Nursing Activities Score per ICU nurse was significant higher in each month of the COVID-period compared to the non-COVID-period with a peak of 98% increase in in April 2020 compared to 2019 (Median (IQR) 89.6 (63.8 – 117.2) versus 45.2 (27.5 – 68.7), p<0.001) (Table 3).

Table 3. Patients per nurse and NAS per nurse per month

Patients per nurse – Median (IQR)			NAS per nurse - Median (IQR)		
2020	2019	p-value	2020	2019	p-value
1.1 (0.9 – 1.4)	1.0 (0.6 – 1.3)	<0.001	70.1 (55.7 – 91.3)	45.6 (27.0 – 72.1)	<0.001
1.3 (0.9 – 1.8)	1.0 (0.6 – 1.2)	<0.001	89.6 (63.8 – 117.2)	45.2 (27.5 – 68.7)	<0.001
0.9 (0.7 – 1.2	1.0 (0.6 – 1.3)	0.291	64.9 (46.4 – 79.1)	45.9 (24.5 – 70.8)	<0.001
1.3 (0.9 – 1.3)	1.0 (0.6 – 1.2)	0.057	56.6 (37.7 – 74.3)	48.8 (26.7 – 71.5)	0.002

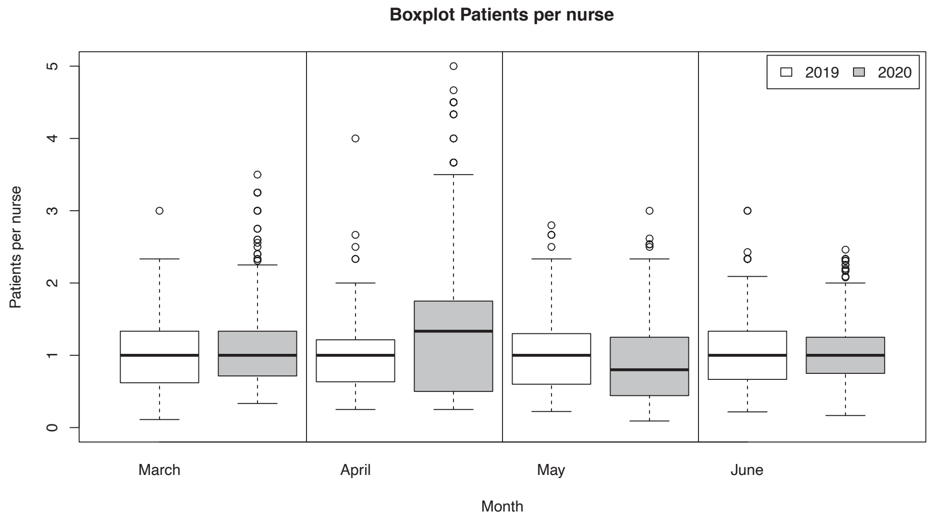

Figure 1. differences in numbers of patients per ICU nurse; comparing months in 2019 to same months in 2020

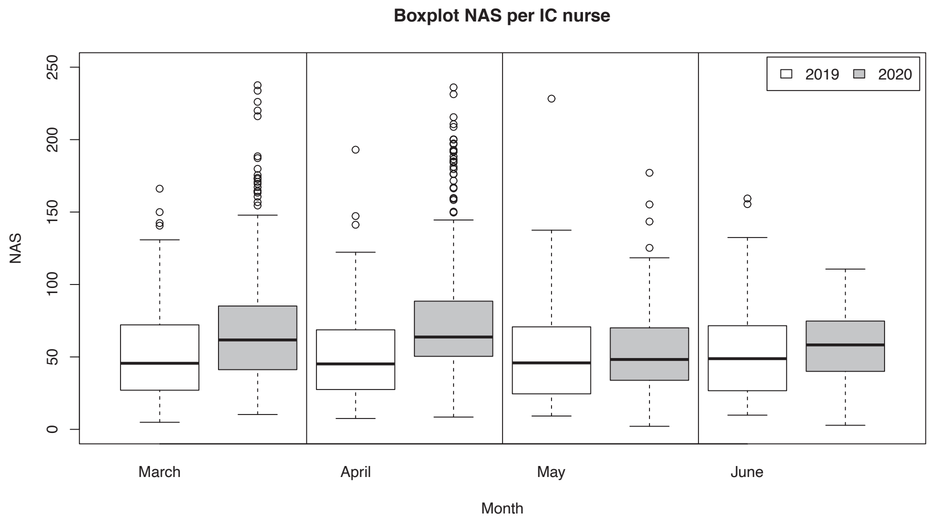

Figure 2. differences in NAS per ICU nurse comparing months in 2019 to same months in 2020

Results differences in nursing workload per patient category

Figure 3 shows the mean Nursing Activities Score per patient for the COVID-19 patients compared with the pneumonia patients and the non-COVID-19 patients compared to the non-pneumonia patients. We found a significant higher Nursing Activities Score in COVID-19 patients compared to the pneumonia patients (Median (IQR) 55.2 (44.9 – 64.8) vs 50 (40.4 – 55.6), p<0.001). The Nursing Activities Score of both groups of other ICU patients (non-COVID-19 patients during the pandemic and non-pneumonia patients in a recent non-COVID-period) was not significantly different (Median (IQR): 42.6 (38.5 – 46.9) vs 42.9 (29.5 – 51.0), p 0.037). We also compared the Nursing Activities Score per patient of the COVID-19 patients to the other ICU patients in the COVID period. We found a significant higher Nursing Activities Score in COVID-19 patients (Median (IQR) 55.2 (44.9 – 64.8) vs 42.6 (38.5 – 46.9), p<0.001).

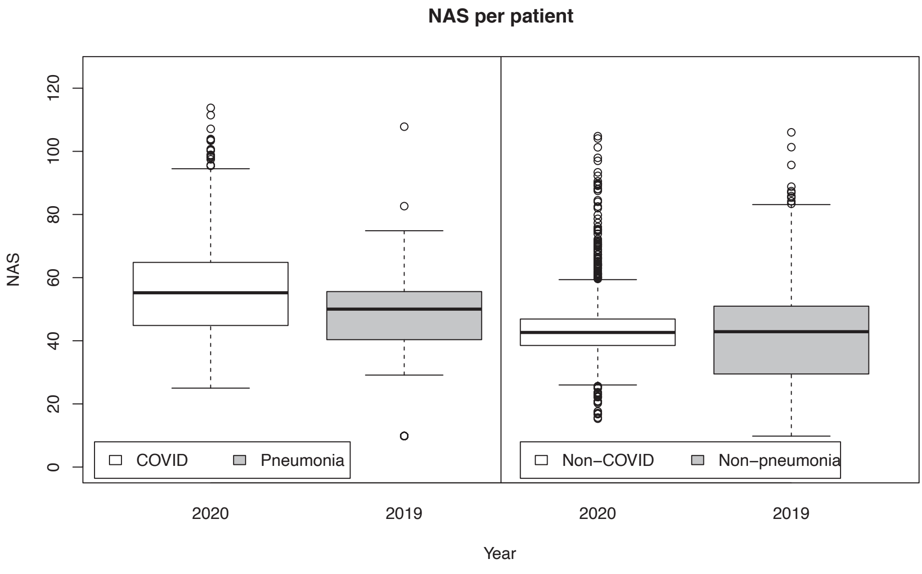

Figure 3. differences in NAS per patient of COVID-19 versus pneumonia patients and non-COVID versus non-pneumonia patients

Comparing the type of nursing interventions of the COVID-19 patients with the pneumonia patients, we found a significant difference in all the nursing interventions except for one intervention; care for the patients with a cardiopulmonary resuscitation after arrest in the past 24 hours (Table 2). Remarkable differences were visible in performing hygienic procedures, mobilization and positioning, support and care for relatives, respiratory care and specific intervention in and outside the ICU. In 18.7% of the COVID-19 patients the nurse needed > 4 hours for hygienic procedures (item 4c) where this was scored in 0.5% of the pneumonia patients admitted during the non-COVID period (p<0.001). Mobilization and positioning with 3 nurses or more (item 6c) was scored in 16.8% of the COVID-19 patients where this was scored in 3.6% of the pneumonia patients admitted during the non-COVID period (p<0.001). Support and care for relatives was scored more often in COVID-19 patients compared to pneumonia patients, both for item 7a - about 1 hour (67.8% versus 46.6%, p<0.001) as well as item 7b - >4 hours (10.7% versus 4.3%, p<0.001). The nursing interventions for respiratory care were in all three items (item 9 - respiratory support, item 10 - care of artificial airways, i.e. tracheostomy or tube, and item 11 - treatment for improving lung function) higher for COVID-19 ICU patients compared to the pneumonia patients. We saw a decrease in the number of patients with a specific intervention on the ICU (item 22) in COVID-19 patients compared to pneumonia patients (4.1% versus 29.5%, p<0.001) and an increase in patients with a specific intervention outside the ICU (item 23) (2.9% versus 1.6%, p<0.001).

Comparing the nursing interventions of the non-COVID patients with the non-pneumonia patients we saw remarkable differences in performing hygienic procedures (item 4), mobilization and positioning (item 6), support and care for relatives (item 7), respiratory care (item 9, 10) and interventions outside the ICU (item 23). We saw an increase in the performance of hygienic procedures in category a - less than two hours (79,2% versus 55,7%, p<0.001) and in the category b - more than two hours (15.1% versus 10.3%, p<0.001). In the category mobilization and positioning (item 6) we saw a decrease in the category b - performing procedures >2 hours per shift, any frequency (12.5% versus 26,5%, p<0.001) and an increase in the category a – performing procedures once per shift (62,9% versus 18.9%, p<0.001). The support and care for relatives for about one hour (item 7a) was higher for the non-COVID-19 ICU patients compared to the non-pneumonia ICU patients (67.7% versus 39.4%, p<0.001). The respiratory care was higher for the non-COVID ICU patients compared to the non-pneumonia patients with respect to the respiratory support (item 10) (78.5% versus 57.5 %, p<0.001) and the care of artificial airways i.e. tracheostomy or tube (item 11) (41,7% versus 30.6%, p<0.001). We saw an increase of interventions outside the ICU (item 23) for the non-COVID ICU patients compared to the non-pneumonia patients (8,9% versus 2,5%, p<0.001).

Table 2. Comparing NAS-interventions per patient category

	COVID-19 vs. pneumonia patients			Non-COVID vs. non-pneumonia ICU patients		
	COVID-19 ICU patients	pneumonia patients	Significance	non-COVID ICU patients	non-pneumonia ICU patients	Significance
Number of patients - N (%):	221 (13.9)	147 (6.1)	N/A	1,364 (86.1)	2,262 (93.9)	N/A
Number of shifts - N (%)	7,628 (44.0)	2,442(12.6)	N/A	9,694 (66.0)	16,990 (87.4)	N/A
NAS-intervention:	N (%)	N (%)	p-value	N (%)	N (%)	p-value
1. Monitoring and titration 1.a. Hourly vital signs	1,793 (23.5)	747 (30.6)	<0.001	4,796 (49.5)	5,031 (29.6)	<0.001
1b. Present at bedside or active ≥ 2 hours	4,455(58.4)	780 (31.9)	<0.001	4,261 (44.0)	4,855 (28.6)	<0.001
1c. Present at bedside and active ≥ 4 hours	1,331 (17.4)	355 (14.5)	<0.001	546 (5.6)	2,041 (12)	<0.001
2. Laboratory	5,761 (75.5)	1,493 (61.1)	<0.001	5,614 (57.9)	8,813 (51.9)	<0.001
3. Medication	5,551 (72.8)	1,638 (67.1)	<0.001	5,776 (59.6)	9,241 (54.4)	<0.001
4. Hygienic procedures 4. a. Performing hygiene procedures	3,729 (48.9)	1,611 (66.0)	<0.001	7,677 (79.2)	9,468 (55.7)	<0.001
4.b. Performing hygiene procedures > 2 hours/shift	2,406 (31.5)	218 (8.9)	<0.001	1,465 (15.1)	1,758 (10.3)	<0.001
4.c. Performing hygiene procedures > 4 hours/shift	1,424 (18.7)	12 (0.5)	<0.001	197 (2.0)	239 (1.4)	<0.001
5. Care of drains	50 (0.7)	740 (30.3)	<0.001	3,562 (36.7)	6,264 (36.9)	0.836
6. Mobilization and positioning 6.a. Performing procedures once/shift	3,327(43.6)	533 (21.8)	<0.001	6,097 (62.9)	3,219 (18.9)	<0.001
6.b. Performing procedures > once/shift or with two nurses	986 (12,9)	814 (33.3)	<0.001	1,214 (12.5)	4,494 (26.5)	<0.001
6.c. Performing mobilization procedures with three or more nurses	1,284 (16.8)	87 (3.6)	<0.001	173 (1.8)	253 (1.5)	0.065
7. Support and care of relatives and patient 7.a. Support and care of relatives or patient for about 1 hour/shift	4,624 (60.6)	1,138 (46.6)	<0.001	6,566 (67.7)	6,702 (39.4)	<0.001

Table 2. Continued

	COVID-19 vs pneumonia patients			Non-COVID vs. non-pneumonia ICU patients		
	COVID-19 ICU patients	**pneumonia patients**	**Significance**	**non-COVID ICU patients**	**non-pneumonia ICU patients**	**Significance**
7.b. Support and care of relatives or patient or about 3 hours /shift	810 (10.6)	104 (4.3)	<0.001	423 (4.4)	830 (4.9)	0.053
8. Administrative and managerial tasks 8.a. Performing routine tasks	6,065 (79.5)	1,802 (73.8)	<0.001	7,676 (79.2)	11,064 (65.1)	<0.001
8.b. Performing tasks for about 2 hours/shift	1,126 (14.8)	50 (2)	<0.001	1,792 (18.5)	551 (3.2)	<0.001
8.c. Performing tasks for about 4 hours/shift	301 (3.9)	4 (0.2)	<0.001	26 (0.3)	35 (0.2)	0.349
9. Respiratory support	7,270 (95.3)	1,758 (72)	<0.001	7,617 (78.6)	9,765 (57.5)	<0.001
10. Care of artificial airways	6,593 (86.4)	1,062 (43.5)	<0.001	4,036 (41.6)	5,192 (30.6)	<0.001
11. Treatment for improving lung function	4,470(58.6)	913 (37.4)	<0.001	2,242 (23.1)	3,801 (22.4)	0.149
12. Vasoactive medication	2,624 (34.4)	524 (21.5)	<0.001	2,885 (29.8)	4,350 (25.6)	<0.001
13. Intravenous replacement of large fluid loss	42 (0.6)	116 (4.8)	<0.001	327 (3.4)	1,127 (6.6)	<0.001
14. Left atrium monitoring	0 (0)	0 (0)	-	247 (2.6)	0 (0)	<0.001
15. Cardiopulmonary resuscitation after arrest	6 (0.1)	1 (0)	0.708	6 (0.1)	25 (0.1)	0.057
16. Hemofiltration and dialysis techniques	732 (9.6)	72 (2.9)	<0.001	463 (4.8)	874 (5.1)	0.191
17. Quantitative urine output measurements	7,229 (94.8)	1,764 (72.2)	<0.001	8,414 (86.8)	11,049 (65.0)	<0.001
18. Measurements of intracranial pressure	0 (0)	0 (0)	-	7 (0.1)	12 (0.1)	1
19. Treatment of complicated metabolic acidosis/alkalosis	0 (0)	0 (0)	-	0 (0)	0 (0)	-
20. Intravenous hyperalimentation	122 (1.6)	15 (0.6)	0.001	594 (6.1)	609 (3.6)	<0.001
21. Enteral feeding	6,893 (90.4)	1,346 (55.1)	<0.001	3,186 (32.9)	5,882 (34.6)	0.002
22. Specific interventions in the ICU	309 (4.1)	721 (29.5)	<0.001	484 (5.0)	4,029 (23.7)	<0.001
23. Specific interventions outside the ICU	220 (2.9)	38 (1.6)	<0.001	859 (8.9)	431 (2.5)	<0.001

DISCUSSION

Our results showed that the increasing demand for nursing care during the COVID-period was recognizable in both a higher number of patients per nurse and a higher mean Nursing Activities Score per nurse, compared to the same months in 2019. Although the number of new admissions on the ICU was lower, the Nursing Activities Score per nurse and the number of patients per nurse were higher. The increase of the Nursing Activities Score per nurse was also disproportionate higher compared to the increase of the number of patients per nurse. This can be explained by the higher Nursing Activities Score per patient but also by the long length of stay of COVID-19 ICU patients. The continuous influx of COVID-19 patients in combination with a long length of stay and therefore a delayed outflow contributed to a high pressure on ICU beds. This pressure on the ICU beds resulted in cancellation of many planned post-operative patients, e.g. cardiac surgery patients. This is visible in the baseline characteristics; the total number of admissions in the COVID-period was lower compared to the non-COVID period, with also a lower number of planned surgical patients.

The percentage of unplanned surgical patients compared to the total ICU population in the COVID-19 period was higher compared to the non-COVID period. Earlier research showed that the nursing workload of unplanned (medical and surgical) admissions is higher compared to planned (surgical) admissions[23]. During the COVID-19 period the percentage of patients with an unplanned admission, both medical and surgical, was increased. Comparing the baseline characteristics of the patients in our study with the baseline characteristics of all hospitals in the NICE database we must consider that there is a difference in the distribution of medical and elective or urgent surgical patients between the groups. However, the mean workload of the non-COVID patients during this period was not increased in our study, probably because the percentage of urgent admissions was still relatively low. Also the APS-score of the COVID-19 patients was higher in our study compared to the COVID-19 patients in all other hospitals. There is no unambiguous explanation for this difference. It is possible that the higher APS-score had an effect on the nursing workload, but the nursing workload is impacted by more aspects than the severity of illness[24].

Although the number of patients per nurse and the Nursing Activities Score per nurse were both increased during the COVID-period, this should be interpreted with caution. To expand the nursing staff also in the Netherlands non-ICU nursing staff was deployed on the ICU during the COVID-19 period. The ICU nurses were supported in the daily care for the ICU patients by e.g., general nurses or anesthesia nurses. They supported in basic care, but also in special procedures such as turning the patient into prone position and back or daily hygienic procedures. It is important to mention that the number of non-ICU nurses has not been included in the data in the NICE capacity registry and therefore not in our analysis because we did not have a data entry field for this kind of nurse. This should be considered when interpreting the results of the Nursing Activities Score per ICU nurse, especially in the month April 2020. The NAS was filled in by the ICU nurse but the time the non-ICU nurse spend at bedside is not mentioned in all the items of the NAS. If the non-ICU nurse support in the mobilization procedures it is incorporated in item 6b because the ICU nurse is performing the procedure with 2 nurses, but the dressing procedures of the non-ICU nurse are not incorporated. This should also be considered interpreting the number of patients per nurse. During the COVID-period the nurse took care for even up to 5 patients per nurse, but the nurse might be supported by a non-ICU nurse. Despite this support, the ICU nurse held the overall responsibility for the care of the patients. The supervision of a general or anesthesia nurse was a new aspect for an ICU nurse. This could mean that the ICU nurses were taking care for three or even more critically ill patients and were supervising a general or anesthesia nurse in the process of daily care. Although the support for the ICU nurses enlightened their task, the new coordinating role added to their responsibilities and therefore to their workload.

Our second aim was to describe differences in nursing workload of COVID-19 patients versus pneumonia patients and differences in nursing workload of non-COVID and non-pneumonia patients admitted to the ICU. The results of our study clearly showed that COVID-19 patients cause a significantly higher ICU nursing workload compared to pneumonia patients in the non-COVID period. This confirms our expectation that the care for a COVID-19 patient requires more time from an ICU nurse than the care for a regular pneumonia patient. This higher workload was mainly due to nursing interventions like monitoring and titration with bedside observation, respiratory care, mobilization, hygienic procedures and taking care for the patient and his or her relatives. The increase in time for monitoring and titration with bedside observations is possibly related to the hygiene procedures. It is conceivable that the increase of the time that ICU nurses stayed at the bedside for observation, monitoring and titration was influenced by the time the nurses needed for complex dressing procedures for personal protection[7]. The ICU nurses perceived the complex dressing procedures as an aggravating factor in the workload and avoided extra dressing procedures by staying at the bedside. This could also be responsible for the increase in time needed for hygienic procedures. It should be noted that a substantial part of the COVID-19 patients is categorized in category 4a, although isolation is part of the definition of 4b. This can be explained by the use of cohort-isolation for COVID-patients in several hospitals. After entering the cohort-unit with the personal protection equipment the nurse could take care for the patients with the standard hygienic procedures. Working a few hours on the cohort-unit without leaving the unit and without being able to take a break and wearing the personal protection equipment all the time however was still an aggravating factor in the nursing workload[25]. Due to the special procedures in the COVID-period there was also an increase in the time needed for the standard hygienic procedures in non-COVID patients.

The workload of the respiratory care was higher, which is in line with the higher number of ventilated COVID-19 ICU patients. The increase of workload in the category 'Performing mobilization procedures with three or more nurses with any frequency' can be explained by the frequency of turning patients into prone- or supine position as this became standard in the treatment of COVID-19 ICU patients[8,26,27]. We also found a difference in workload in the support and care of the patient and his or her relatives. This might have been influenced by both the high ICU mortality in COVID-19 patients (28.9%) as well as by visiting limitations during the COVID-pandemic. As a result of those limitations nurses worked with video conferencing with the family[28]. This video conferencing required a subsequent need for extra nursing time. This aspect can also explain the increase in needed time for support and care of the patient and his or her relatives for the non-COVID-patients because they were confronted with the same visiting limitations.

Comparing the workload of COVID-19 patients of this study with results of other studies we found a higher Nursing Activities Score for COVID-19 patients in the study in Belgium (mean 92.0). A possible explanation could be the length of the shift, which is 12 hours instead of the 8-hours shift in our study. Also in Italy the Nursing Activities Score for COVID-19 patients was slightly higher than in our study (mean 84.0), which represented the nursing activities in 24 hours[7]. However, in both studies the increase of the Nursing Activities Score of COVID-19 patients compared to other ICU patients was 28 – 33%, which is comparable with the 30% increase we found in our study.

Due to the combination of a higher workload per patient, the increase of the proportion of those patients compared to the total ICU patient population due to the long ICU length of stay, there was an increasing demand for the need for nursing care per ICU patient. This can also explain changes in care for the non-COVID patients as e.g the mobilization procedures; we saw a significant increase in category a – performing procedures once per shift with a decrease in category b - Performing procedures more frequently than once/ shift or with two nurses, any frequency. The high demand of the care for COVID-patients may have put pressure on the available nursing time for the other non-COVID patients, visible in the decrease of frequency of mobilization procedures.

Strengths and limitations

A strength of this study is the large amount of Nursing Activities Score from patients in both the COVID-period and the non-COVID period. The number of participating hospitals was limited, but we included data of all shifts and patients in both periods. The included ICUs were representative of Dutch ICUs regarding hospital type (teaching and non-teaching hospitals) and geographical location. The included patients were representative compared to the patients of all the other ICUs in the NICE-database, except for the APS-score and the higher mortality in COVID-patients. The mortality in our study group was however comparable with the mortality in anotherCOVID-19 study about COVID in the Netherlands[1]. Another strength is that we were able to analyze the raw which enabled insight in which aspects the Nursing Activities Score differed between the groups.

Within this research we did not analyze every aspect of the nursing workload. As COVID-19 is a new disease it is possible that the workload in the beginning of the pandemic period was higher due to the unfamiliarity with these kinds of patients. It is possible that this unfamiliarity and lack of knowledge about the clinical course of COVID-19 had an impact on interventions such as being bedside. Analysis of the workload in next COVID-19 waves can help us in this respect.

Another limitation is that we do not have data on non-ICU (general or anesthesia) nursing staff in our capacity module. The NAS was scored by the ICU nurse, but the support of a non-ICU nurse can influence (lower) the time needed for the nursing interventions. We do not know the exact impact of the support by other staff on the workload of the ICU nurses. But, however helpful the support of non-ICU nurses in daily care has been, this support also added a dimension of coordination and supervision to the role of the ICU nurse Unfortunately we were not able to analyze the impact of this change of the nursing role of the ICU nurse on the nursing workload. However, we have learned from this period that participation of other nurses in the daily care on an ICU is possible. They can support the ICU nurse in e.g., mobilization of the patient, hygienic procedures or assistance in patient and family care. Further research should focus on opportunities and restrictions on the changing and coordinating role of the ICU nurse.

CONCLUSIONS

This study showed a higher nursing workload during the COVID-19 period, expressed in both a higher number of patients per nurse and a higher nursing workload per nurse. The higher workload per nurse can be explained by the higher workload of COVID-19 patients compared to pneumonia patients, an increase of the proportion of COVID-19 patients on the total patient population on the ICU and their long length of stay. This higher workload of COVID-19 was mainly due to nursing interventions as being bedside, respiratory care, mobilization, and positioning e.g turning into prone- or back position, hygienic procedures and taking care for the patient and his or her relatives. During the COVID-19 period non-ICU nurses supported the ICU nurses in basic care for ICU patients. However, the opportunities and restrictions of continuous deployment of other nurses in daily care to reduce the ICU nursing workload needs further research. This remains a relevant issue, also after the COVID-19 pandemic, given the shortages of ICU nurses. Further research is also needed to analyze the impact of the high workload on patient outcome.

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CHAPTER 7

General Discussion

7.1 INTRODUCTION

In this thesis on ICU nursing workload, we addressed three research questions.

This chapter first describes and discusses the main findings per research question after which the implications of those findings are discussed.

1. **Which scoring systems to measure the amount of ICU nursing workload do exist and can they be applied to measure workload in the Dutch ICU setting?**

Chapter 2, a systematic literature review, shows a large attention in the literature to nursing workload in Intensive Care over the last decades. We identified 34 different scoring systems of which 27 described a translation of workload into the needed nursing time, and of which the first scoring system dates from 1974. Only a minor part of the scoring systems was validated with time measurements (26%). Most scoring systems were evaluated by comparing them with another system (59%). The Nursing Activities Score (NAS) performed best, it is developed by nurses for measuring nursing workload and validated with time measurements. The review also shows that the most common way to translate the workload score into nursing time needed was by categorizing the results into a patient per nurse ratio. Validation of this translation was mostly evaluated by comparing the results with other systems or with the actual planning, not with objective time measurements. We concluded that due to this poor methodology the translation from a score into a patient per nurse ratio weakens the value of nursing workload scoring systems.

Chapter 3 shows the results of a validation study of the NAS with time and motion techniques in the Dutch ICU setting. This study showed significant differences between the literature based converted NAS-times and the observed times for all items. For most of the nursing activities the converted NAS overestimated the observed time (86%). This chapter shows that after more than 15 years of use the NAS needs a revision with further validation of the translation of assigned points into the nursing time needed.

2. **To what extent are the objective nursing workload and the perceived nursing workload correlated and are they associated with the satisfaction of nurses with their workload?**

Chapter 4 showed that, in contrast to what we expected, workload is perceived differently by nurses than measured with NAS. We found that the severity of illness of the patient, expressed by the APACHE-IV Acute Physiology Score, was significantly associated with the perceived nursing workload. Being a student nurse was also associated with a significant increase of the perceived nursing workload. In chapter 5 it became clear that both the objective and perceived nursing workload are associated with the satisfaction of nurses regarding their workload. This study showed that ICU nurses are most satisfied with their workload when the NAS is around 80 points in total per nurse per shift. Furthermore, a high perceived nursing workload (especially the mental and physical part) as measured with the NASA-TLX, was significant associated with how satisfied ICU nurses were with the nursing workload. This study also showed that nurses are not satisfied with both a very high objective or perceived nursing workload or a low objective or perceived nursing workload. Thus, this study showed us that there is an optimum point in nursing workload regarding the satisfaction of ICU nurses with their workload.

3. What is the impact of COVID-19 on the ICU nursing workload?
While most of the data used for this thesis were collected before March 2020, we were also able to perform one study on data of six hospitals during the COVID-19 pandemic. The analyses described in chapter 6 have learned us that the COVID-19 pandemic had a significant impact on the ICU nursing workload. Firstly, this was caused by a significant higher NAS of the COVID-19 patients compared to the other ICU patients. Secondly, during the COVID-19 period the number of patients per nurse was higher compared to the same period in 2019 without COVID-19. This was caused by a high number of admissions of COVID-19 patients in combination with a long length of stay on the ICU. The combination of a higher NAS per patient and an increase of the number of patients per nurse led to a significant higher NAS per nurse during the COVID-19 period.

7.2 DISCUSSION OF MAIN FINDINGS

Our research showed that nursing workload and the substantiation of nursing staff requirements on the ICU has a long history of interest. Although the evidence for the substantiation of nursing staff requirements with workload scoring systems is limited, new workload systems have been developed over the years. Those findings are confirmed in a recent review of literature related to nurse staffing methods and tools[1]. This research also concluded that it is important to focus on learning more about the use of existing tools rather than developing new tools. Because of the rapid developments in critical care, it may be necessary to incorporate new treatment modalities and new ways of nursing care. It is therefore important to focus on further validation or calibration of existing systems.

Our research showed that the Nursing Activities Score (NAS) performed best for measuring nursing workload and quantification of nursing staff. Earlier validation with time measurements showed that NAS was able to explain 81% of the nursing activities[2]. The interrater reliability of the NAS however showed variable results (Kappa 0.02 – 0.69) with low results for the categories with an estimation of the amount of time spent by the nurse in this activity (e.g. present at bedside and observation for two hours or more)[3,4]. An evaluation of the face validity and content validity also showed that the estimation of time could lead to either an overestimation or underestimation of the needed nursing time[5]. In our study with time and motion techniques we found an overestimation of the workload as measured with NAS. A possible explanation could be the differences in validation techniques. Where the NAS was originally developed with the work-sampling approach obtained by multi moment recordings, we used a time-and-motion technique in our study[2]. Due to those findings, it is important to focus on further validation and if needed recalibration of the NAS, because of the increasing use of nursing workload systems in the substantiation of nursing staff requirements[1].

Our research also showed that it is important to focus not only on the objective nursing workload as measured with those tools but also take the perceived workload into consideration. However, although a first analysis of the crude association between the NAS and the NASA-TLX showed a significant association, the association did not remain significant after adjustment for confounders. Clearly, this aspect of workload needs further investigation. Nevertheless, it appears that the severity of patient illness and the graduation level of the nurse are significant associated with the perceived workload. Planning nursing staff should therefore be based on the Nursing Activities Score, the patient illness and graduation level of the nurse.

Another important perspective we added in our research is the satisfaction of the nurses with their workload. Both in the literature and in nursing practice the terms 'high workload' or 'low workload' are used. But until now we could not find any description on how these qualifications translate into the satisfaction of the nurses with their work done. With our research we connected the measured objective and perceived workload with the satisfaction of nurses with their workload. Furthermore, from this point of view it is important to focus on an optimum NAS per nurse. The NAS is originally developed and validated with the suggestion that the effort of one nurse corresponds with 100 NAS points[2]. This was however never validated as an optimum NAS per nurse. Different studies from all over the world showed that the mean NAS per nurse per shift can differ from 44.5 in Spain up to 101.8 in Norway[6-9]. Our study showed that nurses are most satisfied about the workload when the NAS is around 80 NAS points per nurse. Satisfaction of the nurse is however only a parameter from the nurses' point of view. Earlier research showed for example that a NAS per nurse >61 was associated with an increased mortality risk of the patient[10]. When using an optimum NAS per nurse for planning of nursing staff, it is necessary to develop an evidence-based recommendation on broader knowledge than only the satisfaction of nurses but also take outcome of the patient and health care budgets into account. Further research should therefore focus on the association between an optimum NAS per nurse and quality of patient care.

7.3 IMPLICATIONS OF THE FINDINGS

The findings of our research are important for planning ICU nursing staff. By using the NAS, it is possible to weigh the combined workload that the patients compose in NAS-points against the available number of nurses per shift in NAS-points. This enables the ICU management to substantiate the workload per nurse on an ICU.

Until now NAS has shown to be the best available and most used instrument for measuring nursing workload and the translation to the need for nursing staff. Considerations about the reliability of the items in NAS with an estimation of time can be overcome by recalibration and adaptation of NAS to the current practice to improve the performance. Therefore, we still recommend the use of (an improved) NAS for measuring nursing workload and planning of nursing staff.

The use of NAS per nurse leads to a more objective weighed comparison of both the nursing capacity and the average amount of work required for patient care. The findings of our research are therefore important for the daily practice of patient allocation to the nurses on the ICU at the start of a shift. Looking at the current practice of planning nursing staff, the focus is usually on the number of patients per nurse. The Dutch Guideline for Intensive Care mentions a maximum number of 1.5 to 2 patients per nurse depending on day shift, evening shift, or night shift[11]. However, in this guideline the workload required for a patient is not considered when assigning the number of patients per nurse. Previous research showed that it is more important to focus on the workload per nurse than on the number of patients per nurse[10]. It is therefore recommended to base the patient allocation not only on the number of patients but also on the total NAS per nurse. Subsequently, it can lead to a deviation from the maximum number of patients per nurse as mentioned in the guidelines in case of a very low nursing workload. Based on a very high nursing workload the ICU-management can substantiate decisions regarding reducing bed capacity or extra nursing staff.

Nursing workload systems are not only important for the daily scheduling of ICU nurses but also for the strategic planning over the year. This strategic planning is also based on the Dutch Guideline for Intensive Care, mentioning a nursing formation requirement between 3.5 and 4.2 FTE per bed. For this strategic planning of nursing staff, it is also important to substantiate the formation based on the workload per nurse, for which the NAS per nurse is a good indicator. In the current practice the number of beds and the number of nurses is generally compared among ICUs but based on the findings in our research this should be accompanied with the NAS per nurse. It is important to realize that non-patient related tasks such as resuscitation of patients outside the ICU, coordination tasks or bedside education are not included in the NAS. How and by whom these tasks are performed is different for every hospital and should be considered when using the NAS for strategic planning of the number of full-time equivalent nurses per ICU bed.

By assigning patients to the nurses during a shift, it is important to focus on more than only the objective workload as measured with NAS. The perceived workload is influenced by other factors that are worth to consider. Although the NAS should be an important tool for the patient allocation there should also be a focus on the perceived workload, for instance on both the severity of illness of the patient and the presence of student nurses during that shift. By allocating a patient to a student nurse it is important to focus on the patient workload for both the student and the accompanying graduate ICU nurse.

Finally, our research has shown that there is an optimum point in the workload from the point of view of nursing satisfaction about the workload. This should be considered when adapting the NAS in the current practice of daily and strategic planning. Insight in nurses' satisfaction with workload can support decision making regarding planning of nursing staff. In case of a too high or too low nursing workload, the use of NAS enables the ICU-management to adapt to the circumstances. When the workload is too high, additional staff can be deployed in the next shift or, if not available, the number of available beds can be reduced. A low nursing workload gives room for additional tasks or to open more operational beds. Adaptation of the planning to the circumstances also contributes to the retention of highly educated ICU nurse, which is important in a situation of scarcity.

The COVID-19 period has shown that in emergency situations with an extreme demand on ICU beds and nursing capacity there is a limit to this flexibility. On the other hand, the COVID-pandemic has also opened doors to new opportunities like the deployment of non-ICU trained staff on the ICU. However, the impact of other tasks like coordination or bedside teaching and the impact of the deployment of other staff on the nursing workload of ICU nurses is still unknown and are not part of the current workload scoring systems.

7.4 STRENGTH AND WEAKNESSES

A strength of our work is that we performed a thorough evaluation of the available nursing workload systems. Based on the results of this evaluation we concluded that the NAS is a well performing and the most used system. Therefore, we used the NAS in our consecutive studies. A clear advantage of the use of NAS for our research was that NAS has been used in many international and multicenter studies. This enabled comparing the findings of our research with findings in other studies.

Another strength is the use of a time-and-motion technique for the validation study. The time-and-motion technique is considered as the best measure for time measurements[12]. The NAS is originally developed with the work-sampling approach obtained by multi moment recordings, whereas we used in our study the time-and-motion technique for validation[2]. The time-and-motion technique provides a more accurate estimate which makes the validation reliable.

A strength is also the use of different perspectives on nursing workload: the objective workload as measured by a validated tool like NAS, the perceived nursing workload as measured by a validated tool such as the NASA-TLX, and finally the association of both perspectives with the satisfaction of nurses with this workload.

We realize that conducting a study on nursing workload in which we ask the ICU nurse to complete additional questionnaires is precarious from a workload perspective. However, with the use of the existing data registry with data on workload and patient factors we were able to reduce the extra work to only the NASA-TLX questionnaire and the satisfaction rate.

The use of this existing registry also made it possible to conduct research on workload during the COVID-pandemic on a relatively short notice. The results of our study on nursing workload during the COVID-pandemic places this thesis about workload in the current timeline. It also shows that with an existing nursing workload registry it is possible to respond quickly in current or future dynamics affecting nursing workload.

Nevertheless, like every research there are also some weaknesses to take into consideration. Comparing the number of ICUs included in our study with other studies using data from the NICE registry the number of ICUs is relatively low. Although the eight included ICUs were diverse in size and representative to Dutch ICUs regarding hospital type and geographical location, the number of included ICUs is still low. In addition, in the COVID study data of six ICUs were included. The other ICUs were not able to collect data due to the impact of the COVID-pandemic on those ICUs. The impact of the high workload on the registration shows the limitation of the current way of data collection on nursing workload in some ICUs. Especially when the workload is high the registration is too time consuming to be performed manually and of course subordinate to patient care. This shows the importance of automated extraction of data on nursing workload from the Electronic Patient Record. Automated extraction reduces the workload of the registration itself. This automated extraction can also increase the quality of the data, which is important given that some studies showed various and sometimes disappointing results of the interrater reliability of the NAS. However, NAS also contains items with an estimated time the nurse needed for that specific intervention, e.g. hours of bedside activities (hourly vital signs; present and active for 2 hours or more; present and active for 4 hours or more). The registration of the nursing workload should therefore always to a small extent be supplemented and validated or approved by the ICU nurse.

Finally, our research showed that it is important to focus on both the objective nursing workload and the perceived nursing workload. However, the existing registry does not consist of items to measure the perceived nursing workload like the NASA-TLX. Keeping the workload of registration of extra items in mind, it should be considered to measure the perceived workload and the satisfaction of nurses about the workload not on daily basis, but on a regular basis, for instance, by one week of data collection once or twice a year or during extreme situations like the COVID-pandemic.

7.5 RECOMMENDATIONS AND NEW RESEARCH QUESTIONS

It is important to focus on a continuous validation and recalibration of the NAS. Our research showed that the NAS is currently the best instrument for measuring nursing workload, but the findings of our validation also showed that a revision of the estimated time per intervention is necessary. Further validation of the NAS with time-and-motion techniques will give a more accurate insight in the objective nursing workload. This validation can also lead to broader adaptation of the NAS. We already made a first effort in this direction with a recalibrated version of existing scoring systems; the Nurse Operation Workload (NOW). The NOW includes a selection of items from NAS and TISS nursing activities and a recalibration of time per item[13]. Beside the validation of the NAS points per nurse it is also important to quantify and validate the necessary nursing time needed for indirect patient care or additional nursing tasks like resuscitation outside the ICU or coordinating tasks during a shift. It is worth considering the deployment of non-

ICU nurses not only in emergency situations like the COVID-19 pandemic, but also to cope with the daily scarcity of operational ICU-beds. Further research should include the impact of the supervising role of ICU nurses in workload instruments.

We also recommend a further analysis of the optimal NAS per nurse. Whereas the developers of the NAS defined a total Nursing Activities Score of 100 points equal to the time spend by one Full Time Equivalent (FTE) nurse per shift, our research shows an optimum not exceeding 80 NAS points per nurse. The Dutch Guidelines for Intensive Care mention a maximum number of patients per nurse, but there is no strong evidence available for this number of patients per nurse. In case of a revision of the Dutch Guidelines of Intensive Care we advise a focus on the workload per nurse instead of the number of patients per nurse.

When using the NAS to measure nursing workload and planning of nursing staff it is also important to compare the situation of individual hospitals with other hospitals. This gives ICU management feedback on several important factors such as nursing workload, the number of nurses per patient, the severity of patient illness, bed occupancy and patient outcome to keep on track in continuous quality assessment. Start working with the workload per nurse by using NAS also gives a good opportunity for national research and further validation of the optimal NAS per nurse ratio and development of a recalibrated and adapted scoring system. This improves the application of NAS in daily practice of the nurse and in ICU-management.

Participation in the NICE capacity registry is an accessible way to benchmark data about nursing workload. In this context it is important to make the registration of the NAS as easy and little time consuming as possible. Automated collection and extraction of (a main part of) NAS from the Electronic Patient Record is the most valid and optimal way to reduce the administrative burden for nurses. The incorporation of both medical information and nursing information like NAS can be used for the development of a management tool like a dashboard. This management tool can help ICU-management to identify opportunities for improvement of quality of patient care and organization of care like ICU length of stay or efficient nursing staffing. Following the major role that NICE has played in supplying data for national benchmarks, they may also be able to play a stimulating role to the vendors of Electronic Health Records (EHR) regarding automatic data collection and extraction and development of a dashboard. Their influence however is limited as hospitals are the clients of those EHR vendors and not the NICE foundation.

Finally, further research on the impact of deployment of other non-certified ICU nurses in the ICU on nursing workload is necessary. The COVID-pandemic has learned that this is possible, but the impact on the objective and perceived nursing workload has not been studied yet. Further research should also focus on the potential new role of certified ICU nurses supervising other nurses working in the ICU.

7.6 CONCLUSION

Measuring nursing workload is important for daily and strategic planning. Among the existing nursing workload scoring systems we found NAS most reliable although we also showed that further and continuous validation and recalibration is needed as nursing care develops over time. We demonstrated that besides the use of the NAS for measuring nursing workload and the planning of nursing staff, patient factors like severity of illness and nursing factors like being a student nurse also affect the perceived nursing workload. Both a too high and too low workload will lead to dissatisfaction of the nurse regarding workload. During the COVID-pandemic ICUs were confronted with a high workload. Our research has shown that this was caused by a combination of a higher NAS per patient and an increase of number of patients per nurse. However, the COVID-period also showed that deployment of other nurses on the ICU is possible. It is important to define the optimal nursing workload per nurse that takes multiple dimensions of good employership and quality of care into account.

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SUMMARY

Critical ill patients in the Intensive Care Unit (ICU) require a high amount of care. Due to their critical illness, they are in need for monitoring and use of modalities for organ support, and therefore specialized nursing care. Due this complex and specific care the nursing staff consists mainly of certified ICU nurses, and they can take care for only a limited number of patients per shift. The high need for specialized nursing care is the main reason that the costs for nursing staff are the largest part of the ICU budget. In a situation of shortage of certified ICU nurses in most West European countries it is important to deploy the nursing staff as efficiently as possible. Due to budget constraints overstaffing must be avoided, but understaffing should also be avoided because of the increased risk of burn-out or bore-out. It is therefore important to quantify the amount of nursing work, i.e., the nursing workload and the need for nursing staff.

In this thesis we focus on two aspects of nursing workload; the amount of time needed for patient care (the objective nursing workload) and the impact of this patient care on the nurse (the subjective or perceived nursing workload). Furthermore, we describe the importance of nursing workload for the planning of nursing staff and the impact of COVID on both the workload and planning of nursing staff.

Chapter 2 describes the results of a systematic review on available workload scoring systems and evaluation of the content validity, reliability and validity of those systems. We searched the bibliographic databases MEDLINE, Embase and Cinahl on English, Dutch and German articles about systems measuring nursing workload in Intensive Care that includes a translation into the amount of nursing time needed. From 71 included articles we identified 34 different scoring systems of which 27 systems were included for further analysis as they described a translation of workload into nursing time needed. We identified the Nursing Activities Score (NAS) as the best performing model although there is room for improvement. The NAS is validated with a work sampling method obtained by Multi Moment Recordings and explains 81% of the time spent by nurses. Although originally developed to measure the nursing workload per day it has also been validated for a use per shift. The results of the interrater and intra-rater reliability vary from low to good, with low results for the items that estimate time by nurses and good results for the other items. Due to the important role of workload scoring systems, we concluded that it is necessary to improve the reliability and accuracy of the NAS for a translation into the needed nursing time.

Chapter 3 describes the results of a validation study with the most used ICU workload scoring system to find out if the NAS is in need for a revision after more than fifteen years

since its launch. Different nurses in different hospitals were followed by observers. Time-and-motion techniques were used to measure the nursing time spend on a patient for all nursing activities during day-, evening and night shifts. The original NAS-points were converted to the predefined time and compared with the observed time. The correlation found between the total converted NAS time and the total observed time per patient was 59%. This indicates that the NAS only explains 59% of the nursing time. The converted NAS time per patient was higher compared with the observed time, which indicates that the NAS overestimated the total needed nursing time. For a more effective nursing capacity planning it is therefore advised to gain better insight into the true nursing workload and revise the time weights to each NAS-item.

Chapter 4 describes the results of a study to assess the association between the objective nursing workload and the perceived nursing workload and to identify other factors associated with the perceived nursing workload. During 228 shifts in eight different hospitals the objective nursing workload was measured with the NAS and the perceived nursing workload with the NASA-TLX. Clinical researchers identified other factors based on literature and data available in the Dutch national quality registry for Intensive Care and categorized those factors in three categories: patient factors (severity of illness, comorbidities, age, BMI and planned or unplanned admission), nursing factors (educational level) and contextual factors (number of patients per nurse, type of shift and day of admission or discharge). This study showed that workload is perceived differently by nurses compared to the objective nursing workload as measured with NAS; the NAS was not significantly associated with the perceived nursing workload. However, both the severity of illness of the patient and being a student nurse were factors that increase the perceived nursing workload. Planning of nursing staff should therefore be based on the NAS, the severity of patient illness and the graduation level of the nurse.

Chapter 5 focuses on the association of the objective and perceived nursing workload with the workload satisfaction of ICU nurses. The hypothesis in this study was that both a too low or too high workload could lead to dissatisfaction of the nurse about the nursing workload. We measured both the objective nursing workload with NAS and the perceived nursing workload with NASA-TLX in 226 different shifts in eight different hospitals and asked the nurse at the end of each shift to rate their satisfaction about their workload on a scale from 0 (not satisfied at all) till 10 (very satisfied). This study showed that a NAS-score around 80 points per nurse leads to a significant higher chance of a nurse being satisfied. Furthermore, a high perceived nursing workload with NASA-TLX leads to a significant higher chance of a nurse being satisfied. A further increase of both the objective and perceived nursing workload to a very high or a low workload diminish these positive associations. This should be considered in planning the nursing staff; both a too low and a too high nursing workload should be avoided to keep the job position of an ICU nurse attractive.

Chapter 6 focuses on the nursing workload during the COVID-19 pandemic. Data of 3,994 patients and 36,827 different shifts in 6 different hospitals from the nursing capacity module of the National Intensive Care Evaluation (NICE) registry were used to describe differences in the planning of nursing staff on the ICU in the COVID-period compared to a recent non-COVID-period. Patient data and NAS-data from this registry were used to describe differences in nursing workload in COVID-19 patients, non-COVID pneumonia patients and other patients in Intensive Care. The results of this study showed both a significant higher number of patients per nurse and a significant higher NAS per nurse in the COVID-period compared to the non-COVID period. The higher workload per nurse could be explained by the higher workload of COVID-19 patients, the increase of the proportion of COVID-19 patients and their long length of stay on the ICU. The significant higher NAS of COVID-19 patients compared to non-COVID patients with pneumonia or other non-COVID patients was mainly caused by more intense hygienic procedures, mobilization and positioning, support and care for relatives and respiratory care. This study also showed the opportunities of deployment of other nurses in daily care on the ICU nursing workload. Further research should focus on both the possibilities and the impact of deployment of other staff on the nursing workload.

The NAS is currently the most used system for measuring nursing workload and planning of nursing staff. However, the NAS is somewhat outdated and overestimates the nursing workload. For this reason, we recommend further recalibration of the NAS. Further research should also focus on finding the optimal nursing workload per nurse. It is therefore important to collect data in a capacity registry of a national database to benchmark data about nursing workload and capacity between different ICUs. Those data could also be used for further validation of an optimum nursing workload and the development of national guidelines about nursing capacity and workload per nurse.

SAMENVATTING (NEDERLANDS)

Kritiek zieke patiënten op de Intensive Care (ICU) hebben veel zorg nodig. Vanwege hun kritieke ziekte hebben ze behoefte aan monitoring en gebruik van apparatuur voor orgaanondersteuning, en hiermee dus gespecialiseerde verpleegkundige zorg. Door deze complexe en specifieke zorg bestaat het verpleegkundig personeel voornamelijk uit gediplomeerde IC-verpleegkundigen en kunnen zij slechts een beperkt aantal patiënten per dienst verzorgen. De grote behoefte aan gespecialiseerde verpleegkundige zorg is de voornaamste reden dat de kosten voor verpleegkundig personeel het grootste deel van het IC-budget uitmaken. In een bestaande situatie van een tekort aan gediplomeerde IC-verpleegkundigen in de meeste West-Europese landen is het van belang het verpleegkundig personeel zo efficiënt mogelijk in te zetten. Overbezetting moet worden vermeden vanuit het oogpunt van budgetbeperkingen, maar onderbezetting ook vanwege het verhoogde risico op burn-out of bore-out. Het is daarom belangrijk om de hoeveelheid verpleegkundig werk te kwantificeren; d.w.z. de verpleegkundige werkdruk en hiermee de behoefte aan verpleegkundig personeel.

In dit proefschrift richten we ons op twee aspecten van de werkdruk van de verpleegkundige; de hoeveelheid tijd die nodig is voor patiëntenzorg (de objectieve verpleegkundige belasting) en de impact van deze patiëntenzorg op de verpleegkundige (de subjectieve of ervaren verpleegkundige belasting). Verder beschrijven we het belang van de verpleegkundige werkdruk voor de planning van het verpleegkundig personeel en de impact van COVID op zowel de werkdruk als de planning van verpleegkundig personeel.

Hoofdstuk 2 beschrijft de resultaten van een systematische review van de literatuur naar beschikbare werkbelastingscoringssystemen en evaluatie van de inhoudsvaliditeit, betrouwbaarheid en validiteit van die systemen. De bibliografische databases MEDLINE, Embase en Cinahl zijn doorgezocht op Engelse, Nederlandse en Duitse artikelen over systemen die de verpleegkundige werkdruk op de Intensive Care meten, inclusief een vertaling naar de hoeveelheid benodigde verpleegkundige tijd. Uit 71 geïncludeerde artikelen identificeerden we 34 verschillende scoresystemen, waarvan 27 systemen geïncludeerd zijn voor verdere analyse, omdat ze een vertaling van werklast in benodigde verpleegtijd beschreven. We hebben de Nursing Activities Score (NAS) geïdentificeerd als het best presterende model, hoewel er ruimte is voor verbetering. De NAS is gevalideerd met Multi Moment Opnames en verklaart 81% van de tijd die verpleegkundigen besteden. Hoewel oorspronkelijk ontwikkeld om de verpleegkundige werkbelasting per dag te meten, is het ook gevalideerd voor een gebruik per dienst. De resultaten van de inter- en de intra beoordelaars betrouwbaarheid variëren van laag tot goed, met lage resultaten voor de items waarvoor de verpleegkundigen een tijd inschatten en goede resultaten voor de overige items. Vanwege de belangrijke rol van werklastscoresystemen hebben we geconcludeerd dat het nodig is om de betrouwbaarheid en nauwkeurigheid van de NAS te verbeteren voor een vertaling naar de benodigde verpleegtijd.

Hoofdstuk 3 beschrijft de resultaten van een validatiestudie met het meest gebruikte ICU-werklastscoresysteem om na te gaan of de NAS meer dan vijftien jaar na de lancering toe is aan een revisie. Verschillende verpleegkundigen in verschillende ziekenhuizen werden gevolgd door waarnemers. Tijd-en-bewegingstechnieken werden gebruikt om de verpleegtijd van een patiënt te meten voor alle verpleegkundige activiteiten tijdens dag-, avond- en nachtdiensten. De originele NAS-punten werden omgerekend naar de vooraf gedefinieerde tijd en vergeleken met de waargenomen tijd. De gevonden correlatie tussen de totale geconverteerde NAS-tijd en de totale waargenomen tijd per patiënt was 59%. Dit geeft aan dat de NAS slechts 59% van de verpleegtijd verklaart. De omgerekende NAS-tijd per patiënt was hoger in vergelijking met de geobserveerde tijd, wat aangeeft dat de NAS de totale benodigde verpleegtijd overschatte. Voor een effectievere verpleegkundige capaciteitsplanning is het daarom aan te raden om beter inzicht te krijgen in de werkelijke verpleegkundige werklast en de tijdstoekenning van elk NAS-item te herzien.

Hoofdstuk 4 beschrijft de resultaten van een onderzoek om de associatie tussen de objectieve verpleegkundige werklast en de ervaren verpleegkundige werklast vast te stellen en om andere factoren te identificeren die samenhangen met de ervaren verpleegkundige werklast. Tijdens 228 diensten in acht verschillende ziekenhuizen werd de objectieve verpleegkundige werklast gemeten met de NAS en de ervaren verpleegkundige werklast met de NASA-TLX. Klinische onderzoekers identificeerden andere factoren op basis van literatuur en gegevens die beschikbaar zijn in het Nederlandse kwaliteitsregister voor Intensive Care en categoriseerden die factoren in drie categorieën: patiëntfactoren (ernst van ziekte, comorbiditeiten, leeftijd, BMI en geplande of ongeplande opname), verpleegkundige factoren (opleidingsniveau) en contextuele factoren (aantal patiënten per verpleegkundige, soort dienst en dag van opname of ontslag). Uit dit onderzoek bleek dat werkdruk door verpleegkundigen anders wordt ervaren dan de objectieve verpleegkundige werkdruk zoals gemeten met NAS; de NAS was niet significant geassocieerd met de ervaren verpleegkundige werklast. Echter, zowel de ernst van de ziekte van de patiënt als het zijn van een leerling-verpleegkundige waren factoren die de ervaren verpleegkundige werklast verhogen. De planning van verpleegkundig personeel dient daarom gebaseerd te zijn op de NAS, de ernst van de ziekte van de patiënt en het opleidingsniveau van de verpleegkundige.

Hoofdstuk 5 richt zich op de associatie van de objectieve en ervaren verpleegkundige werklast met de tevredenheid van IC-verpleegkundigen over de werklast. De hypothese in dit onderzoek was dat zowel een te lage als een te hoge werklast kan leiden tot ontevredenheid van de verpleegkundige over de werklast. Zowel de objectieve verpleegkundige werklast met NAS als de ervaren verpleegkundige werklast met NASA-TLX werd gemeten in 226 verschillende diensten in acht verschillende ziekenhuizen. We vroegen verpleegkundige aan het einde van elke dienst om daarnaast hun tevredenheid over hun werklast te beoordelen op een schaal van 0 (helemaal niet tevreden) tot 10 (zeer tevreden). Uit dit onderzoek bleek dat een NAS-score van rond de 80 punten per verpleegkundige leidt tot een significant hogere kans dat een verpleegkundige tevreden is over de werklast. Ook een hoge ervaren verpleegkundige werklast volgens NASA-TLX leidt tot een significant hogere kans dat een verpleegkundige tevreden is. Een verdere verhoging van zowel de objectieve als de ervaren verpleegkundige werklast naar een zeer hoge of een lage werklast verminderen deze positieve associaties. Bij de planning van het verpleegkundig personeel dient hiermee rekening te worden gehouden; zowel een te lage als een te hoge verpleegkundige werkdruk moet worden vermeden om de functie van IC-verpleegkundige aantrekkelijk te houden.

Hoofdstuk 6 richt zich op de verpleegkundige werkdruk tijdens de COVID-19-pandemie. Gegevens van 3.994 patiënten en 36.827 verschillende diensten in zes verschillende ziekenhuizen uit de capaciteitsmodule van het National Intensive Care Evaluation (NICE) register werden gebruikt om verschillen in de planning van verpleegkundig personeel op de IC in de COVID-periode te beschrijven in vergelijking met een recente niet-COVID-periode. Aan de hand van patiëntgegevens en NAS-gegevens uit dit register is gekeken naar verschillen in verpleegkundige werkdruk bij COVID-19-patiënten, niet-COVID patiënten met een longontsteking en andere patiënten op de Intensive Care. De resultaten van dit onderzoek toonden zowel een significant hoger aantal patiënten per verpleegkundige als een significant hogere NAS per verpleegkundige in de COVID-periode in vergelijking met de niet-COVID-periode. De hogere werkdruk per verpleegkundige zou kunnen worden verklaard door de hogere werkdruk van COVID-19-patiënten, de toename van het aandeel COVID-19-patiënten en hun lange ligduur op de IC. De significant hogere NAS van COVID-19-patiënten in vergelijking met niet-COVID patiënten met een longontsteking of andere niet-COVID-patiënten werd voornamelijk veroorzaakt door intensievere hygiënische procedures, mobilisatie en positionering, ondersteuning en zorg voor familieleden en ademhalingszorg. Dit onderzoek toonde ook de mogelijkheden van inzet van andere verpleegkundigen in de dagelijkse zorg op de IC-verpleegkundige werklast. Verder onderzoek zou zich moeten richten op zowel de mogelijkheden als de impact van de inzet van overig personeel op de verpleegkundige werkdruk.

De NAS is momenteel het meest gebruikte systeem voor het meten van de werkdruk van de verpleegkundige en de planning van het verpleegkundig personeel. De NAS is echter enigszins verouderd en overschat de verpleegkundige werklast. Om deze reden raden we aan om de NAS opnieuw te kalibreren. Verder onderzoek zou zich ook moeten richten op het vinden van de optimale verpleegkundige werklast per verpleegkundige. Het is daarom belangrijk om gegevens te verzamelen in een capaciteitsregistratie van een landelijke database om gegevens over de verpleegkundige werkdruk en capaciteit tussen verschillende IC's te benchmarken. Die gegevens kunnen ook worden gebruikt voor verdere validatie van een optimale verpleegkundige werklast en voor de ontwikkeling van landelijke richtlijnen over verpleegkundige capaciteit en werklast per verpleegkundige.

APPENDICES

Appendix 1. Search-rules in the used databases

Database	Search rule
MEDLINE	("Nursing"[Mesh] OR "nursing" [Subheading] OR "Critical Care Nursing"[Mesh] OR "Nursing Stations"[Mesh] OR "Models, Nursing"[Mesh] OR "Students, Nursing"[Mesh] OR "Nursing, Team"[Mesh] OR "Nursing, Practical"[Mesh] OR "Nursing Staff, Hospital"[Mesh] OR "Nursing Staff"[Mesh] OR "Nursing Care"[Mesh] OR "Nursing Assessment"[Mesh] OR "Nurses"[Mesh]) AND ("Critical Care"[Mesh] OR "Intensive Care Units"[Mesh] OR “Step down unit”[tiab] OR "high dependency unit" [tiab] OR "Critically ill patient" [Mesh]) AND (patient classification[tiab] OR "Classification"[Mesh] OR "classification" [Subheading] OR classification systems[tiab] OR quantification [tiab] OR quantificate [tiab] OR nursing score [tiab] OR scoring system [tiab] OR workload [tiab] OR "Personnel Staffing and Scheduling"[Mesh]) NOT (Neonatal OR Burn unit [Mesh])
Cinahl	(AB ("Nursing" OR "Nurse")) AND (AB ((MH "Intensive Care Units+") OR (MH "Critical Care+") OR (MH "Critical Care Nursing+") OR "Intensive Care")) AND (AB ((MH "Workload") OR "workload" OR (MH "Workload Measurement") OR (MH "Nurse-Patient Ratio") OR (MH "Classification+") OR "classification" OR (MH "Classification (Library)") OR (MH "Patient Classification") OR (MH "Nursing Classification+"))) NOT (AB ((MH "Burn Units") OR (MH "Burn Patients") OR "Burn unit" OR (MH "Intensive Care Units, Neonatal") OR (MH "Neonatal Intensive Care Nursing") OR (MH "Intensive Care, Neonatal+") OR "Neonatal"))
Embase	('nursing staff'/exp OR 'nurse'/exp) AND 'intensive care'/exp AND ('workload'/exp OR 'nurse patient ratio'/exp) AND ‘classification’/exp NOT ('burn unit'/exp OR 'newborn intensive care'/exp)

Appendix 2 Nursing Activity Score – weight list

(Miranda, D.R. et al. 2003, Crit Care Med; Padilha et al. 2015, Rev Esc Enferm USP)

BASIC ACTIVITIES		NAS-points
1	**Monitoring and titration**	
1a	Hourly vital signs, regular registration and calculation of fluid balance	4.5
1b	Present at bedside and continuous observation or active for 2 hours or more in any shift, for reasons of safety, severity or therapy, such as: non-invasive mechanical ventilation, weaning procedures, restlessness, mental disorientation, prone position, donation procedures, preparation and administration of fluids and/or medication, assisting specific procedures	12.1
1c	Present at bedside and active for 4 hours or more in any shift for reasons of safety severity or therapy, such as those examples above (1b)	19.6
2	**Laboratory** Biochemical and microbiological investigations	4.3
3	**Medication** Vasoactive drugs excluded	5.6
4	Hygiene procedures	
4a	Performing hygiene procedures such as: dressing of wounds and intravascularcatheters, changing linen, washing patient, incontinence, vomiting, burns, leaking wounds, complex surgical dressing with irrigation, special procedures (e.g. barrier nursing, cross-infection related, room cleaning following infections, staff hygiene), etc	4.1
4b	The performance of hygiene procedures took more than 2 hours in any shift	16.5
4c	The performance of hygiene procedures took more than 4 hours in any shift	20.0
5	**Care of drains** All (except gastric tube)	1.8
6	**Mobilization and positioning**, including procedures such as: turning the patient; mobilization of the patient; moving from bed to chair; team lifting (e.g. immobile patient, traction, prone position)	
6a	Performing procedure(s) up to 3 times per 24 hours	5.5
6b	Performing procedure(s) more frequently than 3 times per 24 hours, or with 2 nurses - any frequency	12.4
6c	Performing procedure with 3 or more nurses - any frequency	17.0
7	**Support and care of relatives and patient,** including procedures such as telephone calls, interviews, counseling. Often, the support and care of either relatives or patient allow staff to continue with other nursing activities (e.g.: communication with patients during hygiene procedures, communication with relatives whilst present at bedside and observing patient)	

BASIC ACTIVITIES		NAS-points
7a	Support and care of either relatives or patient requiring full dedication for about one hour in any shift such as: to explain clinical condition, dealing with pain and distress, difficult family circumstances	4.0
7b	Support and care of either relatives or patient requiring full dedication for 3 hours or more in any shift such as: death, demanding circumstances (e.g. large number of relatives, language problems, hostile relatives)	32.0
8	Administrative and managerial tasks	
8a	Performing routine tasks such as: processing of clinical data, ordering examinations, professional exchange of information (e.g. ward rounds)	4.2
8b	Performing administrative and managerial tasks requiring full dedication for about 2 hours in any shift such as: research activities, protocols in use, admission and discharge procedures.	23.2
8c	Performing administrative and managerial tasks requiring full dedication for about 4 hours or more of the time in any shift such as: death and organ donation procedures, co-ordination with other disciplines.	30.0
VENTILATORY SUPPORT		
9	**Respiratory support** Any form of mechanical ventilation/assisted ventilation with or without positive end-expiratory pressure, with or without muscle relaxants; spontaneous breathing with or without positive end-expiratory pressure (e.g. CPAP or BiPAP), with or without endotracheal tube; supplementary oxygen by any method	1.4
10	**Care of artificial airways** Endotracheal tube or tracheostomy cannula	1.8
11	**Treatment for improving lung function.** Thorax physiotherapy, incentive spirometry, inhalation therapy, intratracheal suctioning	4.4
CARDIOVASCULAR SUPPORT		
12	**Vasoactive medication**, disregard type and dose	1.2
13	**Intravenous replacement of large fluid losses**. Fluid administration > 3 lit/m^2/day, irrespective of type of fluid administered	2.5
14	**Left atrium monitoring**. Pulmonary artery catheter with or without cardiac output measurement	1.7
15	**Cardiopulmonary resuscitation after arrest**; in the past period of 24 hrs (single precordial thump not included)	7.1
RENAL SUPPORT		
16	**Hemofiltration techniques**. Dialysis techniques	7.7
17	**Quantitative urine output measurement** (e.g., by indwelling urinary catheter)	7.0
NEUROLOGICAL SUPPORT		
18	**Measurement of intracranial pressure**	**1.6**
METABOLIC SUPPORT		
19	**Treatment of complicated metabolic acidosis/alkalosis**	1.3

BASIC ACTIVITIES		NAS-points
20	**Intravenous hyperalimentation**	2.8
21	**Enteral feeding** Through gastric tube or other gastrointestinal route (e.g., jejunostomy)	1.3
22	**Specific intervention(s) in the intensive care unit.** Endotracheal intubation, insertion of pacemaker, cardioversion, endoscopies, emergency surgery in the past period of 24 hrs, gastric lavage. Routine interventions without direct consequences to the clinical condition of the patient, such as: X-rays, echography, electrocardiogram, dressings, or insertion of venous or arterial catheters, are not included	2.8
23	**Specific interventions outside the intensive care unit**. Surgery or diagnostic procedures	1.9

Legend: The sub-items of items 1, 4, 6, 7 and 8, are mutually exclusive The weights represent average nursing time (percentage of 24 hours)

Appendix 3 Interface web application MMO

Interface of the web application used by observers during measurements. For each time a nurse started a task, the observer pressed the corresponding button for recording the start time. When a button is switched on, the color changes, which indicates the time of the specific task is recorded. When the nurse ends the activity, the button is switched off and records the time of ending.

Presence central line	Inotropics	Intra aortic balloon pump IABP	Other vasoactive medication	Antiarrhythmics	ECG monitoring	Controlled ventilation	Pressure support CPAP ASB	Others
Anticoagulation	Arterial pressure measurement	Medication via arterial line	Cardiac assist device	Pulmonary or left atrial catheter	Cardiopulmonary resuscitation CPR	Spontaneously breathing via ETT or trach	Oxygen	V:99
Cardiac output volume measurement	Central venous pressure measurement	Pacemaker	Intravenous anticoagulation	Thrombolysis	Cardioversion	Insert / replace artificial airway	Tracheal suction	Patient-related tasks other patient
Bring in sitting position	Bedside (surveillance and titration)	Drain in situ	Patient outside ICU	Induced hypothermia (thermoregulation)	Escorted transport outside ICU	Special respiratory DLV	Other medication	Non patient-related tasks
Positioning	Positioning by 2 persons	Positioning by 3 or more persons	Placing new drain in ICU	Obtain normothermy (thermoregulation)	Hygiene procedures	Special respiratory Abdomen	Special respiratory ECMO	Improve lung function
Parenteral nutrition	Enteral nutrition	Liver dialysis	Balloon tamponade	Gastro- or coloscopy	RRT by dialysis nurse	RRT by ICU nurse	Bronchoscopy	Care for tube
Antibiotics	Reverse isolation	Cytostatics barrier	Droplet isolation	Barrier	Set up RRT by ICU nurse	Urinary tract catheter	Blood sampling	
Intracranial pressure measurement	Continuous EEG monitoring	Intermittent IV treatment epileptic insults	Treatment epileptic insults	Neurocheck	Support patient / family	Administration / management	Administer blood products	Back-up (INTERNET)

Appendix 4 NASA-TLX – questionnaire

Mental Demand: How much mental and perceptual activity was required? Was the task easy or demanding, simple or complex?

Minimal Maximal

0 0 0 0 0 0 0 0 0 0 0

Physical Demand: How much physical activity was required? Was the task easy or demanding, slack or strenuous?

Minimal Maximal

0 0 0 0 0 0 0 0 0 0 0

Temporal Demand: How much time pressure did you feel due to the pace at which the tasks or task elements occurred? Was the pace slow or rapid?

Minimal Maximal

0 0 0 0 0 0 0 0 0 0 0

Overall Performance: How successful were you in performing the task? How satisfied were you with your performance?

Good Poor

0 0 0 0 0 0 0 0 0 0 0

Frustration Level: How irritated, stressed, and annoyed versus content, relaxed, and complacent did you feel during the task?

Minimal (content, relaxed etc.) Maximal (irritated, stressed etc.)

0 0 0 0 0 0 0 0 0 0 0

Effort: How hard did you have to work (mentally and physically) to accomplish your level of performance?

Minimal										Maximal
0	0	0	0	0	0	0	0	0	0	0

Additional question (Chapter 6):

Experienced workload: Grade your satisfaction about the experienced workload during this shift:

0	1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0	0

Appendix 5 Association framework with confounders per factor

Factors:

1. NAS
2. APS
3. Number of comorbidities
4. Age
5. BMI
6. Type of admission (planned/unplanned)
7. Day of admission or discharge
8. Kind of shift (day, evening, night)
9. Numbers of patients/nurse
10. Student/certified ICU nurse

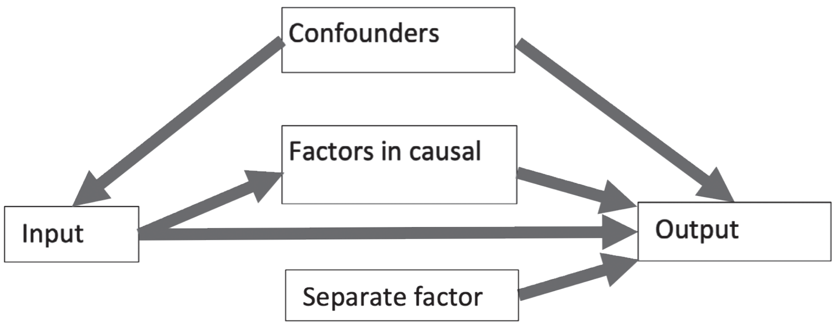

Figure 1.0 format analyzing confounders association

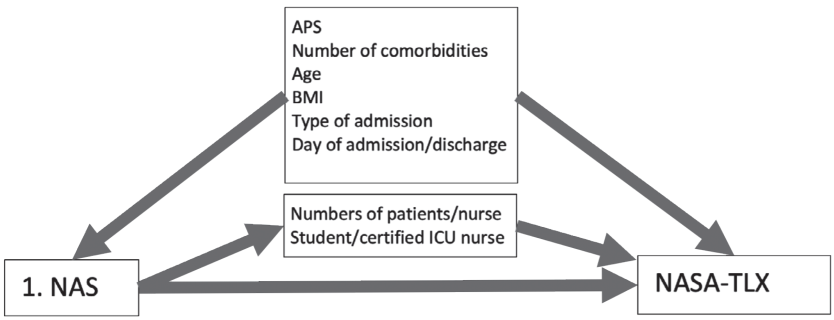

Figure 1.1 analyzing confounders association NAS and NASA-TLX

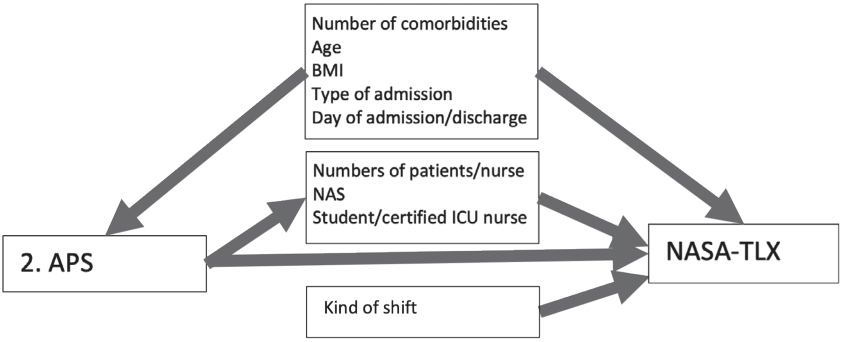

Figure 1.2 analyzing confounders association APS and NASA-TLX

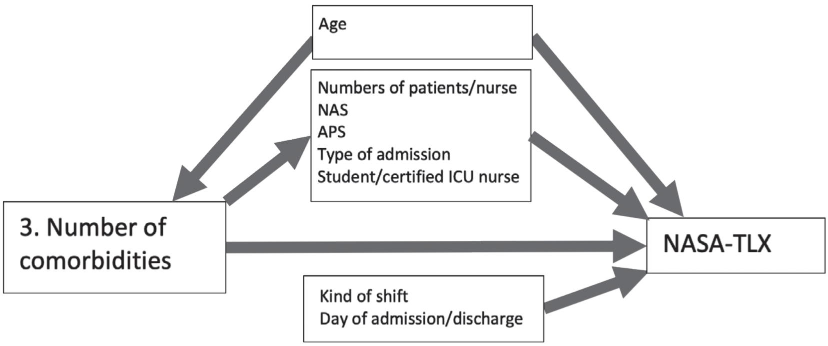

Figure 1.3 analyzing confounders association Number of comorbidities and NASA-TLX

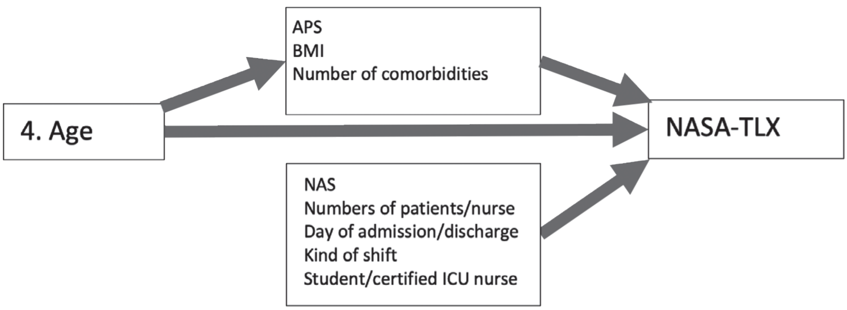

Figure 1.4 analyzing confounders association Age and NASA-TLX

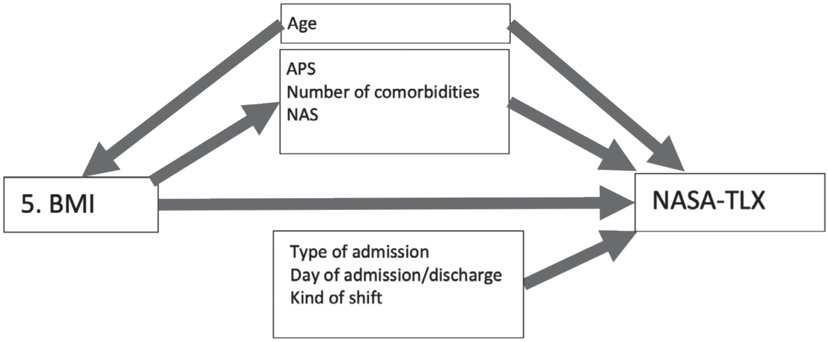

Figure 1.5 analyzing confounders association BMI and NASA-TLX

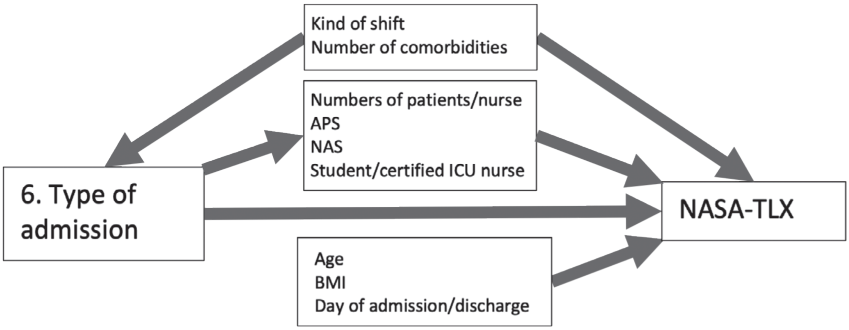

Figure 1.6 analyzing confounders association Type of admission and NASA-TLX

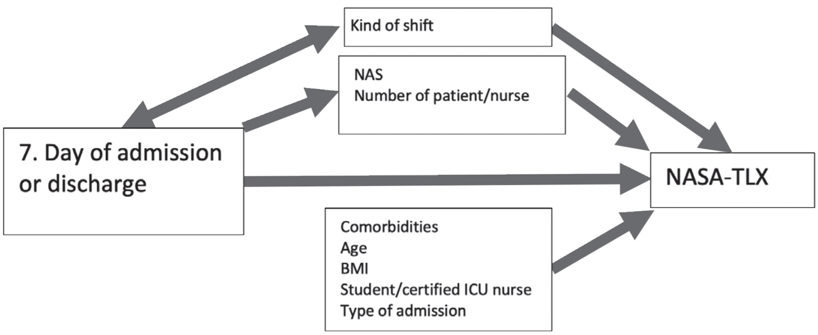

Figure 1.7 analyzing confounders association day of admission or discharge and NASA-TLX

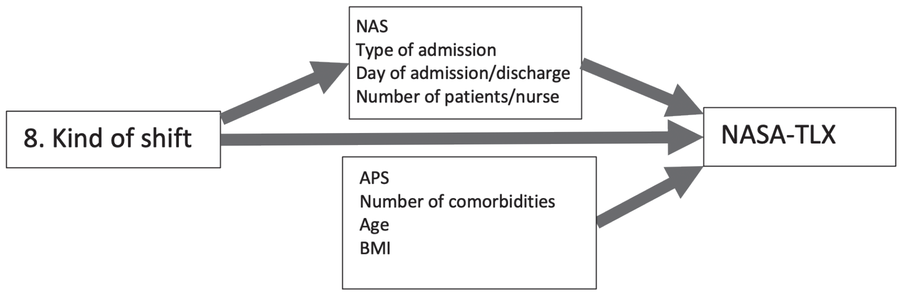

Figure 1.8 analyzing confounders association kind of shift and NASA-TLX

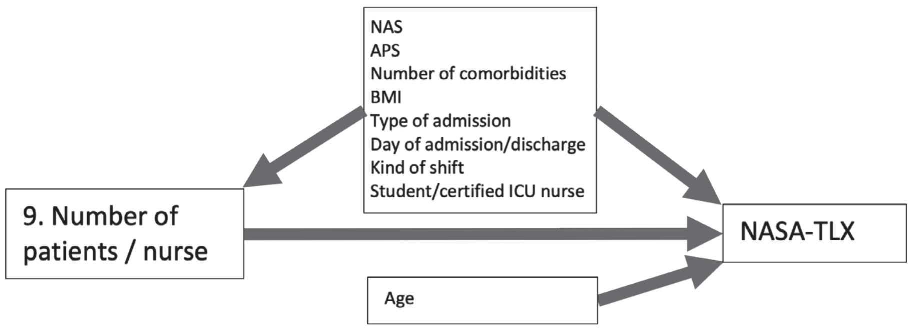

Figure 1.9 analyzing confounders association Number of patients/nurse and NASA-TLX

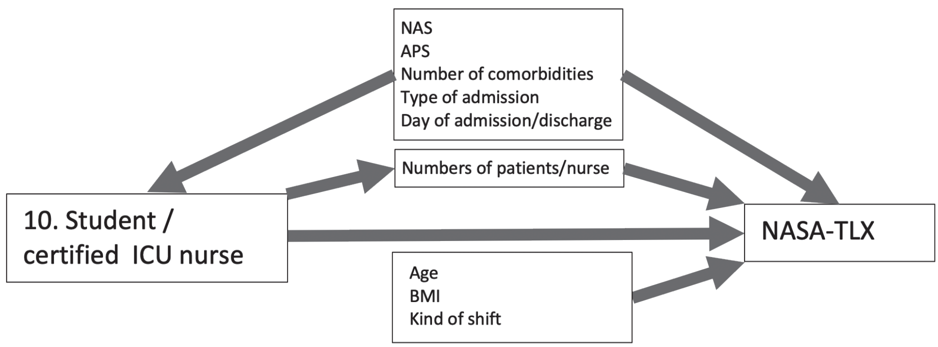

Figure 1.10 analyzing confounders association Student / certified ICU nurse and NASA-TLX

Appendix 6. Baseline characteristics all other hospitals in the NICE database

	COVID-19 vs pneumonia patients			Non-COVID vs non-pneumonia patients		
Patient factors: Patient type	**COVID-19 patients**	**Pneumonia- patients**	**p-value**	**Non-COVID patients**	**Non-pneumonia patients**	**p-value**
Number of patients – N (%)	2,514 (13.1 %)	1,837 (8.0%)		16,673 (86.9 %)	2262 (92.0%)	
ICU admission type:						
Medical patients – N (%)	2,480 (98.6)	1,834 (99.8)	<0.001	8,634 (51,8)	10,667 (50.7)	0.040
Elective surgical patients – N (%)	10 (0.4)	0 (0)	0.007	5,843 (35.0)	7,740 (36.8)	0.001
Urgent surgery patients – N (%)	20 (0.8)	1 (0.1)	0.001	2,095 (12.6)	2,591 (12.3)	0.440
Comorbidities:						
Diabetes Mellitus – N (%)	472 (18.8)	368 (20.0)	0.287	2,720 (16.3)	34,41 (16.3)	0.955
Renal insufficiency – N (%)	68 (2.7)	177 (9.6)	<0.001	914 (5.5)	1,355 (6.4)	<0.001
Cardiovascular insufficiency – N (%)	29 (1.2)	84 (4.6)	<0.001	797 (4.8)	994 (4.7)	0.809
Respiratory insufficiency – N (%)	283 (11.3)	738 (40.2)	<0.001	2,185 (13.1)	3,195 (15.2)	<0.001
Apache-APS score – Median (IQR)	45 (36-56)	53 (41 – 69)	<0.001	39 (27 – 58)	37 (26 – 55)	<0.001
Age – Median (IQR)	65 (56 – 72)	69 (59 – 77)	<0.001	65 (54 – 73)	66 (54 – 74)	<0.001
BMI – Median (IQR)	27.8 (25.3-31.2)	25.5 (22.5 – 29.2)	<0.001	26.1 (23.4 – 29.4)	26.1 (23.4 – 29.6)	0.675
Mechanical ventilation in first 24 hours-N (%)	1,959 (77.9)	1,038 (56.5)	<0.001	8,060 (48,3)	9,568 (45.4)	<0.001
Mortality						
ICU-mortality - N (%	462 (18.4)	339 (18.5)	0.959	1,529 (9.2)	1,771 (8.4)	0.014
In hospital mortality – N (%)	715 (28.4)	475 (25.9)	0.064	2,141 (12.8)	2,482 (11.8)	0.003
Length of ICU stay in days – Median (IQR)	16 (8 – 28)	3.1 (1.4 – 7.4)	<0.001	1 (0.8 – 2.5)	1 (0.8 – 2.7)	0.021

CURRICULUM VITAE

Margaretha Eline was born on June 18th, 1975, in Zevenbergen, the Netherlands and grew up with her six brothers and sisters in Dalfsen. In 1993 she finished secondary school in Zwolle and started in the school of nursing. After that she finished her specialization as an ICU nurse in Isala. From 2003 she combined her work as an ICU nurse with the Master of Nursing Science in Utrecht. She obtained her master's degree in 2007; the subject of her master thesis was 'workload on the ICU'.

In 2007 she quit working as an ICU nurse at bedside to work full-time as a nursing scientist and manager of the Research Department of the Anesthesiology and Intensive Care in Isala. In Isala she gained experience in different functions like policy advisor of the Board of Directors in Isala and Program manager. In 2016 she found her way back to the Department of Anesthesiology and Intensive Care. Currently she enjoys her daily job as a manager for the Anesthesiology and Intensive Care professional group in Isala. In the same year, 2016, she started as a PhD-student at the Department of Medical Informatics in the Amsterdam UMC, the Netherlands. Under supervision of prof. dr. Nicolette F. de Keizer she continued research about nursing workload on the ICU, together with dr. Jan Jaap Spijkstra and dr. Jasper Haringman.

Living in Zalk with Jamie, Marga enjoys living in the countryside. There in her free time she enjoys spending time with family and friends, baking, cooking, gardening, hiking and fishing.

PORTFOLIO

PhD candidate: Marga E. Hoogendoorn
Period: October 2016 – December 2021
Promotor: Prof. dr. Nicolette F. Keizer
Co-promotores: Dr. Jasper Haringman
Dr. Jan Jaap Spijkstra

ECTS = European Credit Transfer System; 1 ECTS = 28 hours

	Year	ECTS
PhD-training		
Scientific writing	2017	1.5
Clinical Epidemiology: Systematic Review	2017	0.7
Clinical Epidemiology: Evaluation of Medical tests	2019	0.9
eBrok course	2019	1.0
Computing in R	2020	0.4
Other courses		
Projectmanagement	2017	1.0
Guideline Development	2018	1.0
Effective leadership	2021	1.5
Oral presentations		
Update NAS in the Netherlands (Digital event Quebec, Canada)	2016	0.5
Projectmanagement, how does it work? (Zwolle, the Netherlands)	2016	0.5
Nursing workload on the ICU (Utrecht, the Netherlands)	2017	0.5
What can NICE mean for nurses? (Utrecht, the Netherlands)	2017	0.5
NICE for nurses (Nieuwegein, the Netherlands)	2017	0.5
Update of NAS in the Netherlands (Digital event, Brazil)	2018	0.5
Nursing workload in management (Utrecht, the Netherlands)	2018	0.5
Nursing workload measurements (Nieuwegein, the Netherlands)	2018	0.5
Network of nursing research (Zwolle, the Netherlands)	2018	0.5
Nursing workload on the ICU (Utrecht, the Netherlands)	2019	0.5
Workload measurement on the ICU (Nieuwegein, the Netherlands)	2019	0.5
Nursing capacity: what do you need in planning? (ESICM Live)	2020	0.5
Nursing capacity registration (Nieuwegein, the Netherlands)	2021	0.5

	Year	ECTS
Seminars		
NICE-discussion meeting (Nieuwegein, the Netherlands)	2016	0.4
Lecture round Patient Safety	2017	0.4
Venticare live (Utrecht, the Netherlands)	2017	0.8
Development areas of expertise Intensive Care	2017	0.4
NICE-discussion meeting (Nieuwegein, the Netherlands)	2017	0.4
Meeting Professional Counsel IC (Utrecht, the Netherlands	2018	0.4
Multicultural nursing on the ICU MICE (Utrecht, the Netherlands)	2018	0.2
4th Update in Transfusion Medicine (Zwolle, the Netherlands)	2018	1.0
NICE-discussion meeting (Nieuwegein, the Netherlands)	2018	0.4
Quality standards (V&VN Utrecht, the Netherlands)	2018	0.4
Workload measurement on the ICU (Nieuwegein, the Netherlands)	2019	0.4
Venticare (Den Bosch, the Netherlands)	2019	0.8
Move with the ICU-patient (Zwolle, the Netherlands)	2019	0.4
Working with the EPA-system (Zwolle, the Netherlands)	2019	0.2
Preparing for care is better than cure (Hilversum, the Netherlands)	2020	0.4
5th Update in Transfusion Medicine (Zwolle, the Netherlands)	2020	1.0
Nursing capacity: what do you need in planning? (ESICM Live)	2020	1.0
Data against COVID-19 in the ICU (online seminar)	2020	0.2
Congres Acute Care (online seminar)	2021	0.4
Management & Innovation in acute encephalopathy en delirium (online seminar)	2021	0.2
Connection during COVID (webinar)	2021	0.2
Venticare (webinar)	2021	0.4
NICE-discussion meeting (Nieuwegein, the Netherlands)	2021	0.4
Other		
Organizer annual scientific meeting Department Anesthesiology & Intensive Care, Zwolle, the Netherlands	2016-2020	5.0
Organizer 4th and 5th Update in Transfusion Medicine	2018/2020	2.0

	Year
Other activities	
Research Program Nursing workload quantification on the ICU – AMC, Amsterdam, the Netherlands	2016 - present
Participation International Research Group Theme: Nursing Activities Score and measuring workload on the ICU – Universidade de Sao Paolo, Department of nursing	2009 - present
Member of the board of NICE (National Intensive Care Evaluation)	2014 - present
Member of the board of V&VN-IC (Dutch society of ICU nurses)	2014 - 2019
Member of the Innovation and research council Isala, Zwolle, the Netherlands	2019 - present
Co-creation sessions ‘ICU-networks in the Netherlands’ (Zorginstituut Nederland)	2019 - 2020
Sepsis Guideline Working group	2019 - 2021
Taskforce ICU formation NVIC (Dutch Association of Intensive Care)	2020 - present
Earned grants	
EffCNa Research Award – “Quantification of nursing workload on the ICU”	2018
Care Innovation Voucher Isala – “Improving delirium care with objective monitoring”	2018
Care Innovation Voucher Isala - “Ketamine-treatment at home”	2020

LIST OF PUBLICATIONS

Publications in this thesis

Workload scoring systems in Intensive Care and their ability to quantify the need for nursing time: A systematic literature review. Hoogendoorn ME, Margadant CC, Brinkman S, Haringman JJ, Spijkstra JJ, de Keizer NF. Int J Nurs Stud. 2020; 101 (jan)

Validation of the Nursing Activities Score (NAS) using time-and-motion measurements in Dutch Intensive Care Units: an observational study. Margadant CC, Hoogendoorn ME, Bosman RJ, Spijkstra JJ, Brinkman S, de Keizer NF. Neth J Crit Care; 2021; 29(1)

The objective nursing workload and perceived nursing workload in Intensive Care Units: Analysis of association. Hoogendoorn ME, Brinkman S, Spijkstra JJ, Bosman RJ, Margadant CC, Haringman J, de Keizer NF. Int J Nurse Stud. 2021; 114 (Feb)

A bell-shaped association between both the objective and perceived nursing workload and workload satisfaction of Intensive Care nurses. M.E. Hoogendoorn, S. Brinkman, J.J. Spijkstra, J.J. Haringman, R.J. Bosman, N.F. Keizer. Accepted: Nurs Health Care Int J, 2021; 5 (5): 000247

The impact of COVID-19 on nursing workload and planning of nursing staff in Intensive Care; a prospective descriptive multicenter study. Hoogendoorn M, Brinkman S, Bosman RJ, Haringman J, De Keizer N, Spijkstra JJ. Int J Nurse Stud; 2021; 121 (sept)

Other publications

Effect of patient characteristics and contextual factors on needed nursing time in Intensive Care Units. Margadant CC, Brinkman S, Hoogendoorn ME, Bosman RJ, Spijkstra JJ, de Keizer NF. *Submitted*

Nurse Operation Workload (NOW): a new nursing workload model for Intensive Care Units based on time measurements. Margadant CC, de Keizer NF, Hoogendoorn ME, Bosman RJ, Spijkstra JJ, Brinkman S. J. Nurse Stud. 2021; 113 (Jan)

The Nursing Activities Score per Nurse Ratio is associated with in-hospital mortality, whereas the Patient per Nurse ratio is not. Margadant CC, Wortel SA, Hoogendoorn ME, Bosman RJ, Spijkstra JJ, Brinkman S, de Keizer NF. Crit.Care Medicine, 2020, Jan, 48(1), 3-9

Implementation of a specific safety check is associated with lower postoperative mortality in cardiac surgery. Spanjersberg AJ, Ottervanger JP, Nierich AP, Speekenbrink RGH, Stooker W, Hoogendoorn M, van Veghel D, Houterman S, Brandon Bravo Bruinsma G.J.J Thorac Cardiovasc Surg. 2020 May;159(5):1882-1890, Epub 2019 Aug 28.

Nursing Activities Score: an updated guideline for its application in the Intensive Care Unit. Padilha KH, Stafseth S, Soms D, Hoogendoorn ME, Carmona Monge FJ, Gomaa OH, Giakoumidakis K, Giannakopoulou M, Gallani MC, Cudak E, de Souza Nogueira L, Santoro C, Cardoso de Sousla R, Barbosa RL, Reis Miranda DD. Rev Esc Enferm USP. 2015 Feb;49 Spec No:131-7

Multinational development and validation of an early prediction model for delirium in ICU patients. Wassenaar A, van den Boogaard M, van Achterberg T, Slooter AJ, Kuiper MA, Hoogendoorn ME, Simons KS, Maseda E, Pinto N, Jones C, Luetz A, Schandl A, Verbrugghe W, Aitken LM, van Haren FM, Donders AR, Schoonhoven L, Pickkers P. Intensive Care Med. 2015 Jun;41(6):1048-56.

Nursing workload on the ICU; a multicentre study using the Nursing Activity Score. Padilha KG, Stafseth S, Hoogendoorn M, Carmona J, Gooma JM, Cudak E, Santoro C, Barbsoa EL, de Sousa RC, Reis Miranda D [in admission]

Development of a nursing intervention to prepare frail older patients for cardiac surgery (the PREDOCS programme), following phase one of the guidelines of the Medical Research Council. Ettema RG, Hoogendoorn ME, Kalkman CJ, Schuurmans MJ. Eur J Cardiovasc Nurs. 2013 Nov 1.

Prevention of ICU delirium and delirium-related outcome with haloperidol: a study protocol for a multicenter randomized controlled trial. van den Boogaard M, Slooter AJ, Brüggemann RJ, Schoonhoven L, Kuiper MA, van der Voort PH, Hoogendoorn ME, Beishuizen A, Schouten JA, Spronk PE, Houterman S, van der Hoeven JG, Pickkers P. Trials. 2013 Nov 21; 14; 400.

Direct cost analysis of intensive care unit stay in four European countries: applying a standardized costing methodology. Tan SS, Bakker J, Hoogendoorn ME, Kapila A, Martin J, Pezzi A, Pittoni G, Spronk PE, Welte R, Hakkaart-van Roijen L. Value Health, 2012 Jan 15(1), 81-6

Microcosting of inpatient care in the Netherlands: the impact of mechanical ventilation. Tan SS, Hakkaart L, Bouwmans CA, Hoogendoorn ME, Spronk PE, Bakker J. Journal of Intensive Care Medicine, June-August 2008, 23(4); 250-7

AUTHOR CONTRIBUTIONS

Chapter 2: Workload scoring systems in Intensive Care and their ability to quantify the need for nursing workload: a systematic literature review

Study conception and design: M.E. Hoogendoorn, N.F. de Keizer, C.C. Margadant
Acquisition of data: M.E. Hoogendoorn, C.C. Margadant
Analysis and interpretation M.E. Hoogendoorn, C.C. Margadant
Drafting of manuscript: M.E. Hoogendoorn
Critical revision manuscript: S. Brinkman, J. Haringman, J. J. Spijkstra, C.C. Margadant, N.F. de Keizer

Chapter 3: Validation of the Nursing Activities Score (NAS) using time- and-motion measurements in Dutch intensive care units

Study conception and design: C.C. Margadant, M.E. Hoogendoorn, S. Brinkman, N.F. de Keizer
Acquisition of data: C.C. Margadant, M.E. Hoogendoorn
Analysis and interpretation: S. Brinkman, C.C. Margadant, M.E. Hoogendoorn
Drafting of manuscript: C.C. Margadant
Critical revision manuscript: S. Brinkman, M.E. Hoogendoorn, R.J. Bosman, J.J. Spijkstra, N.F. de Keizer

Chapter 4: The objective nursing workload and perceived nursing workload; analysis of association

Study conception and design: M.E. Hoogendoorn, S. Brinkman, N.F. de Keizer,
Acquisition of data: M.E. Hoogendoorn, C.C. Margadant
Analysis and interpretation: M.E. Hoogendoorn, J. Haringman, S. Brinkman
Drafting of manuscript: M.E. Hoogendoorn
Critical revision manuscript: R.J. Bosman, S. Brinkman, J. Haringman, C.C. Margadant, J.J. Spijkstra, N.F. de Keizer

Chapter 5: A bell-shaped association between both the objective and perceived nursing workload and workload satisfaction of Intensive Care nurses

Study conception and design: M.E. Hoogendoorn, S. Brinkman, N.F. de Keizer,

Acquisition of data: M.E. Hoogendoorn, S. Brinkman

Analysis and interpretation: M.E. Hoogendoorn, J. Haringman, J.J. Spijkstra

Drafting of manuscript: M.E. Hoogendoorn

Critical revision manuscript: R.J. Bosman, S. Brinkman, J. Haringman, C.C. J.J. Spijkstra, N.F. de Keizer

Chapter 6: The impact of COVID-19 on nursing workload and planning of nursing staff in Intensive Care; a prospective descriptive multicenter study

Study conception and design: J.J. Spijkstra, J. Haringman

Acquisition of data: M.E. Hoogendoorn, S. Brinkman

Analysis and interpretation: M.E. Hoogendoorn, J.J. Spijkstra, J. Haringman,

Drafting of manuscript: M.E. Hoogendoorn

Critical revision manuscript: R.J. Bosman, S. Brinkman, J. Haringman, J.J. Spijkstra, N.F. de Keizer

DANKWOORD

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Jamie, mijn grote liefde.
Woorden zijn overbodig.