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Workload-based nursing staffing requirements in post-anesthesia care units of four Chinese tertiary hospitals using the Workload Indicators of Staffing Need method

Shuying Gao
Lishui City People's Hospital
Mengting Ai
Lishui City People's Hospital
Faxing Wang
Lishui City People's Hospital
Yun Xiang
502767289@qq.com

Lishui City People's Hospital

Article

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Abstract

Post-anesthesia care units (PACUs) require nursing staffing that reflects rapidly changing perioperative workload, yet quantitative evidence from Chinese hospitals remains limited. We applied the World Health Organization Workload Indicators of Staffing Need (WISN) method in PACUs of four tertiary hospitals in Zhejiang Province, China. Nursing activities, annual service volume, available working time, and activity standards were assessed using operational records, direct observation, expert consultation, and semi-structured interviews. Across the four PACUs, 62 nurses were available compared with an estimated requirement of 78.65, corresponding to a shortage of 16.65 nurses and an overall WISN ratio of 0.79. Hospital-level WISN ratios ranged from 0.67 to 0.84, indicating staffing shortages in all participating units. Additional activities contributed to workload-based staffing requirements, with individual allowance factors ranging from 2.15 to 3.04. These findings indicate a consistent mismatch between existing PACU nursing capacity and workload-based staffing requirements across the participating hospitals and suggest that WISN may provide a useful framework for workload-informed workforce planning in perioperative care.

Introduction

Post-anesthesia care units (PACUs) are an essential component of perioperative care, providing continuous monitoring and management of patients during recovery from anesthesia[1]. PACU nurses undertake multiple time-sensitive clinical activities, including physiological monitoring, airway management, pain and sedation assessment, and early recognition and management of postoperative complications[1]. Changes in surgical volume, patient complexity, and perioperative care pathways have placed increasing demands on PACU services and nursing care. The dynamic nature of post-anesthesia recovery, characterized by rapid patient turnover and variations in recovery needs, places distinctive demands on nursing workload and resource allocation[2]. Inadequate nurse staffing may compromise the capacity to deliver timely and appropriate care and has been associated with adverse patient outcomes in both PACU and broader acute-care settings[3, 4].

Appropriate nurse staffing is therefore important for maintaining the quality and efficiency of perioperative care. However, staffing decisions in clinical practice are often based on fixed nurse-to-patient or nurse-to-bed ratios, historical staffing patterns, or managerial experience. Although these approaches are straightforward to implement, they may not adequately account for variations in service volume, activity duration, patient turnover, or indirect nursing responsibilities[5, 6]. These limitations may be particularly relevant in PACUs, where nursing workload is influenced by rapidly changing patient care demands and the frequency, complexity, and duration of nursing activities[2]. A workload-based approach that incorporates both direct patient-care activities and indirect nursing responsibilities may therefore provide a more objective basis for estimating staffing requirements.

The Workload Indicators of Staffing Need (WISN) method developed by the World Health Organization provides a systematic framework for estimating health workforce requirements according to actual

workload[7, 8]. The method incorporates workload components, activity time standards, available working time, service activities, and allowance activities when estimating staffing requirements[7]. In contrast to staffing approaches based primarily on fixed ratios, WISN allows staffing requirements to be quantitatively linked to the frequency and time requirements of specific activities. The method has been applied to nursing workforce planning across different healthcare settings and provides a standardized approach for quantifying staffing requirements and identifying workforce gaps[8–10]. However, evidence regarding its application specifically to PACU nursing remains limited, particularly in Chinese tertiary hospitals, where multicenter assessments of PACU staffing requirements based on actual workload are scarce.

Therefore, this multicenter study applied the WISN methodology to PACUs in four tertiary hospitals in Zhejiang Province, China. The study aimed to quantify workload-based nursing staffing requirements, compare estimated requirements with existing staffing levels, and identify staffing gaps across participating PACUs. By characterizing both direct nursing activities and allowance activities, this study sought to provide empirical evidence for workload-informed PACU workforce planning.

Methods

Study design and setting

This multicenter cross-sectional study was conducted in the post-anesthesia care units (PACUs) of four tertiary hospitals in Zhejiang Province, China. The participating hospitals were designated Hospitals A–D to maintain institutional anonymity. The Workload Indicators of Staffing Need (WISN) methodology developed by the World Health Organization (WHO) was used to estimate workload-based nursing staffing requirements for each PACU.

The WISN assessment was based primarily on PACU operational and nursing workforce data from January to December 2025. The participating hospitals were selected by convenience sampling based on their willingness to participate and availability of complete PACU operational and workforce data.

The participating PACUs provided post-anesthesia recovery care for patients undergoing a broad range of surgical procedures, including general surgery, orthopedics, thoracic surgery, neurosurgery, and obstetrics and gynecology. PACU nursing responsibilities included continuous physiological monitoring, recovery-related nursing care, patient transfer and handover, and other clinical and organizational activities.

Ethical considerations

Ethics approval

waiver. The study protocol was reviewed by the Medical Ethics Committee of Lishui People's Hospital (Approval No. 2024-045). The committee determined that formal ethics approval was not required and granted an exemption from formal ethical review because the WISN assessment primarily used hospital-level operational and workforce data, while the semi-structured interviews were limited to routine nursing workflows, activity-time requirements, and staffing practices. No clinical intervention was performed, and no identifiable patient information was collected.

Informed consent

waiver. The requirement to obtain informed consent from the nursing staff participating in the semi-structured interviews was waived by the Medical Ethics Committee of Lishui People's Hospital (Approval No. 2024-045) because the interviews concerned routine professional practices and the study was considered minimal risk.

All methods were performed in accordance with relevant institutional guidelines and regulations.

WISN framework and classification of nursing activities

Nursing staffing requirements were assessed according to the WHO WISN framework. Nursing workload was classified into three categories: health service activities, support activities, and additional activities.

Health service activities comprised routine nursing activities for which annual service statistics were available, including pre-recovery preparation, recovery-related nursing care, patient transfer and handover, and post-recovery equipment and material organization. Support activities were routinely performed by all or most PACU nurses but were not generally captured in annual service statistics; these included departmental education and training, shift handovers, and routine departmental meetings.

Additional activities comprised responsibilities assigned to designated individual nurses rather than routinely performed by all PACU nursing staff. These included equipment and device management, cardiopulmonary bypass-related activities, external training and continuing education, teaching, supply and consumable management, administrative duties, anesthesia billing and data entry, research activities, Acute Pain Service-related activities, and other institution-specific responsibilities.

Data sources and collection

Data required for the WISN analysis were obtained from annual PACU operational records, nursing workforce and scheduling records, direct observation of nursing activities, interviews with nursing personnel, and expert consultation. Workforce-related data included the number of available nurses, annual working days, working hours per day, public holidays, weekends, annual leave, sick leave, special leave, training days, and other applicable non-working time. These data were used to determine the annual available working time (AWT) for PACU nurses at each hospital.

For health service activities routinely captured in service statistics, annual service volumes and corresponding activity standards were collected. These activities included pre-recovery preparation, recovery-related nursing care, patient transfer and handover, and post-recovery equipment and material organization. Hospital-specific annual workloads, activity standards, and AWT were used to calculate the standard workload and the basic staffing requirement for each health service activity.

For nursing responsibilities not adequately represented by routine annual service statistics, data on support and additional activities were collected in accordance with the WISN framework. Support activities included departmental education and training, shift handovers, and routine departmental meetings and were used to calculate the category allowance standard (CAS) and category allowance factor (CAF). Additional activities included equipment and device management, external training and continuing education, teaching activities, Acute Pain Service (APS) rounds, supply and consumable management, research activities, administrative management, anesthesia billing and data entry, and other hospital-specific responsibilities. For each additional activity, the number of staff involved, workload parameter, measurement unit, and annual time requirement were recorded and used to calculate the individual allowance standard (IAS) and individual allowance factor (IAF).

Determination and validation of activity standards

Activity standards were defined as the time required to complete individual nursing activities under routine PACU practice. For health service activities with routinely available service statistics, activity standards were determined primarily through direct observation of routine nursing practice and were supplemented by PACU operational records and information obtained from interviews with nursing personnel. The resulting standards were expressed as the time required per service unit, such as minutes per patient or minutes per activity. Because PACU workflows differed among the participating hospitals, hospital-specific activity standards were retained where applicable rather than imposing a uniform value across all institutions.

For support activities, including departmental education and training, shift handovers, and routine departmental meetings, time requirements were derived primarily from departmental records and information provided by the participating PACUs. These time requirements were converted into proportions of annual available working time and used to calculate the category allowance standard (CAS) and category allowance factor (CAF).

For additional activities undertaken by designated nursing staff, hospital-specific workload parameters were determined from departmental records and information on routine work arrangements. For each activity, the number of staff involved, workload frequency or duration, measurement unit, and corresponding annual time requirement were determined. These parameters were used to calculate the annual individual allowance standard (IAS) and individual allowance factor (IAF). Because the type and distribution of additional responsibilities differed among the participating PACUs, these parameters were determined separately for each hospital.

The preliminary activity standards and workload parameters were reviewed through expert consultation to assess their consistency with routine PACU nursing practice. Information obtained from direct observation, operational records, interviews, and expert consultation was cross-checked, and discrepancies were reconciled before the final parameters were entered into the WHO WISN tool. Hospital-specific WISN Institution Full Reports were subsequently reviewed to verify the entered activity standards, workload parameters, allowance standards, and calculated staffing requirements.

WISN Calculation Procedures

Available working time

Available working time (AWT) represented the annual time available for one nurse to perform work-related activities. For each hospital, AWT was calculated by subtracting public holidays, weekends, annual leave, sick leave, training days, and other applicable leave or absence from the total calendar days in the reference year and multiplying the resulting available working days by the number of working hours per day:

AWT = (total calendar days − public holidays − weekends − annual leave − sick leave − training days − other applicable leave or absence) × working hours per day

AWT was calculated separately for each participating hospital to account for differences in institutional working calendars and recorded staff absences.

Health service activities and standard workloads

For health service activities, annual workloads were obtained from hospital service statistics. The activity standard represented the time required to complete one unit of the corresponding activity. Before calculation, AWT and activity standards were converted to consistent time units. For activities with standards expressed in minutes per service unit, annual AWT was converted from hours to minutes.

The standard workload, defined as the number of service units that could theoretically be completed by one nurse during the annual available working time, was calculated as:

Standard workload = AWT /Activity standard

Staffing requirement for an activity = annual workload / standard workload

The staffing requirements for all health service activities were summed to obtain the basic staffing requirement (A):

$$A = \sum \frac{Annual\ workload_i}{Standard\ workload_i}$$

Hospital-specific annual workloads, activity standards, standard workloads, and calculated staffing requirements were retained for the WISN analysis.

Category allowance factor

Support activities routinely performed by all or most PACU nurses were incorporated using the category allowance standard (CAS). The time devoted to each support activity was expressed as a proportion of annual available working time, and the individual CAS values were summed to obtain the total CAS:

Total CAS = Σ CAS_i

The category allowance factor (CAF) was calculated as:

$$CAF = \frac{1}{1 - Total\ CAS}$$

The basic staffing requirement for health service activities was subsequently adjusted for support activities by multiplying the basic staffing requirement (A) by the corresponding hospital-specific CAF:

Adjusted staffing requirement = A × CAF

Individual allowance factor

Additional activities performed by designated members of the nursing workforce were incorporated using individual allowance standards (IAS). For each additional activity, the number of staff involved, workload frequency or duration, measurement unit, and corresponding annual time requirement were recorded. The annual time requirements for all applicable additional activities were summed to obtain the total annual IAS for each hospital.

The individual allowance factor (IAF), representing the additional full-time-equivalent nursing requirement attributable to individual allowance activities, was calculated as:

$$IAF = \frac{Annual\ tatol\ IAS}{AWT}$$

Because the type, frequency, and distribution of additional responsibilities varied among PACUs, IAS and IAF were determined separately for each participating hospital.

Total staffing requirement and WISN indicators

The total nursing staffing requirement for each PACU was estimated by combining the basic staffing requirement for health service activities, the category allowance adjustment for support activities, and the individual allowance requirement:

Required staff=(A×CAF) + IAF

The staffing shortage was calculated as:

Staffing shortage = required staff − available staff

A positive value therefore indicated that the number of available nurses was below the estimated workload-based staffing requirement.

The WISN ratio was calculated as:

$$WISN = \frac{Available\ staff}{Required\ staff}$$

A WISN ratio of 1.0 indicates that available staffing is in balance with the workload-based staffing requirement. A ratio below 1.0 indicates that available staffing is below the estimated requirement, whereas a ratio above 1.0 indicates staffing above the estimated workload-based requirement.

WISN data processing

Hospital-specific AWT, annual service workloads, activity standards, CAS values, and IAS parameters were entered into the WHO WISN tool. An Institution Full Report was generated for each participating hospital. The input parameters and calculated outputs were cross-checked for completeness and internal consistency.

The institution-level reports were used to obtain the basic staffing requirements for health service activities, allowance factors, total workload-based nursing staffing requirements, staffing shortages, and WISN ratios for Hospitals A–D. Hospital-level outputs were subsequently consolidated to characterize the overall nursing workforce status across the four participating PACUs. The WISN implementation and calculation framework used in this study is summarized in Table 1.

Table 1
Implementation of the Workload Indicators of Staffing Need methodology

Step	Analysis phase	Description
1	Identification of study units	PACUs from four tertiary hospitals in Zhejiang Province, China, were included as the study units.
2	Estimation of available working time	Annual available working time (AWT) for nurses was calculated by subtracting public holidays, weekends, annual leave, sick leave, training days, and other applicable non-working days from the annual calendar and multiplying the resulting available working days by the number of working hours per day. AWT ranged from 1,780 to 1,944 h/year across the participating hospitals.
3	Classification of nursing activities	Nursing activities were classified according to the WISN framework into health service activities, support activities, and additional activities using operational records, direct observation, semi-structured interviews, and expert consultation.
4	Determination of activity standards	Activity standards for health service activities were determined primarily through direct observation and supplemented by operational records and interviews. Workload parameters for support and additional activities were derived primarily from departmental records and interviews and were reviewed through expert consultation.
5	Estimation of staffing requirements for health service activities	Annual workloads for individual health service activities were divided by the corresponding standard workloads to estimate the basic staffing requirement (A).
6	Incorporation of allowance activities and calculation of total staffing requirements	Support activities were incorporated using the category allowance factor (CAF), whereas additional activities performed by designated staff were incorporated using the individual allowance factor (IAF). Total staffing requirement was calculated as: Required staff = (A × CAF) + IAF.
7	Calculation of WISN indicators	Staffing adequacy was assessed using the staffing shortage and WISN ratio. Staffing shortage was calculated as required staff minus available staff, whereas the WISN ratio was calculated as available staff divided by required staff.
8	Interpretation of staffing requirements	Available staffing was compared with workload-based staffing requirements. A WISN ratio of 1.0 indicates staffing in balance with workload; a ratio below 1.0 indicates staffing below the estimated workload-based requirement.

Statistical analysis

The analysis was primarily descriptive. WISN parameters were calculated separately for each participating PACU using hospital-specific workload and workforce data. Available working time, activity standards, allowance factors, available staffing, workload-based staffing requirements, staffing shortages, and WISN ratios were summarized using hospital-specific values, totals, or ranges, as appropriate. Aggregate values across the four hospitals were additionally calculated to describe the overall PACU nursing workforce status. No inferential statistical comparisons were performed because

the primary objective was to estimate workload-based staffing requirements rather than to test differences between hospitals.

Results

Overall PACU nursing staffing requirements

A total of four tertiary-hospital post-anesthesia care units (PACUs) were included in the WISN analysis (Table 2). Across the four participating PACUs, 62 nurses were available, compared with a total workload-based staffing requirement of 78.65 nurses. This corresponded to an overall staffing deficit of 16.65 nurses and an overall WISN ratio of 0.79, indicating that the available nursing workforce was below the estimated workload-based requirement.

Table 2
WISN-based nursing staffing requirements in the participating post-anesthesia care units

Hospital	Available nursing staff, n	Required nursing staff, n	Staffing shortage, n	WISN ratio
Hospital A	19	22.50	3.50	0.84
Hospital B	14	17.16	3.16	0.82
Hospital C	11	16.46	5.46	0.67
Hospital D	18	22.53	4.53	0.80
Total	62	78.65	16.65	0.79

Abbreviation: WISN, Workload Indicators of Staffing Need.

Hospital-level staffing requirements

All four participating PACUs had WISN ratios below 1.0 (Table 2). Hospital C showed the largest staffing deficit, with 11 nurses available compared with a calculated requirement of 16.46 nurses, corresponding to a deficit of 5.46 nurses and the lowest WISN ratio (0.67). Hospital D had 18 nurses available compared with a requirement of 22.53 nurses, resulting in a deficit of 4.53 nurses and a WISN ratio of 0.80. Hospital A had 19 nurses available compared with a requirement of 22.50 nurses, corresponding to a deficit of 3.50 nurses and a WISN ratio of 0.84. Hospital B had 14 nurses available compared with a requirement of 17.16 nurses, corresponding to the smallest staffing deficit of 3.16 nurses and a WISN ratio of 0.82. Thus, although the magnitude of the staffing deficit varied among hospitals, available nursing staffing was below the workload-based requirement in each participating PACU.

Available working time and nursing activity standards

Available working time (AWT) varied across the four hospitals (Table 3), ranging from 1,780 h/year in Hospital B to 1,944 h/year in Hospital A. The corresponding AWT values were 1,904 h/year in Hospital C and 1,940 h/year in Hospital D.

Table 3
Annual available working time of PACU nurses in the participating hospitals

Item	Hospital A	Hospital B	Hospital C	Hospital D
Total calendar days per year	365	365	365	365
Public holidays, days	13	13	13	13
Weekend days	104	104	104	104
Annual leave, days	0.5	11.5	9	0
Sick leave, days	0.5	13	0	0
Training days	3	0	0	4.5
Other applicable leave/absence, days	1	1	1	1
Total non-working days	122	142.5	127	122.5
Working hours per day	8	8	8	8
Available working days per year	243	222.5	238	242.5
Available working time, h/year	1,944	1,780	1,904	1,940

Activity standards for health service, support, and additional nursing activities are summarized in Table 4. Health service activities included pre-recovery preparation, recovery-related nursing care, patient transfer and handover, and post-recovery equipment and material organization. Activity standards varied according to the type of nursing activity and, for some activities, across the participating hospitals. The activity standard for recovery-related nursing care within the operating room ranged from 41 to 60 min per patient, while patient transfer and handover required 15–18 min per patient.

Table 4
Activity standards for health service, support, and additional activities of PACU nurses

Workload category	Nursing activity	Activity standard or workload parameter
Health service activities	Pre-recovery preparation	60 min/activity
	Recovery-related nursing care in the operating room	41–60 min/patient
	Recovery-related nursing care outside the operating room	30 min/patient
	Patient transfer and handover	15–18 min/patient
	Post-recovery equipment and material organization	60 min/activity
Support activities	Departmental education and training	2 h/month
	Shift handover and routine meetings	1–7 h/month
Additional activities	Equipment and device management	8–20 h/month
	Cardiopulmonary bypass-related activities	29.8 h/month
	External training and continuing education	3–15 days/year
	Teaching and educational activities	0–16 h/month
	Supply and consumable management	52–160 h/month or 2 h/day, depending on hospital
	Administrative management	20–176 h/month
	Anesthesia billing and data entry	8.8 h/day
	Research activities	32 h/month
	Acute Pain Service (APS) rounds	90–480 min/day

Detailed hospital-specific annual workloads, activity standards, standard workloads, and calculated staffing requirements for individual health service activities, including the basic staffing requirement (A), are provided in Supplementary Table 3.

Category allowance standards and factors

The total Category Allowance Standard (CAS) ranged from 0.02 to 0.06 of available working time across the four hospitals, corresponding to approximately 2%–6% of working time (Table 5). The resulting

Category Allowance Factors (CAFs) ranged from 1.02 to 1.06. Detailed hospital-specific CAS components and corresponding CAF values are provided in Supplementary Table 1.

Table 5
Category allowance standards and category allowance factors for PACU nurses

Support activity	Time requirement	CAS, proportion of available working time
Departmental education and training	2 h/month	0.01–0.016
Shift handover and routine meetings	1–7 h/month	0.01–0.04
Total CAS, proportion of available working time		0.02–0.06
Category allowance factor (CAF)		1.02–1.06

Individual allowance activities and factors

Individual allowance activities varied across the participating PACUs (Table 6). Total Individual Allowance Standards (IAS) ranged from 3,822 to 5,916.7 h/year. Hospital A had the highest total IAS (5,916.7 h/year), followed by Hospital D (5,632 h/year), Hospital C (4,916 h/year), and Hospital B (3,822 h/year). The corresponding Individual Allowance Factors (IAFs) were 3.04, 2.90, 2.58, and 2.15, respectively.

Table 6
Individual allowance standards and factors across the participating PACUs

Hospital	Total annual IAS, h/year	IAF
Hospital A	**5916.7**	**3.04**
Hospital B	**3822.0**	**2.15**
Hospital C	**4916.0**	**2.58**
Hospital D	**5632.0**	**2.90**

Individual allowance activities included equipment and device management, external training, teaching, supply management, administrative duties, anesthesia billing and data entry, research activities, acute pain service-related activities, and other hospital-specific responsibilities. The composition and workload associated with these activities differed among the four PACUs. Detailed hospital-specific IAS components and IAF values are provided in Supplementary Table 2.

Discussion

This multicenter study applied the WISN methodology to quantify nursing staffing requirements in PACUs across four tertiary hospitals in Zhejiang Province, China. Three main findings emerged. First, all

four participating PACUs had fewer nurses than estimated by their workload-based staffing requirements, with WISN ratios ranging from 0.67 to 0.84 and an overall ratio of 0.79. Second, the magnitude of the staffing deficit varied across hospitals despite their common tertiary-hospital status, suggesting that staffing requirements were influenced by institution-specific workload and organizational characteristics. Third, support and additional activities accounted for measurable components of nursing workload, highlighting the importance of considering responsibilities beyond direct patient care when estimating PACU staffing requirements. Together, these findings demonstrate a consistent mismatch between available nursing capacity and workload-based staffing requirements across the participating PACUs.

PACUs are dynamic perioperative environments in which nurses undertake multiple time-sensitive activities, including continuous physiological monitoring, airway management, pain and sedation assessment, and early recognition and management of postoperative complications[1, 2]. The early postoperative period is also associated with clinically important risks such as respiratory depression, reinforcing the need for continuous assessment and timely intervention in the PACU[11]. Nursing workload during post-anesthesia recovery can vary considerably according to patient condition, recovery requirements, and the frequency and duration of nursing activities. Idoffsson et al. developed and validated a PACU-specific workload instrument and demonstrated the importance of objective workload measurement for evaluating PACU nursing workload and supporting staffing decisions[2]. Importantly, Kiekkas et al. reported an association between nurse understaffing and adverse events among PACU patients, providing empirical evidence that staffing adequacy may be relevant to patient safety during post-anesthesia recovery[12]. Against this background, the finding that all four PACUs in the present study had WISN ratios below 1.0 suggests a consistent workload-based staffing deficit across the participating institutions.

The variation in WISN ratios among hospitals is also noteworthy. Hospital C had the lowest ratio (0.67), whereas ratios in the other hospitals ranged from 0.80 to 0.84. These differences should not be interpreted solely in terms of the absolute number of nurses employed. WISN estimates staffing requirements by integrating available working time, service workload, activity standards, and allowance activities, thereby relating staffing requirements to the workload structure of individual institutions[8]. International experience with WISN has similarly emphasized that workload components, activity standards, and local service organization are central to the interpretation and implementation of WISN-derived staffing requirements[13]. Previous research has shown that conventional staffing methodologies based on fixed ratios, bed numbers, or other relatively static measures may not fully capture variation in nursing workload and service organization[5, 6]. The hospital-level differences observed in the present study therefore reinforce the importance of considering workload alongside conventional staffing indicators when evaluating PACU nursing requirements.

Another important finding was the contribution of support and additional activities to estimated staffing requirements. The total CAS accounted for approximately 2%–6% of available working time, while the

IAF ranged from 2.15 to 3.04 full-time-equivalent nurses across the participating hospitals. These findings indicate that responsibilities not represented by routine patient-service statistics constitute a meaningful component of PACU nursing workload. Such activities included equipment and device management, teaching, supply management, administrative duties, anesthesia billing and data entry, research activities, external training, and acute pain service-related activities. Workload-based staffing studies in other clinical settings have similarly demonstrated the importance of accounting for activities beyond direct patient care when estimating nursing requirements[7, 9, 10]. Studies applying the WISN approach have further shown that appropriately defined activity standards and allowance activities are essential for translating service workload into staffing requirements[14]. Incorporating these activities allows staffing estimates to reflect a broader range of routine professional responsibilities rather than direct patient-care activities alone.

The present findings also illustrate the potential value of WISN as a structured framework for PACU workforce assessment. In contrast to staffing approaches based primarily on fixed ratios, WISN links workforce requirements to locally observed workload, available working time, activity standards, and allowance activities[8, 13]. This feature may be particularly relevant to PACUs, where workload depends not only on patient volume but also on the intensity and duration of recovery-related nursing activities and the organizational responsibilities assigned to nursing staff[2]. The hospital-level variation observed in this study suggests that a uniform staffing standard may not fully reflect differences in PACU workload across institutions. Periodic workload-based assessment may therefore complement existing staffing approaches by identifying discrepancies between available staffing and estimated service requirements and by informing institution-specific workforce planning.

The findings should nevertheless be interpreted within the scope of the WISN methodology. WISN estimates staffing requirements according to observed workload and defined activity standards; it does not establish that increasing staffing to the calculated level will necessarily improve patient outcomes. Nevertheless, evidence from both PACU-specific and broader acute-care settings indicates that nurse understaffing is associated with adverse patient outcomes[3, 4, 12]. However, the present study did not evaluate clinical outcomes such as postoperative complications, unplanned escalation of care, PACU length of stay, or patient safety events. The WISN ratios identified here should therefore primarily be interpreted as indicators of workload-based staffing adequacy rather than direct measures of quality of care. Future studies integrating WISN assessments with patient-level and workforce outcomes are needed to determine whether workload-based staffing adequacy is associated with measurable improvements in PACU safety, efficiency, and staff well-being.

Several limitations should be acknowledged. First, only four tertiary hospitals from a single province in China were included, which may limit the generalizability of the findings to hospitals with different service models, case mixes, or workforce structures. Second, although activity standards and workload parameters were derived from multiple sources, including operational records, direct observation, interviews, and expert consultation, some estimates depended on locally reported practices and expert

judgment and may therefore be subject to measurement variability. Third, the cross-sectional assessment was based primarily on workload data from 2025 and may not fully capture seasonal or temporal variations in surgical volume and PACU activity. Fourth, differences in local workflow and the allocation of support and additional responsibilities may limit the direct transferability of individual activity standards between institutions. Finally, this study focused on workforce requirements and did not examine relationships between staffing adequacy and patient or workforce outcomes.

In conclusion, the WISN assessment identified workload-based nursing staffing deficits across all four participating tertiary-hospital PACUs, with variation in the magnitude of the deficit among institutions. The findings also demonstrate that support and additional activities contribute to PACU nursing workload and should be considered when estimating staffing requirements. WISN provides a structured framework for integrating service workload, available working time, activity standards, and indirect responsibilities into workforce assessment. Further multicenter studies involving more diverse hospitals and incorporating patient and workforce outcomes are needed to evaluate the broader applicability and clinical relevance of workload-based PACU staffing models.

Declarations

Competing interests

The authors declare no competing interests.

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Author Contribution

Shuying Gao contributed to the conception and design of the study, data analysis and interpretation, and drafting of the manuscript. Mengting Ai contributed to data collection and conducted the semi-structured interviews. Faxing Wang contributed to the study methodology, data analysis and interpretation, and critical revision of the manuscript. Yun Xiang contributed to the conception and design of the study, supervised the research process, contributed to data analysis and interpretation, and critically revised the manuscript. All authors reviewed and approved the final manuscript.

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Data Availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request. Data supporting the main findings are provided within the article and its Supplementary Information.

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