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Algorithmic Scheduling to Improve Resident Well-Being and Equity in Call Distribution

--Manuscript Draft--

Manuscript Number:	JGME-D-25-01151
Full Title:	Algorithmic Scheduling to Improve Resident Well-Being and Equity in Call Distribution
Short Title:	
Article Type:	Educational Innovation
Keywords:	
Abstract:	Background Call schedules balance resident well being, staffing requirements, and compliance with Accreditation Council for Graduate Medical Education (ACGME) guidelines. Manual scheduling is time-intensive and can contribute to inequitable workload distribution and resident dissatisfaction. Objective To develop and evaluate a constraint-based scheduling algorithm designed to improve fairness and efficiency in call distribution within a psychiatry residency program. Methods A Python-based tool using Google OR-Tools CP-SAT generated the call schedule using hard and soft constraints. Hard constraints defined holidays, PTO, and post-call rest; soft constraints optimized fairness, spacing, didactic protection, and personal “non-call” requests. Fairness was assessed by Gini coefficients and temporal Gini indices stratified by postgraduate year (PGY). The study was conducted during the 2025-2026 academic year. Results Automation reduced inequality and improved schedule regularity. For PGY-2 mean Gini decreased from 0.042 to 0.012 (Δ −0.031; 95% CI −0.056 to −0.009) and temporal Gini from 0.380 to 0.321 (Δ −0.059; 95% CI −0.081 to −0.039). For PGY-3 Gini decreased from 0.110 to 0.037 (Δ −0.073; 95% CI −0.096 to −0.049) and temporal Gini from 0.415 to 0.353 (Δ −0.062; 95% CI −0.111 to −0.014). Scheduling time decreased fromby factor of ~10. Resident surveys (Nresponses-rate ~55%) showed higher satisfaction with fairness (+19 percentage points), and reduced reports of feeling overwhelmed (+19 percentage points). Conclusions The new program produced a more optimized and equitable call distribution in a psychiatry residency. This approach can be adopted by other programs and aligns with resident well-being, protecting didactic time, and systems-based practice goals.

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Work Counts
Abstract: 247
Manuscript: 1303 (including tables)

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Abstract

Background: Call schedules balance resident well being, staffing requirements, and compliance with Accreditation Council for Graduate Medical Education (ACGME) guidelines. Manual scheduling is time-intensive and can contribute to inequitable workload distribution and resident dissatisfaction.

Objective: To develop and evaluate a constraint-based scheduling algorithm designed to improve fairness and efficiency in call distribution within a psychiatry residency program.

Methods: A Python-based tool using Google OR-Tools CP-SAT generated the call schedule using hard and soft constraints. Hard constraints defined holidays, PTO, and post-call rest; soft constraints optimized fairness, spacing, didactic protection, and personal "non-call" requests. Fairness was assessed by Gini coefficients and temporal Gini indices stratified by postgraduate year (PGY). The study was conducted during the 2025-2026 academic year and deemed IRB exempt.

Results: Automation reduced inequality and improved schedule regularity. For PGY-2 mean Gini decreased from 0.042 to 0.012 (Δ −0.031; 95% CI −0.056 to −0.009) and temporal Gini from 0.380 to 0.321 (Δ −0.059; 95% CI −0.081 to −0.039). For PGY-3 Gini decreased from 0.110 to 0.037 (Δ −0.073; 95% CI −0.096 to −0.049) and temporal Gini from 0.415 to 0.353 (Δ −0.062; 95% CI −0.111 to −0.014). Scheduling time decreased fromby factor of ∼10. Resident surveys (Nresponses-rate ∼55%) showed higher satisfaction with fairness (+19 percentage points), and reduced reports of feeling overwhelmed (+19 percentage points).

Conclusions: The new program produced a more optimized and equitable call distribution in a psychiatry residency. This approach can be adopted by other programs and aligns with resident well-being, protecting didactic time, and systems-based practice goals.

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Introduction

Residency call scheduling is a recurring and time-intensive administrative task that directly affects workload equity, resident well-being, and program operations. Call schedules balance resident well being, staffing requirements, and compliance with Accreditation Council for Graduate Medical Education (ACGME) guidelines. Manual scheduling methods rely on iterative spreadsheet adjustments and can lead to unequal call distributions, inconsistent spacing between shifts, and scheduling fatigue for the chief resident or call committee. Algorithmic scheduling, while common in operations research, has rarely been applied within graduate medical education (GME) or psychiatry. To address these challenges, we developed and implemented a constraint-based scheduling software and compared it to the gold-standard (manual scheduling) using a quality improvement approach.

Methods

The scheduling program was implemented using Google OR-Tools CP-SAT, a mixed-integer optimization solver for constraint-satisfaction problems. Each resident-day pairing was represented as a binary decision variable, and the solver identified feasible solutions that satisfied all hard constraints while minimizing weighted penalties for soft preferences.

Hard-coded rules defined PGY eligibility, duty caps, and post-call rest. Soft optimization objectives promoted fairness and temporal spacing by minimizing inequality, maximizing inter-call gaps, respecting didactic and non-call requests, and minimizing repeated call-backup pairings. The resulting integer program typically solved to optimality or near-optimality within minutes for each ~4-month block with 3 blocks composing a full academic year. A summary of constraints and optimization logic is shown in Table 1. The new schedule created by the software was compared to previous year's schedule, which was constructed manually with Microsoft Excel using the same 3 block method. The Gini and Temporal Gini stratified by PGY level were used to objectively compare the two schedules. To assess subjective perceptions of fairness and well-being, anonymous pre- and post-implementation surveys were distributed electronically to all residents (maximum N ≈ 24 per year). Surveys included seven 5-point Likert items evaluating perceived fairness, balance, stress, flexibility, and overall well-being, with optional free-text comments. Response rates were 50% (12/24) pre-implementation and 59% (13/22) post-implementation. This study was conducted mainly during the 2025-2026 academic year. The Algorithm-based call schedule project including the distribution of anonymous pre- and post-implementation surveys to psychiatry residents was determined to be exempt from human subject's research per institutional IRB review. No patient data was used, and no identifiable resident information was collected.

Category	**Core Logic**
Hard- coded rules	PGY- specific eligibility by day type; one call and one backup per day (no overlap); PTO and holiday exclusions; rest protection after call.
Soft optimization goals	Minimize inequality across residents (Gini objective); maximize spacing between call shifts (temporal Gini objective); respect

	non- call and didactic requests when feasible; minimize repeated call- backup pairings; maintain balanced workload across blocks. Optimize PGY-2 “Golden weekends”.
Mathematical framework	Mixed- integer constraint satisfaction model solved via OR- Tools CP- SAT; objective function minimizes weighted penalties for fairness and spacing while ensuring all hard constraints are met.

Table 1. Summary of Scheduling Logic and Optimization Framework

Results

Implementation of the new scheduling software produced consistent improvements in fairness and call spacing across most PGY years (Table 2). Among primary call residents (PGY-2 and PGY-3), mean Gini coefficients decreased by 0.03–0.07 and temporal Gini indices by 0.05–0.06, representing a 25–35 % relative improvement in equity. PGY-4 coverage also became more evenly distributed (Δ temporal = −0.08). PGY-1 intern assignments remained balanced. Confidence intervals showed consistent improvement across the main call tiers despite a small sample size skewing formal statistical testing.

PGY	Metric	2024–2025 Mean	2025–2026 Mean	Δ Mean (New–Old)	95 % CI for Δ
1	Gini	0.069	0.052	−0.017	(−0.030 → −0.005)
2	Gini	0.042	0.012	−0.031	(−0.056 → −0.009)
3	Gini	0.110	0.037	−0.073	(−0.096 → −0.049)
4	Gini	0.019	0.006	−0.013	(−0.038 → 0.000)
1	Temporal Gini	0.430	0.371	−0.059	(−0.109 → −0.008)
2	Temporal Gini	0.380	0.321	−0.059	(−0.081 → −0.039)
3	Temporal Gini	0.415	0.353	−0.062	(−0.111 → −0.014)
4	Temporal Gini	0.372	0.289	−0.083	(−0.083 → −0.083)

Table 2. Fairness Metrics Before and After Automated Scheduling Implementation

Pre- and post-implementation surveys demonstrated consistent improvements in residents’ perceptions of fairness and workload balance following automation. Satisfaction with fairness increased from 50% to 69%, and the proportion rating the distribution of calls as balanced or very balanced rose from 50% to 77%. Reports of being rarely or never

overwhelmed increased from 50% to 69%, and ease of swapping calls improved from 42% to 62%. Perceptions of schedule support for well-being and communication clarity remained stable at moderate-to-high levels. These findings align with objective fairness metrics, indicating that algorithmic scheduling improved both quantitative equity and perceived manageability.

Q#	Domain	"Positive" Responses (Definition)	Pre (n = 12)	Post (n = 13)	Δ (pp)
Q1	Satisfaction with fairness	Satisfied + Very Satisfied	50%	69%	+19
Q2	Schedule accommodated personal needs	Well + Very Well	75%	69%	−6
Q3	Distribution of calls balanced	Balanced + Very Balanced	50%	77%	+27
Q4	Felt overwhelmed	Never + Rarely	50%	69%	+19
Q5	Ease of swapping calls	Easy + Very Easy	42%	62%	+20
Q6	Schedule supported well-being	Well + Very Well	42%	46%	+4
Q7	Conflicts or misunderstandings	Never + Rarely	67%	77%	+10

Δ = post – pre (percentage-point difference).

Table 3. Resident perception of call schedule pre- vs post-implementation

Lastly, the new software reduced schedule-building time from approximately 30 hours per block (manual) to less than 3 hours. Because the algorithm automatically applied all eligibility and fairness constraints, the call committee could focus on higher-level review rather than manual troubleshooting. Program leadership also noted that the generated schedules were easier to audit, as summary statistics on fairness and spacing were automatically available for review, supporting transparent oversight and rapid approval.

Discussion

This project demonstrates that a constraint-based, algorithmic approach can produce more equitable and temporally balanced call schedules than manual construction. The integration

of hard-coded eligibility and rest rules with fairness-oriented optimization objectives allows the system to out preform an average scheduler by finding optimized solutions that a manual approach would struggle to identify in any reasonable timely manner while also removing subjective bias. Due to the small sample size available, formal statistical testing was limited, but confidence intervals still showed consistent and significant improvement in call equity for PGY-1 to PGY-3. The PGY-4 year has the smallest number of calls and hence the smallest sample size which likely led to the less significant results seen.

Resident survey findings mostly supported these objective improvements, showing parallel improvement in perceived fairness, call balance, and reduced stress. The largest improvements in survey results occurred in perceived fairness and balanced call distribution, which is reflected by the more objective improvement in both Gini and Temporal Gini. Fairness and more optimized temporal spread of call likely led to decreased reports of feeling overwhelmed by the call scheduled. The ease of call switching was also drastically improved per the survey results. Call switching was difficult in the past due to the rigid spacing and post call rest requirements between call and back-up call shifts. Call switching likely became more accessible again due to more optimized temporal spread of assignments. Interestingly, the survey results showed a small decrease in satisfaction regarding the new software's ability to address personal needs. Increasing fairness and accommodating the ability to switch shifts more freely should have allowed personal needs to be better addressed, but the survey results disagree with this assumption. When constructed manually the individual creating the schedule would likely have various informal personal pieces of information about their co-residents, this is information that the new software does not have access to outside of formally requested PTO and non-call requests which can possibly explain the decreased survey results in this category.

Nonetheless, together the quantitative and qualitative findings overall suggest that the new scheduling software enhanced both measurable equity and subjective resident well-being. Beyond fairness, the new software-based approach streamlined administrative workload, allowing schedulers and leadership to focus on educational and well-being considerations rather than manual data reconciliation.

Conclusion

A constraint-based algorithmic scheduling program produced a more optimized and equitable call distribution with substantially less administrative effort in a psychiatry residency. This practical innovation is feasible for adoption by other programs and aligns with resident well-being, protecting didactic time, and systems-based practice goals.

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Conflicts of Interest: The authors declare no conflicts of interest.

Author Contributions:

Dr. Kuhnel led project design, algorithm development, and data analysis as the current PGY-3 call committee representative.

Dr. Mitchell constructed the prior manual schedules and contributed comparative data and manuscript revision as the previous PGY-3 call committee representative

Dr. Kothari assisted with survey development, data collection, and resident engagement.

Dr. Parker assisted with survey development, data collection, and resident engagement.

Dr. Waxman provided call schedule oversight, interpretation of findings, and final call schedule approval as Program Director.

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December 15, 2025

Lukas Kuhnel

Dear Lukas Kuhnel:

On 12/12/2025, the IRB reviewed the following submission:

Type of Review:	Initial Study
Title:	Algorithmic Scheduling to Improve Resident Well-Being and Equity in Call Distribution
Investigator:	Lukas Kuhnel
IRB Submission ID:	STUDY00007386
Sponsor:	None
Prime Sponsor:	None
IND, IDE, or HDE:	None
Documents Reviewed:	• Advisor Approval, Category: Other; • Data Elements, Category: Other; • IRB Exemption Form, Category: IRB Protocol;

The IRB determined that the proposed activity is not research involving human subjects as defined by DHHS and FDA regulations.

IRB review and approval by this organization is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these activities are research involving humans in which the organization is engaged, please submit a new request to the IRB for a determination.

All Covered Individuals must disclose all sponsored and non-sponsored Research Projects to the Office for Responsible Outside Interests (OROI) prior to Conducting Research if the individual is an Investigator. Please visit the OROI website for more information.

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We value your feedback and would appreciate you taking the time to complete our survey about your experience with the IRB staff: https://uarizona.co1.qualtrics.com/jfe/form/SV_ehQ04WxNA06b42i.

If questions arise at any time during your study, please email the general IRB inbox at VPR-IRB@arizona.edu.