

Waiting times, patient flow, and occupancy density in South African primary health care clinics: implications for infection prevention and control

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1 Abstract

2 Background

3 Transmission of respiratory pathogens, such as *Mycobacterium tuberculosis* and severe acute respiratory
4 syndrome coronavirus 2, is more likely during close, prolonged contact and when sharing a poorly ventilated
5 space. In clinics in KwaZulu-Natal (KZN) and Western Cape (WC), South Africa, we estimated clinic visit
6 duration, time spent indoors and outdoors, and occupancy density of waiting rooms.

7 Methods

8 We used unique barcodes to track attendees' movements in 11 clinics in two provinces, multiple imputation
9 to estimate missing arrival and departure times, and mixed-effects linear regression to examine associations
10 with visit duration.

11 Results

12 2,903 attendees were included. Median visit duration was 2 hours 36 minutes (interquartile range [IQR]
13 01:36–3:43). Longer mean visit times were associated with being female (13.5 minutes longer than males;
14 $p < 0.001$) and attending with a baby (18.8 minutes longer than those without; $p < 0.01$), and shorter mean
15 times with later arrival (14.9 minutes shorter per hour after 0700; $p < 0.001$) and attendance for tuberculosis
16 or ante/postnatal care (24.8 and 32.6 minutes shorter, respectively, than HIV/acute care; $p < 0.01$).

17 Overall, attendees spent more of their time indoors (median 95.6% [IQR 46–100]) than outdoors (2.5% [IQR
18 0–35]). Attendees at clinics with outdoor waiting areas spent a greater proportion (median 13.7% [IQR 1–
19 75]) of their time outdoors.

20 In two clinics in KZN (no appointment system), occupancy densities of ~ 2.0 persons/m² were observed in
21 smaller waiting rooms during busy periods. In one clinic in WC (appointment system), occupancy density did
22 not exceed 1.0 persons/m² despite higher overall attendance.

23 **Conclusions**

24 Longer waiting times were associated with early arrival, being female, and attending with a young child.

25 Attendees generally waited where they were asked to. Regular estimation of occupancy density (as patient
26 flow proxy) may help staff assess for risk of infection transmission and guide intervention to reduce time
27 spent in risky spaces.

28 **Key words**

29 tuberculosis; SARS-COV-2; COVID-19; transmission; airborne; nosocomial; infection prevention; healthcare-
30 associated infection; health services management

31

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32 **Background**

33 Transmission of respiratory infections is a persistent problem in health care facilities, where proportions of
34 attendees who are infectious and susceptible are likely to be higher than in other settings.^[1–3] As well as
35 creating risk for individuals attending for care, nosocomial transmission can ‘institutionally amplify’
36 epidemics and represents a serious threat to health care worker (HCW) safety.^[4–7] Pathogens such as
37 *Mycobacterium tuberculosis* (*Mtb*)^[8,9] and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-
38 2)^[10,11] are more likely to be transmitted during close, prolonged contact and between individuals ‘sharing
39 air’ in a poorly ventilated space.^[12,13]

40 Reducing overcrowding and time spent in health care facilities are recommended infection prevention and
41 control (IPC) measures for tuberculosis (TB) and other respiratory infections.^[14,15] Several initiatives to
42 reduce frequency of clinic visits have been tested and deployed, primarily with the intention of providing
43 ‘differentiated care’.^[16,17] However, interventions that focus on the movement of people around the facility
44 (‘patient flow’) have received less attention than individual-focused IPC interventions, such as mask-wearing,
45 triage, and prompt initiation of treatment,^[18,19] and ‘passive’ interventions, such as structural changes to
46 improve ventilation.^[20] This is partly because of the complexity of intervening to change patient flow or
47 waiting times in busy facilities, which can vary widely in size, layout, internal organisation, and patient
48 load.^[21] Considerations also differ for hospitals and primary health care (PHC) clinics; this article relates
49 mainly to operations at PHC level.

50 **Estimating time spent in South African PHC clinics**

51 The nearly 3,500 PHC clinics in South Africa function in diverse epidemiological, political, cultural, and
52 climactic conditions and serve individuals with a wide range of needs.^[22] Long clinic waiting times have been
53 documented over many years^[23,24] and are frequently cited as a concern for patients.^[25–27] The ‘Ideal Clinic’
54 initiative, devised and scaled up by the National Department of Health since 2013, aims to enable universal
55 standards of practice, routine measurement of relevant metrics, and fair comparisons of performance
56 between facilities.^[28] Regular estimation of waiting times is recommended by Ideal Clinic and is standard

57 practice in most clinics, though the methods used vary by province. National guidelines recommend that
58 total visit times should be less than three hours.^[29]

59 Most approaches to estimating waiting times conceptualise the patient's journey through the clinic as linear,
60 with each individual passing through the clinic as quickly as possible while ensuring that the necessary 'touch
61 points' are accessed. In South Africa, waiting times are usually measured through the provision of a physical
62 card to all or a selection of patients attending on the day.^[30] This card is time-stamped at the beginning and
63 end of each interaction with a service or 'touch point' (for example, when an individual has their blood
64 pressure measured or sees a clinician). This method is useful for estimating time spent waiting for services
65 and the efficiency of selected processes but is less useful in assessing risk of respiratory disease transmission,
66 as it does not describe where patients are waiting. This method also does not include non-patient attendees
67 (e.g., parents accompanying children), any of whom may be susceptible to infection or have undiagnosed
68 disease, nor does it allow for estimation of staff exposure to 'high risk' areas.

69 This work was conducted as part of the *Umoya omuhle* study, a multidisciplinary initiative taking a 'whole
70 systems' approach to TB IPC in South African PHC clinics.^[31] This study component aimed to develop and test
71 a method to 1) estimate how long attendees spent in clinics, and determine why some individuals spent
72 longer than others; 2) estimate how long attendees spend in outdoor and indoor clinic areas; 3) describe
73 variation in occupancy of waiting areas over the clinic day; and 4) collect data for mathematical modelling of
74 IPC interventions in clinics to reduce risk of *Mtb* transmission (McCreesh et al., in preparation).

75 **Methods**

76 The literature was reviewed to explore methods previously used to estimate waiting times, occupancy
77 density, crowding, and patient flow (Appendix 1). The methods that allowed estimation of the broadest
78 range of outcomes were waiting/working time surveys (either paper-based or using a real-time location
79 system)^[23,27,32] and camera-based systems.^[33–35] Given the resources available to the study, as well as the
80 ethical and logistical complications of using camera-based systems in multiple public clinics, an approach

81 based on waiting time surveys was used. As described below, unique barcodes and hand-held barcode
82 scanners were used instead of radio-frequency identification tags^[36–38] or a paper-based system.^[30]

83 **Data collection**

84 Data were collected in clinics in KwaZulu-Natal (KZN) province (coded KZN1–6) from 22 February to 14
85 March 2019 and in Western Cape (WC) province (coded WC1–6) from 14–22 May 2019. Clinics were visited
86 at least once prior to data collection to provide written information, discuss concerns with managers and
87 staff, and observe patient flow (Supplementary figure 1). On the day of data collection, a member of the
88 research team attended the morning staff meeting to answer additional questions and issue unique
89 barcodes to staff (including non-clinical staff). Each HCW who accepted a barcode was asked for their job
90 title and role that day. No other personal information was collected. Cards were used that could be easily
91 divided into two after completion to protect confidentiality (Supplementary figure 2). At the top of the card
92 was a unique one-dimensional (1D) barcode and brief instructions. The rest of the card contained a brief
93 questionnaire and the same 1D barcode. After questionnaire completion, the card was divided along a
94 perforated line, the bottom part returned to the researcher, and the top part retained by the participant (or
95 HCW) to be worn, on a lanyard, around their neck.

96 Researchers (usually 6–10 individuals, depending on the size of the clinic) were positioned at key points
97 throughout the premises, including facility entrance(s), the window where patient files were issued (filing
98 station), the triage/vitals station, and doorways of consultation rooms and waiting areas (Supplementary
99 figure 3). Each researcher carried a cordless, hand-held barcode scanner (OPN-2001, Opticon Limited, United
100 Kingdom); clinic staff in certain locations (most often consultation rooms) were also asked to carry scanners
101 and were instructed on how and when to use them. Scanners were cleaned of all data and time-
102 synchronised before each day's data collection.

103 All individuals attending the clinic during the hours of data collection were asked to participate. A researcher
104 approached attendees and explained the purpose of the study and that participation was voluntary and

105 anonymous. Numbers and details of individuals who refused were not recorded because the enrolment
106 process was time-sensitive. Individuals who agreed to participate were asked to complete the card
107 (recording their sex, age group, and reason for attendance) and to wear the barcode until they left the clinic.
108 If requested, the researcher completed the card on a participant's behalf. Individuals attending together had
109 their cards stapled together before storage; this was accounted for during data entry.

110 At the beginning of data collection, all individuals already in the clinic were asked to participate and their
111 location noted by use of a designated scanner. Simultaneously, researchers positioned at the entrance(s)
112 asked individuals who were entering the clinic to participate. Within 60–90 minutes of commencing data
113 collection, all individuals were offered the opportunity to participate; this sometimes took longer for busier
114 clinics.

115 Barcode scanners at doorways and other designated 'transition points' were used to scan every person with
116 a barcode who passed through. Scanners at filing or vitals stations (where blood pressure and other
117 measurements were taken), consultation rooms, or at other service points were used to scan an individual's
118 arrival and departure from that station or room. Individuals leaving the clinic had their barcode scanned as
119 they left. For logistical reasons, data collection was stopped at 1400; at this point all individuals remaining in
120 the clinic were scanned, with designated scanners used to note their location. A questionnaire was
121 administered to the facility manager or nurse in charge to record information about staffing levels and other
122 factors that may have affected service provision. The dimensions of waiting areas were measured using a
123 Bosch PLR 40R digital laser measure (Bosch, Gerlingen, Germany; accuracy +/-2 mm).

124 **Data management**

125 Data from barcode scanners were transferred to a password-protected computer at the end of each day's
126 data collection. Data from completed cards were entered into a Research Electronic Data Capture (REDCap)
127 database,^[39,40] hosted at the Africa Health Research Institute, that was programmed to assign a 'group ID' to

128 all individuals attending together (denoted by cards having been stapled together). Data from questionnaires
129 administered to facility managers were entered into a password-protected Excel spreadsheet.

130 **Analysis**

131 Analysis had three strands, examining 1) time spent in clinic and factors that influenced this; 2) the
132 proportion of each individual's time in clinic that was spent in indoor spaces (higher transmission risk) vs.
133 outdoors (lower risk, primarily due to better ventilation), and how this varied by clinic and reason for visit;
134 and 3) in clinics with more than one indoor waiting area, occupancy density of each indoor waiting area and
135 how this varied over the course of the day. Supplementary table 3 describes the clinics and numbers of
136 individuals included in each analysis.

137 **Time spent in clinic**

138 A large number of data were missing for arrival and departure times because several individuals were
139 already in the clinic when data collection began or remained in the clinic when data collection ended and
140 therefore did not have their arrival and/or departure time recorded. Multiple imputation was used to
141 generate arrival and/or departure times for individuals in whom one or both was not recorded (see
142 Appendix 2.2.1 for details).

143 Data were excluded from this analysis where clinic entry and exit were not recorded (because the research
144 team was too small to monitor all entrances and exits of the clinic). Using multiply-imputed data ($n = 20$
145 imputations), relationships between individual characteristics and time spent in clinic (continuous outcome)
146 were examined using a mixed-effects linear regression model with a random effect for clinic. Province was
147 included as fixed effect. The shape of the relationship between time of arrival and time spent in clinic was
148 examined using fractional polynomials regression with a set of defined powers ($-2, -1, -0.5, 0.5, 1, 2$, and
149 $\ln[x]$) and a maximum of two power terms in the model. The differences in model deviances were compared:
150 the linear model was used if the improvement in fit was not statistically significant at $p < 0.05$. Province, age
151 group, sex, and the ratio of patients to clinical staff were included in the multivariable model as a priori

152 confounders; other variables were included if they showed an important association ($p < 0.05$) in the
153 univariable model. Coefficients, representing the difference in mean time spent in clinic (in minutes), are
154 reported with 95% confidence intervals (CIs).

155 **Proportion of time spent indoors vs. outdoors**

156 Non-imputed data were used from clinics where a scanner had been positioned at all facility entrance/s and
157 all indoor/outdoor doorways. Individuals with a total captured visit time of less than five minutes were
158 excluded, as they were considered likely to have discarded their barcode. Each individual's pathway through
159 the clinic was mapped: for each barcode scan recorded, the individual's location in the time preceding the
160 scan was categorised as 'indoors', 'outdoors', or 'unknown' (if they appeared to have moved between two
161 unconnected locations, indicating a missing barcode scan) based on the location of their previous scan. Total
162 time spent in each type of location (as a proportion of the individual's overall recorded time in clinic) was
163 summarised by clinic and by self-reported reason for clinic attendance.

164 **Occupancy density**

165 Non-imputed data were used from clinics that had more than one indoor waiting area and where a barcode
166 scanner had been positioned at all entrances and exits of at least two waiting areas. Data were divided into
167 10 second slices and entries and exits from each demarcated space noted for each 10 second period; the
168 number of individuals within a space at the end of each 10 second period was divided by the floor area and
169 volume of that space to give the occupancy density (in persons/m² and persons/m³, respectively) for that 10
170 second period.

171 Analyses were conducted in Stata versions 14 and 16 (Statacorp, College Station, Tx). Figures were created
172 using Stata, Microsoft PowerPoint, Microsoft Excel, and Inkscape v0.92.4.^[41]

173 **Ethical considerations**

174 Identifiable data were not collected from participating individuals; written informed consent was not
175 requested. This study received ethical approval from the Biomedical Research Ethics Committee of the

176 University of KwaZulu-Natal (ref. BE082/18), the Human Research Ethics Committee of the Faculty of Health
177 Sciences of the University of Cape Town (ref. 165/2018), the Research Ethics Committee of Queen Margaret
178 University (ref. REP 0233), and the Observational/Interventions Research Ethics Committee of the London
179 School of Hygiene & Tropical Medicine (ref. 14872).

180 **Results**

181 Patient flow in study clinics was broadly organised around three key steps in the following order: 1) patient
182 registration (file collection); 2) vital signs; and 3) HCW consultation. Individuals usually waited in different
183 parts of the clinics for each step. The pathway taken depended on the reason for visit (many individuals also
184 visited one or more of the in-clinic pharmacy, phlebotomist, and other specialist practitioners) and was
185 implemented variably in clinics based on their size, design, and organisation of care. In most clinics,
186 individuals attending for TB care (i.e., those being investigated for TB or taking anti-TB treatment) were ‘fast-
187 tracked’ and skipped steps 1 and 2 above. Clinics varied widely in size, population served, services offered,
188 and organisation of care. Importantly, some clinics routinely asked patients to wait in covered outdoor
189 waiting areas, whereas others had only indoor areas. All clinics in WC and no clinics in KZN operated a date-
190 time appointment system for at least some patients (Supplementary table 5); no clinics had an active queue
191 management system.

192 Twelve datasets were available for analysis from 11 clinics: six in KZN and five in WC (Table 1; clinic WC4
193 could not be visited for logistical reasons and clinic KZN1 was visited for a second time to attempt better
194 coverage). Data were collected for 2,903 patients and visitors: 1,925 (66.3%) in KZN and 978 (33.7%) in WC).
195 Across clinics, a median 70% (interquartile range [IQR] 69%–74%) of clinic attendees were female. Most
196 individual characteristics were similar between provinces, with the only large differences seen in ‘main
197 reason for clinic visit’: in KZN clinics, a median 32.6% of clinic attendees reported attending for HIV care or
198 antiretroviral therapy (ART), compared with a median 3.5% in WC clinics. This was thought likely due, at least
199 in part, to an error during data collection in WC clinics, with ‘acute care’ consistently incorrectly marked by
200 those attending for HIV care (49% in WC vs. 29% in KZN). Because no identifying details of individuals were

201 collected, this could not be rectified, and the two categories were combined in analysis (but are shown
202 separately in Table 1).

203 [Table 1. Characteristics of clinics, individuals attending, and staff working on the day of data collection, overall
204 and by province \(N = 12 exercises at 11 clinics; N = 2,903 attendees\)](#)

205 **Time spent in clinics**

206 Data were excluded from clinic KZN4 (n = 269) as all entrances and exits had not been monitored. Data from
207 2,634 individuals attending 10 clinics (11 data collection exercises) underwent multiple imputation and were
208 included in this analysis (1,063 [40%] missing time of arrival and 934 [35%] missing time of departure;
209 Supplementary table 4). Overall median time spent in clinic was 2 hours 36 minutes (IQR 01:36–3:43). This
210 was similar in each province (KZN 02:33 [IQR 01:35–3:40; n = 1,656]; WC 02:42 [IQR 01:37–03:49; n = 978]).
211 Visit durations by demographics and reason for visit are provided in Supplementary table 6.

212 In univariable analysis (Table 2), there was strong evidence of an increase in mean time spent in clinic for
213 individuals who were female (p <0.001), attending with a baby (p <0.001), or attending with ≥1 other person
214 (p <0.01). There was also strong evidence of differences by reason for visit (p <0.01): individuals attending
215 for TB care and ante/post-natal care spent the shortest time in clinic. Mean time in clinic reduced by ~15
216 minutes for each hour that arrival was delayed after 0700 (p <0.001).

217 [Table 2. Results of univariable and multivariable mixed-effects linear regression using imputed data, showing
218 effects of different factors on total time spent in clinic \(n = 2,634; 11 exercises in 10 clinics\)](#)

219 In multivariable analysis, longer mean times remained associated with being female (13.5 [95% CI 6–21]
220 minutes longer than males) and attending with a baby (18.8 [95% CI 8–30] minutes longer than those
221 attending without). Reason for visit (p <0.01) and time of arrival (p <0.001) also remained important: those
222 attending for TB care or ante/post-natal care spent a mean 24.8 (95% CI 9–41) minutes and 32.6 (95% CI 11–
223 54) minutes less in clinic, respectively, than those attending for HIV/acute care, and mean time in clinic

224 reduced by 14.9 (95% CI 13–17) minutes for each hour that arrival was delayed after 0700. The results of the
225 fractional polynomial models showed that the linear model adequately described the relationship between
226 the time at clinic and arrival time (Appendix 3.2.1).

227 **Proportion of time spent indoors vs. outdoors**

228 The 2,190 clinic attendees included in this analysis (≥ 5 minutes captured; 10 visits; 9 clinics) spent a median
229 95.6% (IQR 45.6–100) of their time indoors and a median 2.5% (IQR 0–35.3) outdoors (Supplementary table
230 7), with the remainder in unknown locations. This varied by clinic (Figure 1A): in four clinics with an outdoor
231 waiting area that was used as part of normal patient flow, individuals spent a median 13.7% (IQR 1.4–74.5; n
232 = 1,362) of their time outdoors, compared with a median 0% (IQR 0–1.4; n = 828) outdoors among attendees
233 at the five clinics without an outdoor waiting area or where the outdoor area was not used.

234 [Figure 1. Box and whiskers plots showing proportions of time spent indoors and outdoors, by clinic \(panel A\)](#)
235 [and for two visits to clinic KZN1, by selected reasons for visit \(panel B\)](#)

236 In clinics with outdoor waiting areas, the wide IQR (1.4–74.5) for estimated time spent outdoors reflects the
237 considerable variation seen among attendees to clinic KZN1, where the outdoor waiting area is used only by
238 individuals in the ‘chronic’ stream. For example, in the second exercise at KZN1, individuals attending for
239 ‘acute’ care spent a median 89.8% (IQR 18.9–98.3; n = 118) of their time indoors, compared with those
240 attending for HIV care, who spent a median 98.6% (IQR 92.8–100; n = 125) of their time *outdoors* (Figure 1B).
241 Estimates by reported reason for visit for each clinic are provided in Supplementary table 8.

242 **Occupancy density of indoor spaces**

243 Data from three clinics were sufficient to estimate occupancy density of at least three indoor spaces (Figure
244 2). In clinic KZN6 (Figure 2, panel 2), the occupancy density of area A consistently declined over the course of
245 the day as individuals moved into areas B and C. Because of its relatively large volume, the occupancy
246 density of area A never went above 0.9 persons/m². In contrast, in the smallest space (area C), occupancy

247 peaked at around 1200, with density around or above 2.0 persons/m² from 1000–1200. In clinic KZN2 (panel
248 3), the smaller overall numbers of attendees meant that although the spaces are of similar size to clinic
249 KZN6, density was generally lower. Overall occupancy was highest in clinic WC1, but the larger waiting
250 spaces in this clinic meant that occupancy density was never higher than 1.0 persons/m² (panel 4), even in
251 the smallest space. Clinic WC1 also had a well-functioning date-time appointment system, which is likely why
252 occupancy of these spaces was more evenly distributed over the day compared with the other two clinics.

253 [Figure 2. Line graph and heat maps showing, respectively, total numbers of people in and approximate](#)
254 [occupancy density \(in persons/m²\) of three indoor waiting areas in each of clinics KZN2, KZN6, and WC1](#)
255 [between 0800 and 1345](#)

256 Occupancy density by room volume (persons/m³) was calculated for the same spaces (Supplementary table
257 9). This is a more relevant measure of occupancy density for predominantly airborne pathogens, such as
258 *Mtb*. All assessed waiting spaces in clinics KZN2 and KZN6 had relatively low ceilings (maximum height 2.5–
259 2.7 m) and occupancy density was higher (median 0.21–1.02 persons/m³) than in spaces in clinic WC1, where
260 ceilings were higher (maximum height 4.2–5.9 m; median occupancy density 0.10–0.14 persons/m³).

261 Discussion

262 We tracked 2,903 clinic attendees at 11 PHC clinics in two provinces of South Africa. Median time spent in
263 clinic was 2 hours 36 minutes (IQR 01:36–03:43). People who arrived early in the morning spent longer in
264 clinic, as did women and individuals attending with babies. Individuals attending for TB and maternal care
265 spent less time in clinic. People attending clinics that had outdoor covered waiting areas spent more of their
266 visit time outdoors, though differences were also seen between individuals attending the same clinic based
267 on how care was organised for different ‘streams’. In clinics with multiple indoor waiting areas, occupancy
268 was often not distributed evenly between areas or over time; periods of high occupancy density (>2
269 persons/m²) were observed in smaller waiting areas.

270 Time spent in clinic was below the national target maximum time^[29] of three hours for around 60% of clinic
271 attendees (ranging from 48% to 82% across clinics), but was over four hours for around 20% (range 7%–37%)
272 and over five hours for around 9% (range 4%–27%). Detailed comparison with other studies is challenging,
273 given the variation in operational characteristics of PHC clinics and methods used (Supplementary table 10).
274 On crude comparison, median time spent in clinic in our study was slightly higher than seen in recent South
275 African studies (Stime et al. [urban KZN, 2016],^[24] median 01:48 for sexually transmitted infection care and
276 median 02:46 for HIV care; Egbujie et al. [rural KZN, 2014],^[42] median 01:56 in nine PHCs) and slightly lower
277 than seen in older studies (Bachmann and Barron [urban WC, 1997],^[23] median 2.6 hours and 4.1 hours for
278 ‘preventive’ and ‘curative’ care, respectively). Patterns in our data were also observed by previous
279 investigators, including longer times for individuals who arrived earlier^[23,24,42] and the early arrival of the
280 majority of attendees, often before the clinic opened.^[30] A higher patient to nurse ratio was strongly
281 associated with longer waiting times in the study by Egbujie et al.,^[42] but not in our study, possibly because
282 our estimates of staff numbers included all clinical staff, not only nurses. We are not aware of any previous
283 studies that estimated proportions of time spent indoors vs. outdoors or the occupancy density of waiting
284 areas.

285 Early arrival and queueing outside clinics is common in South Africa. It is influenced by the frequent absence
286 of appointment and queue management systems; the organisation of services around the ‘morning rush’;
287 the lack of incentives for staff to change working patterns; and complex factors outside the health system,
288 such as the availability of public transport and the community’s trust in the system. Detailed exploration of
289 these issues is beyond the scope of this paper, but some discussion can be found in the report of an *Umoya*
290 *omuhle* workshop on patient flow that involved a range of South African experts.^[43]

291 The observed between-clinic and within-clinic variation in proportions of time spent indoors versus outdoors
292 reflects the importance of both clinic design and the organisation of care in moderating the risk of
293 respiratory disease transmission in these settings. The existence of an outdoor, ‘low risk’ waiting area is of
294 little benefit if most individuals spend most of their time in poorly ventilated indoor spaces. However, the

295 use of outdoor spaces may be less feasible in areas with lower temperatures. Thermal comfort and user
296 acceptability are important considerations when planning changes to patient flow.

297 In clinics where it may be impractical to wait outdoors, risk indoors can be moderated through more even
298 distribution of occupancy throughout the available space. For example, during the busiest period in a small
299 clinic like KZN6 (106 people in the clinic [Figure 3]), restricting occupancy of the smaller waiting spaces (B
300 and C) to 20 and 16 individuals, respectively, would have left 70 individuals in the largest space and resulted
301 in an occupancy density of around 1 person/m² in all three spaces. This is in line with 2014 WHO guidelines
302 for spatial separation as part of IPC for ‘epidemic- and pandemic-prone acute respiratory infections’, which
303 recommend maintaining a distance of at least 1 metre between patients.^[15]

304 South African draft national guidelines^[44] suggest a number of potential interventions to reduce waiting
305 times and improve patient flow. Some have been tested in South Africa and other similar settings and are
306 discussed briefly below.

307 **Potential interventions**

308 Interventions to improve flow can be classified broadly as targeting two domains: 1) reducing the number of
309 individuals overall and/or in particular spaces; and 2) reducing the time spent by attendees overall and/or in
310 particular spaces. Most measures affect both domains, sometimes indirectly.

311 Initiatives to reduce numbers of attendees include the Central Chronic Medicine Dispensing and Distribution
312 (CCMDD) system, where certain groups of patients collect chronic medication from community-based
313 sites,^[17,45] and reducing the frequency of routine clinic visits for certain conditions, for example by increasing
314 the amount of medication provided (trials among people taking ART have shown promising results).^[16,46–49]

315 Measures to improve the overall efficiency of the clinic aim to move people through the facility as quickly as
316 possible and to reduce the likelihood of bottlenecks in flow. These include holistic approaches, such as

317 'Lean',^[50,51] value-stream mapping,^[52] and other quality improvement methods,^[53] as well as more targeted
318 changes in staffing or resources at specific points in clinical pathways.^[24]

319 Streaming and triage interventions focus on the movement of people once they enter a health facility. In line
320 with Ideal Clinic guidance,^[28] every clinic in our study operated a streaming system that allowed people
321 attending for TB care to bypass many of the steps in the pathway. This is partly intended to reduce the risk of
322 *Mtb* transmission and is made feasible by the relatively small numbers of people treated for TB at each clinic
323 and because no additional triage process is required. Triage (broadly defined as the process of prioritising
324 patients for care based on their needs)^[54] has also been shown to reduce waiting times in a hospital in South
325 Africa, though it was less effective when used in two PHC clinics.^[55,56] Effective triage can be challenging and
326 resource-intensive to sustain,^[57] and sub-optimal implementation of symptom-based triage for TB IPC has
327 been documented by several studies.^[58-61] Active queue management has also been tested: a qualitative
328 study around the use of a 'Fast Queue' in clinics in KZN found that the use of multiple, managed queues was
329 generally well-received by attendees, particularly if accompanied by smooth (i.e., unidirectional) flow and
330 effective communication with HCWs, though there were still those who experienced long waiting times.^[62]

331 Date-time appointment systems have been most widely used to reduce both numbers of people and time
332 spent in clinics. Appointment systems have been shown to reduce waiting times in outpatient ART clinics in
333 Ethiopia^[63] and Kenya,^[64] antenatal clinics in Mozambique,^[65] and PHC clinics in South Africa,^[42] the last as
334 part of a suite of interventions that included streaming, training, and infrastructure upgrades. Investigators
335 describe generally encouraging results, though they also highlight the considerable challenges involved in
336 standardising implementation at facilities that are differently organised. During the *Umoya omuhle* patient
337 flow workshop, discussions around appointment system implementation emphasised the importance of
338 support processes (such as pre-retrieval of files) and technological infrastructure in sustaining this complex
339 intervention.^[43]

340 **Recommendations**

341 Building flexibility into the organisation of flow would allow a clinic to adapt to and absorb periods of
342 increased traffic without putting patients or staff at risk; for example, by moving people from an
343 overcrowded area to one that is relatively empty, or by activating 'overflow' covered outdoor waiting areas.
344 However, any such initiative would require 1) a queue management system, to ensure that individuals
345 moved between areas are not placed at a disadvantage, and 2) clinic managers to have a) easy access to
346 real-time information about flow and b) the resources and freedom to try to improve flow.^[27] Patient flow
347 can be difficult to measure quickly: previous published descriptions focus on largely qualitative descriptions
348 of observed movement patterns.^[23,66] Occupancy density, however, is easy to measure (e.g., through manual
349 headcounts) and, measured periodically across a clinic, could be used as a proxy estimate for flow. We
350 suggest that regular, light-touch ('diagnostic') approximation of this metric may have numerous potential
351 direct and indirect benefits, including improved efficiency; shorter waiting times; better clinic-specific
352 decision-making; and a strengthened relationship between the clinic and its community.^[27,43,67]

353 Importantly, interventions intended to reduce attendance and waiting times may adversely affect the flow
354 around the which the clinic was designed and may therefore increase the rate of transmission to an
355 individual during the time they do spend in the clinic. Most clinics are designed with waiting areas that get
356 successively smaller as patients move through the pathway; as pathways diverge, patients 'diffuse' through
357 the clinic and one would expect occupancy to be lower. However, if the overall 'patient load' is greater than
358 the capacity of the clinic, or if different stages of the pathway are variably efficient, or if certain attendees
359 (e.g., those with appointments) are allowed to skip parts of the queue, bottlenecks can arise in areas that
360 are designed to hold fewer people, leading to higher than optimal occupancy of 'downstream' areas and/or
361 under-use of 'upstream' areas. Interventions to improve flow and reduce waiting times are acutely
362 vulnerable to achieving "many small successes and one big failure"^[68] and should be undertaken with careful
363 consideration of potential effects on other parts of the pathway, possible increases in risk of disease

364 transmission, and adjustments that may be needed in resource allocation, ventilation, and the organisation
365 of care.

366 **Limitations**

367 The method employed in this study was relatively inexpensive, built on methods already widely used in
368 South African PHCs, and included elements that could be incorporated into routine estimation of waiting
369 times and flow. Numbers of individuals who declined to participate were not recorded and we were
370 therefore unable to assess for selection bias introduced by the enrolment process. Starting data collection
371 after some individuals had arrived and stopping data collection at 1400 (because of logistical restrictions)
372 reduced the numbers of individuals whose data could be used to estimate total waiting time, requiring the
373 use of multiple imputation to deal with missing data. Multiple imputation assumes that the data are missing
374 at random, which means that the observed values can be used to predict the missing values. However, if the
375 assumption is incorrect, the results may be biased. Furthermore, the validity of results derived from multiply
376 imputed data depend on the appropriateness of the imputation model. Future exercises should, at a
377 minimum, continue to record clinic exits for as long as possible. Because of variability between and within
378 clinics, and because data were collected on only one day from almost all clinics, estimates presented here
379 should not be considered representative of the two provinces, types of clinics, or the clinics themselves. In
380 busy clinics in particular, many attendees' barcodes were not scanned every time at every scanning point,
381 and estimates of waiting area occupancy and time spent indoors or outdoors should be treated as
382 approximations. Even so, our headline findings are plausible and consistent with those from other studies.

383 **Conclusions**

384 Measuring patient flow is important for estimating clinic efficiency and disease transmission risk. In our
385 study, women, individuals arriving early, and those attending with young children spent longer at clinic.
386 Attendees generally waited where they were asked to: using outdoor waiting areas as part of patient
387 pathways increased the proportion of visit time spent outdoors. Occupancy of indoor spaces varied
388 considerably over the day and people often were not distributed evenly throughout the available space.

389 Regular, light-touch estimation of occupancy density (as a proxy for patient flow) may help staff to assess for
390 the risk of nosocomial transmission and guide the use of interventions to reduce time spent in risky spaces.

391 **List of abbreviations**

392 ART: antiretroviral therapy; CI: confidence interval; HCW: health care worker; hh: hours; IPC: infection
393 prevention and control; IQR: interquartile range; KZN: Kwa-Zulu Natal; mm: minutes; *Mtb*: *Mycobacterium*
394 *tuberculosis*; NCD: noncommunicable disease; PHC: primary health care; REDCap: Research Electronic Data
395 Capture; ref.: reference; SARS-COV-2: severe acute respiratory syndrome coronavirus 2; TB: tuberculosis;
396 WC: Western Cape

397 **Declarations**

398 **Ethics approval and consent to participate**

399 Identifiable data were not collected from participating individuals and written informed consent was
400 therefore not requested. This study received ethical approval from the Biomedical Research Ethics
401 Committee of the University of KwaZulu-Natal (ref. BE082/18), the Human Research Ethics Committee of the
402 Faculty of Health Sciences of the University of Cape Town (ref. 165/2018), the Research Ethics Committee of
403 Queen Margaret University (ref. REP 0233), and the Observational/Interventions Research Ethics Committee
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405 **Consent for publication**

406 Not applicable.

407 **Availability of data and materials**

408 Data will be available from LSHTM DataCompass. Questionnaires used are provided in the supplementary
409 material.

410 **Competing interests**

411 The authors declare that they have no competing interests. All authors have completed the ICMJE uniform
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423 **Authors' contributions**

Conceptualisation	ADG, ASK, AV, HM, KK, NM, TAY
Methodology	ADG, ASK, AV, NM
Formal analysis	ASK, KB, NM
Investigation	ADG, ASK, IIK, IG
Resources	ADG, ASK, IG, NM
Data curation	ASK
Writing – original draft	ASK
Writing – review & editing	All authors
Visualisation	ASK
Supervision	ADG, AV, KB
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424

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Preprint

603 **Tables and figures**

604 **Table 1. Characteristics of clinics, individuals attending, and staff working on the day of data collection,**
 605 **overall and by province (N = 12 exercises at 11 clinics; N = 2,903 attendees)**

Characteristic	All clinics, n	KZN province, n (row %)	WC province, n (row %)
Number of clinics	11	6 (54.5)	5 (45.5)
Number of data collection exercises	12	7 (58.3)	5 (41.7)
Hours of data collection, HH:MM	77:02	44:32 (57.8)	32:30 (42.2)
Patients & visitors included	2,903	1,925 (66.3)	978 (33.7)
On the day of data collection	Median (range) per exercise	Median (range) per exercise	Median (range) per exercise
Hours of data collection, HH:MM	06:15 (05:37–07:18)	06:15 (05:40–07:08)	06:15 (05:37–07:18)
Clinical staff working*, n	16 (3–45)	14 (8–45)	17 (3–45)
Administrative staff working*, n	11 (4–21)	10 (7–17)	16 (4–21)
Patients† per clinical staff*, n	14 (5–27)	14 (6–27)	14 (5–18)
Patients and visitors included, n	252 (69–417)	269 (170–417)	144 (69–337)
Proportion female, %	70.0 (56.3–789.7)	71.2 (68.4–74.8)	69.2 (56.3–79.7)
Proportion aged			
0–5 years, %	9.1 (0.7–30.8)	8.4 (7.1–10.1)	10.4 (5.6–30.8)
6–15 years, %	3.4 (0–9.4)	3.5 (1.5–6.2)	3.2 (0–8.3)
16–25 years, %	17.3 (6.3–25.7)	20.1 (15.9–25.3)	15.0 (13.1–17.4)
26–35 years, %	27.3 (19.4–36.2)	27.8 (25.8–32.0)	22.5 (19.4–36.2)
36–45 years, %	18.6 (15.0–35.7)	18.0 (15.3–24.8)	20.3 (15.0–21.1)
>45 years, %	18.0 (7.2–35.4)	18.4 (17.1–22.1)	16.9 (7.2–35.4)
Proportion attending with a baby or very young child, %	11.5 (0.7–36.2)	11.2 (0.7–17.9)	12.1 (10.4–36.2)
Proportion attending with ≥1 other person‡, %	24.9 (1.5–60.8)	22.9 (1.5–35.9)	27.9 (15.4–60.8)
Proportion attending for			
Acute care/minor problems, %	37.0 (9.3–53.5)	28.8 (9.3–41.7)	48.7 (34.8–53.5)
HIV care/ART, %	16.1 (0.8–85.9)	32.6 (14.2–85.9)	3.5 (0.8–7.1)¶
Tuberculosis, %	3.8 (0.6–16.3)	2.2 (0.6–16.3)	9.0 (2.1–13.3)
NCDs (including mental health), %	4.4 (0–16.9)	4.1 (0.4–5.3)	6.9 (0–16.9)
Mother & child§, %	12.4 (0.7–30.4)	14.7 (0.7–19.7)	7.7 (4.2–30.4)
Maternal & obstetric, %	2.9 (0–8.7)	3.2 (0–4.7)	2.7 (0–8.7)
Accompanying a patient, %	14.6 (1.5–22.5)	12.4 (1.5–17.1)	19.2 (10.1–22.5)
Attending for another person, %	2.6 (0–6.3)	2.9 (0–4.3)	1.7 (0–6.3)

606 *Based on questionnaire administered to manager or senior member of staff; data from clinic KZ04 (including number
 607 of staff) captured only for HIV/chronic unit

608 †Counted as those who reported a main visit reason that was not ‘accompanying’ or ‘attending for another person’

609 ‡Not including babies and very young children

610 §Includes attendance for family planning

611 ||Two exercises conducted at clinic KZ01, roughly one month apart

612 ¶Likely due to an error during data collection (see text). ‘HIV care/ART’ combined with ‘Acute care/minor problems’ for
 613 subsequent analysis.

614 ART: antiretroviral therapy; KZN: KwaZulu-Natal; NCD: noncommunicable disease; WC: Western Cape

615 **Table 2. Results of univariable and multivariable mixed-effects linear regression using imputed data,**
 616 **showing effects of different factors on total time spent in clinic (n = 2,634; 11 exercises in 10 clinics)**

Variable	n	Univariable analysis*		Multivariable analysis*	
		Difference in time spent, <i>p</i> minutes (95% CI)		Difference in time spent, <i>p</i> minutes (95% CI)	
Province					
KwaZulu-Natal	1,656	REF	0.998	REF	0.734
Western Cape	978	-0.03 (-32.2, 32.2)		-5.1 (-34.8, 24.5)	
Sex					
Male	783	REF	<0.001	REF	<0.001
Female	1,851	17.0 (9.4, 24.5)		13.5 (6.0, 21.0)	
Age group					
<16 years	381	REF	0.250	REF	0.332
16–45 years	1,703	-7.0 (-17.8, 3.7)		-5.6 (-17.2, 5.9)	
≥46 years	550	-10.3 (-22.2, 1.6)		-9.9 (-22.7, 2.9)	
Patients† to clinical staff‡ ratio					
<10:1	698	REF	0.734	REF	0.821
≥10:1	1,936	-6.2 (-41.9, 29.5)		-3.8 (-36.9, 29.3)	
Attending with a baby or child aged less than ~15 months					
No	2,271	REF	<0.001	REF	0.002
Yes	344	25.6 (15.2, 36.0)		18.8 (8.1, 29.6)	
Not recorded	19	17.0 (-23.1, 57.1)		10.0 (-28.8, 48.8)	
Attending with ≥1 other person§					
No	1,983	REF	0.004	REF	0.076
Yes	651	12.6 (4.0, 21.2)		8.9 (-0.9, 18.7)	
Time of arrival					
Per hour later than 07h00	2,634	-15.1 (-17.1, -13.1)	<0.001	-14.9 (-16.9, -12.9)	<0.001
Reason for visit					
Acute care/HIV care	1,526	REF	0.002	REF	0.008
Tuberculosis	145	-27.2 (-43.8, -10.6)		-24.8 (-40.6, -8.9)	
NCDs (incl. mental health)	157	-9.1 (-24.4, 6.2)		-5.9 (-20.8, 9.0)	
Mother & child (incl. family planning)	297	9.5 (-2.6, 21.6)		-3.6 (-15.7, 8.5)	
Ante/post-natal	66	-22.1 (-44.4, 0.1)		-32.6 (-54.0, -11.2)	
Accompanying	360	2.9 (-7.9, 13.8)		-7.3 (-18.7, 4.2)	
Attending on another's behalf	79	-15.0 (-36.2, 6.3)		-11.6 (-32.0, 8.7)	
Not recorded	4	40.5 (-48.6, 129.5)		29.8 (-55.4, 115.1)	

617 *Mixed-effects linear regression with a random effect for clinic day (i.e., two visits to clinic 1 treated as separate
 618 clusters).

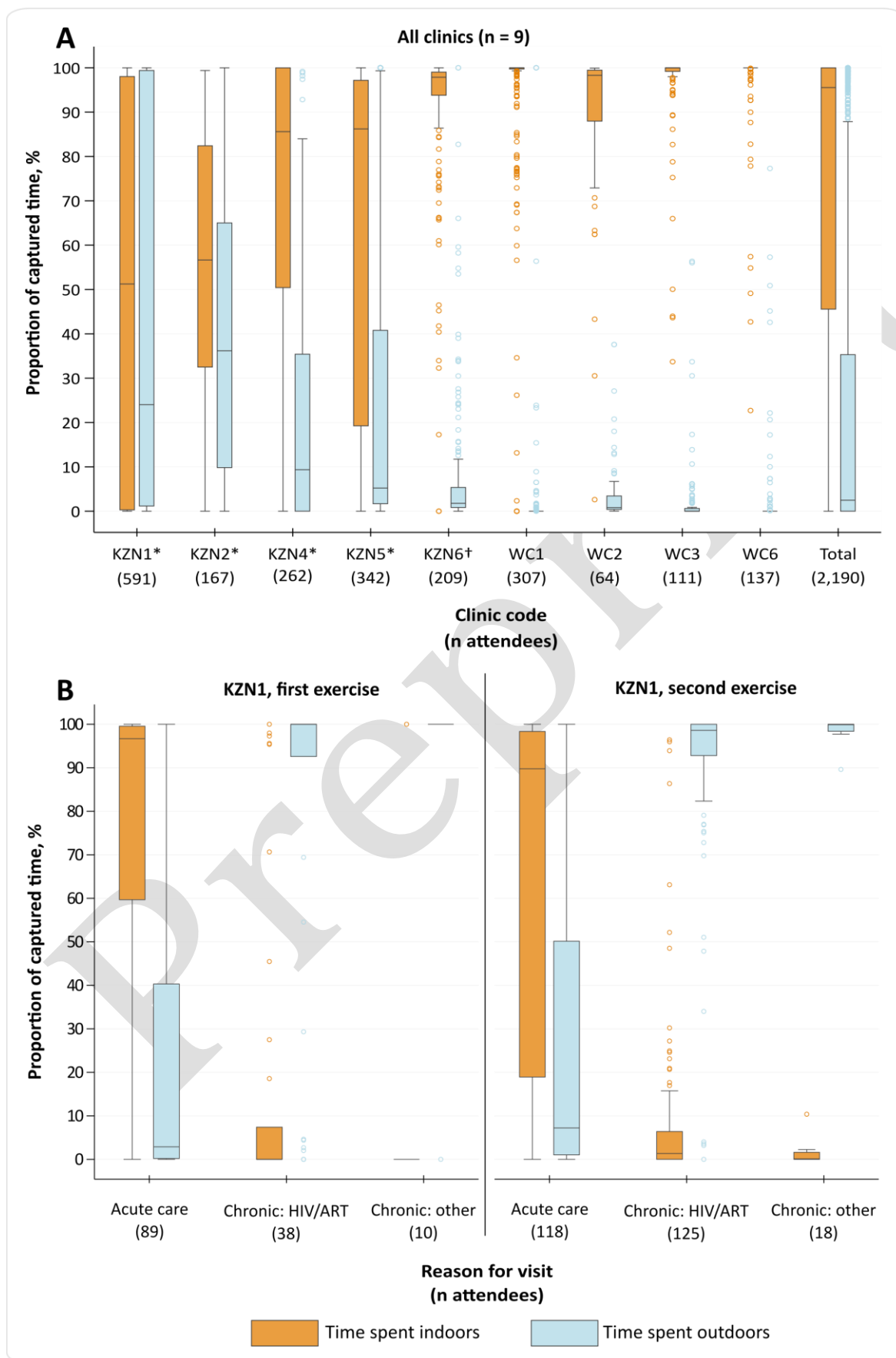
619 †Attendees who reported a main visit reason that was not 'accompanying' or 'attending for another person'

620 ‡Includes enrolled ('staff') and professional nurses, clinical nurse practitioners, clinical and enrolled nursing assistants,
 621 and doctors. Does not include lay-counsellors, peer navigators, community health workers, pharmacists, or
 622 nursing/medical students.

623 §Not including babies and very young children

624 ART: antiretroviral therapy; CI: confidence interval; incl.: including; REF: reference; NCD: non-communicable diseases

625 **Figure 1. Box and whiskers plots showing proportions of time spent indoors and outdoors, by clinic (panel**
 626 **A) and for two visits to clinic KZN1, by selected reasons for visit (panel B)**



627

628 *Clinic has at least one outdoor waiting area that is part of the patient pathway.

629 †Clinic has at least one outdoor waiting area, but it is not part of the patient pathway.

630 The central horizontal line represents the median value; boxes represent the interquartile range (IQR); and whiskers
631 represent largest and smallest values within 1.5 IQR of the upper and lower quartiles, respectively. Time spent in
632 unknown locations was negligible for most clinics and is therefore not shown.

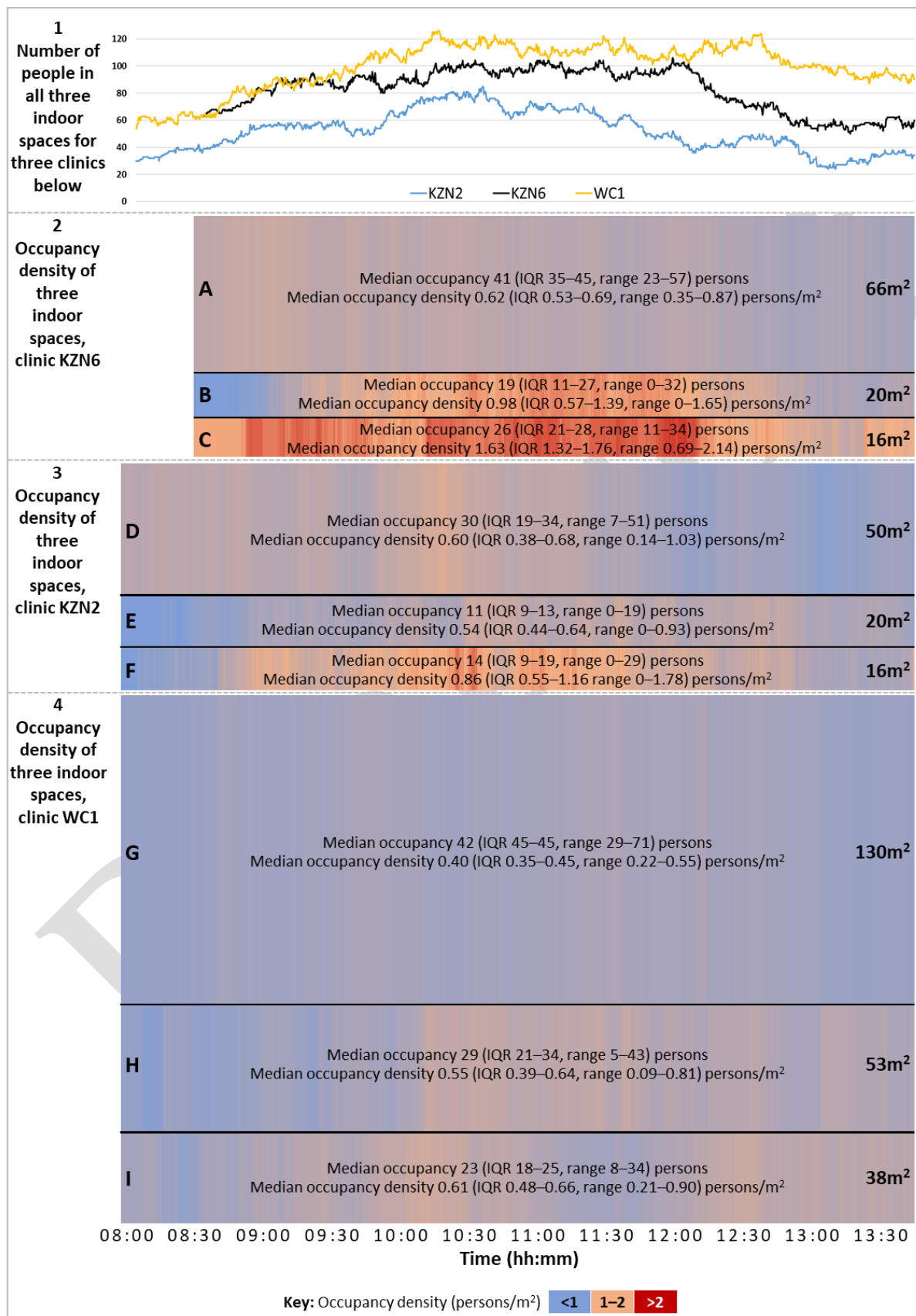
633 **Panel A:** Proportions are shown by clinic for all attendees at nine clinics with at least five minutes captured. Data from
634 both data collection exercises at clinic KZN1 are shown combined.

635 **Panel B:** Proportions are shown by self-reported reason for attendance for individuals with at least five minutes
636 captured who were attending clinic KZN1 for the three selected reasons.

637 ART: antiretroviral therapy; KZN: KwaZulu-Natal; TB: tuberculosis; WC: Western Cape

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638 **Figure 2. Line graph (panel 1) and heat maps (panels 2–4) showing, respectively, total numbers of people**
 639 **in three indoor waiting areas and approximate occupancy density (in persons/m²) of each waiting area in**
 640 **each of clinics KZN2, KZN6, and WC1 from 0800–1345***



641

642 *Data available only from 0830 for clinic KZN6.
643 Height of each row proportional to the area of the space. Each clinic was visited on a different day. See Supplementary
644 table 8 for occupancy density relative to room volume (persons/m³).
645 Total numbers (line graph) indicative only of numbers of people occupying the three spaces examined, not overall
646 numbers of people in the entire clinic.
647 Spaces A, D, and G were the main (pre-filing +/- pre-vitals) formal waiting areas for their respective clinics; spaces B, C,
648 H, and I were formal (pre-vitals and/or pre-consultation) waiting areas; space E was a corridor used as a pre-
649 consultation waiting area; and space F was a combined pre-vitals waiting area, vitals administration area, and patient
650 registration area.
651 hh: hours; IQR: interquartile range; mm: minutes

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