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Factor analysis of community-ranked built environment factors contributing to pedestrian injury risk in Kampala city, Uganda

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ABSTRACT

Background Examining community perspective on an issue is not only a key consideration in research on road safety but also on other topics. There is substantial theoretical and empirical knowledge on built environment factors that contribute to pedestrian injury but how the community views these factors is least studied and constitutes the focus of this study. Our study investigated how respondents ranked the relative importance of selected built environment factors that contribute to pedestrian injury risk in Kampala city, Uganda and examined the underlying pattern behind the rankings.

Methods Eight hundred and fifty-one pedestrians selected from 14 different road sections in Kampala city were asked to rank each of the 27 built environment variables on a 4-point Likert scale. Point score analysis was used to calculate scores for the different built environment variables and rank them in order of perceived contribution while factor analysis was used to determine the pattern underlying the responses.

Results Factor analysis isolated two factors that explained 92% of the variation in respondents' rankings: 'road adjacent trip generators and attractors' and 'structure of traffic flows'. This finding implies that pedestrians in Kampala city perceived trip generators and attractors adjacent to the road and the structure of traffic flows as major explanations of the influence of the built environment on pedestrian injury risk.

Conclusion While these rankings and factors identified may not necessarily equate to actual risk, they are important in providing an understanding of pedestrian injury risk from the perspective of the community.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Theoretically derived built environment factors associated with pedestrian injury risk.

WHAT THIS STUDY ADDS

⇒ Community ranking of the built environment factors that contribute to pedestrian injury risk.
⇒ Identifying the underlying pattern in the ranking of several built environment variables that contribute to pedestrian injury risk.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Road traffic practitioners' understanding of what built environment factors pedestrians assess as important and what the underlying patterns of these might be.

INTRODUCTION

Getting community perspectives on an issue is currently at the centre of public health, environmental and development research.[1–3] For example, Latulippe and Klenk[4] emphasise the need to create room for a diversity of perspectives in research and practice to identify issues that might have not been captured by professionals whom Robert Chambers has referred to as ivory tower experts.[5] Public health research has generally relied primarily on quantitative methods of inquiry.[6] Even though it has evolved to include social epidemiology, community views are still largely ignored. The importance of securing community perspective is reflected in the increasing emphasis on knowledge coproduction and participatory approaches, which seek to cogenerate knowledge with the involvement of local stakeholders that is useful.[7 8]

Researchers have developed models showing the dimensions of the built environment and how they contribute to pedestrian and overall road traffic injury risk. In their foundational work, Cervero and Kockelman[9] indicated that the built environment concept consisted of three core dimensions, namely, density, diversity and design (3Ds). More dimensions were later added to this well-cited model such as destination accessibility and the distance to transit.[10 11] These dimensions have led to several specific factors being identified and used in pedestrian road safety empirical research. The theoretical and empirical research that led to the generation of these factors mainly used secondary data and quantitative methods.[12–16] However, a systematic analysis of the community perspective on these factors is lacking in the literature. Moreover, existing research on the perspective of pedestrians and overall road traffic injury risk[17–25] has focused on a few selected factors but not on as many as possible of the factors advanced by Ewing and other researchers.

How the community views these factors is the core research problem and constitutes the contribution of this study to knowledge. This objective is achieved by asking respondents to rank 27 built environment variables on a 4-point Likert scale. Why is this knowledge necessary? It could point decision-makers to community knowledge and understanding of how these factors contribute to pedestrian injury as a basis to address them. This study answers two questions: (1) How do

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pedestrians in Kampala city, Uganda rank the relative importance of built environment factors contributing to pedestrian injury risk? (ii) Is there a pattern in the way pedestrians in Kampala city rank the built environment factors that contribute to pedestrian injury risk?

METHODS

Study design and setting

A cross-sectional survey in Kampala, the capital of Uganda, was conducted. Kampala has a day population of 2.9 million, 60% of which comprise the working class.[26] It is estimated that 50% of workers in Kampala walk to and from work.[27] Kampala is also a hub for all public transport in the country which consists of taxis or minibuses and commercial motorcycles, commonly referred to as boda bodas.[28]

Study population and study sample

The study population or community was adult pedestrians in Kampala city. The study sample included those that were found walking in selected spots on interview days.

Sample size

The sample size was calculated using the appropriate formula for such studies[29]; considering a 95% CI, 50% prevalence of pedestrians in Kampala city[27] and 5% maximum error. The sample size was adjusted for clusters existing using a design effect of 2. A 10% non-response was considered as observed in an earlier study.[21] A total of 851 pedestrians were selected.

Sampling technique

The study adopted both stratified random and convenience sampling techniques. Stratified random sampling was used to select road sections for interviewing pedestrians while convenience sampling was used to select pedestrians to interview at the selected road sections (whoever showed up at a selected interview location during the days and times the research assistants were present and consented was admitted into the study). For this study, we stratified 1582 crash locations identified from a previous study that used 5-year crash data (2015–2019) from the traffic police[30] into five categories (from very high risk to very low risk) based on total pedestrian crash frequency. Each category had different probabilities of selection of a road section as an interview location. All locations classified as very high risk were selected, while three locations from each of the remaining strata were randomly sampled totalling up to a list of 14 road sections. Details of the most prominent traffic attractors around the road sections selected for conducting interviews as well as the nature of the road design alongside other sampling strategy details are provided in table 1.

Data collection

Pedestrian intercept interviews were conducted in the selected road sections by trained research assistants. A semistructured questionnaire was used to collect pedestrian information including demographics and the rankings of the perceived contribution of 27 different built environment variables (listed in table 2) to pedestrian injury risk. The list of variables to be considered for ranking was generated based on built environment variables identified as being associated with pedestrian injury from previous research.[12–14 16 31 32] Some of the built environment variables were protective of injury risk such as speed calming measures while some increased risk such as arterial roads. The variables selected were examined thoroughly to determine their global use as well as application to Kampala.

Table 1 A sampling technique for the study

Category	Total pedestrian crash frequency (2015–2019) range	Total number of locations from phase 1 of the study	Probability of selection	Sampled interview sites per category and nature of prominent road design and/or road use around	Number of pedestrians killed or seriously injured (KSI) at the location (n)	Percentage proportion over total number KSI (n/N)100	Number of respondents to interview per location
Very high risk	>50	2 locations	100%	Clock tower[1,2]	74	0.18408	156
				Shoprite to container village stretch[2,4]	99	0.246269	208
High risk	50–30	4 locations	75%	Kibuye roundabout[2,3]	37	0.09204	78
				Mini price [1,2,4]	36	0.089552	76
				Spear motors [1,5,6]	31	0.077114	65
Mild/moderate risk	29–20	16 locations	19%	Katwe wansi[7]	27	0.067164	57
				Traffic lights-Wandegeya [2,5,8]	22	0.054726	46
				Madaala [2,7,9]	27	0.067164	57
Low risk	10–19	63 locations	5%	UMI-Jinja road [5,10,11]	14	0.034826	29
				North road-Entebbe road [7, 12,13]	16	0.039801	34
				Kiwatule Northern By-pass [12,14]	15	0.037313	31
Very low risk	1–9	1497 locations	1%	Kigudu zone Kalerwe [2,10,12]	1	0.002488	2
				Kawaala road near Yiga's church [15,16, 17]	1	0.002488	2
				Kobil Salama road[4,16,18]	2	0.004975	4

[1]Busy junction. [2] Market present. [3]Roundabout. [4]Taxi park. [5]School. [6]Factory. [7]Bend. [8]Junction with traffic lights. [9]Zebra crossing. [10]Wide road. [11]Multi lanes.[4] [12]Bars. [13]Recreation. [14]Slope. [15]Church. [16]Narrow road. [17]Ditch. [18]Petrol station.
*Number of pedestrians to interview at location is equal to number of KSI at location multiplied by percentage proportion.

Table 2 Built environment variables ranked for study

Number	Variable
1.	Schools
2.	Health centres/hospitals
3.	Markets/trading centres
4.	Retail shops
5.	Taxi parks
6.	Fuel stations
7.	Bars/night clubs
8.	Commercial areas with arcades and plazas
9.	Worship places such as churches and mosques
10.	Industries/factories
11.	Residential land use
12.	Population density of an area
13.	Socio-economic status of an area
14.	Highways
15.	Arterial/major roads
16.	Local/minor roads
17.	By-passes
18.	Fly-overs
19.	Junctions/intersections
20.	Roundabouts
21.	Traffic lights at intersections
22.	Speed calming measures, for example, humps
23.	Bends
24.	Number of lanes
25.	Width of roads
26.	Vehicular traffic
27.	Pedestrian volumes

Some variables such as market and trading centres, taxi parks and fuel stations were added as new variables based on the city of Kampala. For each of these 27 built environment variables, respondents were asked to indicate to what extent they perceived its presence influenced pedestrian injury risk. This was regardless of the direction of influence (whether positive or negative). Respondents then ranked the contribution of the variables to pedestrian injury risk on a 4-point Likert scale ranging from 4 (extremely high), 3 (high), 2 (moderate) and 1 (low).

The questionnaire was interviewer administered. Face validity was established by having colleagues in the same research area read through the questionnaire to ascertain the relevance of the questions on the tool. Before its use, the tool was pilot tested among pedestrians at a roundabout in Kampala city. Necessary modifications were made and the validated tool was then translated to the most common local dialect in Kampala. The questionnaire was then converted to electronic format using Kobo Collect software[33] and loaded onto a Kobo Collect-enabled mobile device. Data collection took place for 3 months (November 2021 to January 2022).

Data management and analysis

Data were downloaded online from Kobo Collect as an Excel file. The Excel file was then exported to STATA V.14 software (Stata, 2015) for analysis. Numerical values, or point scores, were allocated to the various categories of importance as follows; extremely high—4, high—3, moderate—2 and low—1. The overall ranking of the contribution of each variable to pedestrian injury risk was measured using point score analysis by totaling the point scores for all the pedestrians interviewed, for the variable in question. Point score analysis was used to rank variables in order of perceived contribution.

To reduce the number of built environment factors to a manageable number and establish a pattern among them, factor analysis, a data reduction technique, was used.[34] Principal component analysis (PCA) is another data reduction technique; however, factor analysis and not PCA was used because while factor analysis derives a mathematical model from which factors are estimated, PCA merely decomposes the original data into a set of linear variates. As such, only factor analysis can estimate the underlying factors relying on various assumptions for estimates to be accurate. The major assumption of factor analysis is that these algebraic factors represent real-world dimensions; the nature of which must be “guessed at” by inspecting which variables have high loads on the same factor. The suitability of the data for factor analysis was assessed using appropriate statistical tests. The first step in factor analysis was to determine the correlation among the variables. From the correlation matrix, there was generally moderate to low correlation among the variables. The correlation matrix was then rotated using varimax orthogonal rotation and was used to place factors in positions where variables with high correlations (loadings) on it could be isolated. The rotation produced factors and factor loadings; factor loadings tell us about the relative contribution that a variable makes to a factor.[34] An Eigenvalue is the sum of the squares of factor loadings. Eigenvalues explain how much of the total variance is explained by each of the newly derived variables. The Eigenvalue was used to determine which factors were significant and would, therefore, be retained for further description and analysis on account of the Kaiser criterion (Eigenvalues >1). Next, a confirmatory scree plot was performed for factor validation. The naming of each factor was done after examination of the common characteristics of the variables that loaded highly on it.

RESULTS

Respondent characteristics

One thousand, one hundred and ninety-two (1192) pedestrians were approached out of which eight hundred and fifty-one (851) were interviewed and three hundred and forty-one (342) refused to answer because they did not have time. The overall response rate was 60%. Five hundred and seventy (67.1%) of the respondents were male while the rest were female. The mean age of respondents was 33 years (SD=12.14; median=30) with the youngest respondent being 18 years and the oldest 72 years. Five hundred and fifty-four (65.1%) lived in Kampala while the rest lived outside Kampala. Mean years lived in Kampala were 14.5 (SD=10.65; median=11) with 1 year being the minimum and 68 years the maximum. The majority of the population (82.2%) worked in Kampala. Mean years worked in Kampala were 8 (SD=8.36; median=6) with less than 1 year being the minimum and 50 years the maximum. Nearly half (49.9%) were businessmen, followed by professionals (13.8%) and students (12.2%). Other occupations included drivers, casual labourers, security guards, farmers, and support staff; each making up less than 10%. The taxi was the most dominant means of transport used (41.5%), followed by walking (24. 9%) and commercial motorcycles (22.2%). Other means were private vehicles (7.4%) and cycling (3.9%). The majority of the respondents had not been involved in a traffic crash before (66.3%). Most of those involved in a crash before had been involved as pedestrians (73.5%). The bulk of the respondents had attained up to the secondary level of education (47.3%), followed by tertiary

Table 3 Total score for the ranking of perceived contribution of different built environment variables to pedestrian injury risk

		Perceived contribution of Built Environment variable to pedestrian injury risk								
Variable number	Built environment variable	Extremely high	Score in points	High	Score in points	Moderately high	Score in points	Low	Score in points	Total score in points
V09	Presence of worship places	6	24	474	1422	221	442	150	150	2038
V11	Presence of residential land use	16	64	451	1353	228	456	156	156	2029
V06	Presence of fuel stations	6	24	467	1401	225	450	153	153	2028
V16	Presence of flyovers/overpass	32	128	438	1314	188	376	193	193	2011
V20	Presence of calming speed-calming measures such as humps	5	20	442	1326	228	456	176	176	1978
V04	Presence of retail shops	10	40	392	1176	282	564	167	167	1947
V02	Presence of health centres	6	24	403	1209	236	472	206	206	1911
V10	Presence of industries	29	116	353	1059	219	438	250	250	1863
V15	Presence of by-passes	28	112	311	933	224	448	288	288	1781
V01	Presence of schools	4	16	364	1092	188	376	295	295	1779
V05	Presence of taxi parks	6	24	319	957	255	510	271	271	1762
V08	Presence of commercial activities	7	28	291	873	278	556	275	275	1732
V14	Presence of local roads	8	32	302	906	253	506	288	288	1732
V25	Socio-economic status of an area	16	64	305	915	197	394	333	333	1706
V19	Presence of traffic lights	3	12	279	837	249	498	320	320	1667
V22	Number of lanes	19	76	248	744	229	458	355	355	1633
V23	Width of roads	13	52	233	699	202	404	403	403	1558
V18	Presence of roundabouts	6	24	206	618	273	546	366	366	1554
V24	Population density	7	28	243	729	152	304	449	449	1510
V13	Presence of arterial roads	9	36	199	597	224	448	419	419	1500
V26	Vehicular volumes	6	24	223	669	164	328	458	458	1479
V21	Presence of bends	4	16	239	717	101	202	507	507	1442
V27	Pedestrian volumes	5	20	212	636	138	276	496	496	1428
V03	Presence of markets	3	12	141	423	229	458	478	478	1371
V07	Presence of bars	17	68	174	522	118	236	542	542	1368
V12	Presence of highways	8	32	74	222	166	332	603	603	1189
V17	Presence of junctions	3	12	79	237	109	218	660	660	1127

education (33.3%), primary education (16.8%) and no education (2.6%). Overall, the respondents sampled had diversity in age and experience.

Respondents' rankings and factors generated

Results of total scores for Likert-scale option for each variable are shown in table 3. The presence of worship places, residential land use and fuel stations were ranked as the top three built environment variables having the highest influence on pedestrian injury risk while the presence of bars, highways and junctions were ranked to have the lowest influence on pedestrian injury risk.

Two factors, accounting for 92% of the variability in road users' rankings, were retained as principal on the basis of the Kaiser criterion (Eigenvalues >1) (table 4) and the confirmatory scree plot (figure 1). Variables mostly closely related to factor 1 (factor loadings 0.6000 and above ranging from 0.6081-0.6882) were: worship places, commercial activities, residential land use, taxi parks and industries. Moderately related variables to factor 1 (factor loadings 0.5000–0.5900) were: health centres, fuel stations and retail shops. Factor 1 was, therefore, named '*road adjacent trip generators and attractors*'. This factor accounted for 76% of the tracer percentage. This finding implies that pedestrians in Kampala city considered trip generators and attractors adjacent to the road to be a major influence on pedestrian injury risk. Variables most closely related to factor 2 (factor loadings 0.7000 and above ranging from 0.7436-0.7673) were: vehicular volumes, pedestrian volumes and population density. Moderately related variables to factor 2 (factor loadings 0.5000–0.6900 were: bends and width of roads. Factor 2 was, therefore, named '*structure of traffic flows*', accounting for 16.07% of the tracer percentage. This result implies that pedestrians in Kampala city perceive the structure of traffic flows as a major explanation of the influence of the built environment on pedestrian injury risk. Variables with negative relationship included presence of highways for factor 1 and presence of traffic lights and social economic status for factor 2.

DISCUSSION

Factor analysis isolated 'road adjacent trip generators and attractors' as key contributors to pedestrian injury in Kampala city, Uganda. A keen look at variables that closely related on factor 1 (worship places, commercial activities, residential land use, taxi parks, industries, health centres, fuel stations, retail shops) reveals that these social, cultural and economic activities are the origins and destinations of trips for different purposes.[35] Being located near roads implies that pedestrian trips associated with these sites face injury risk during interaction with other modes of transport, especially if the road infrastructure and users do not adhere to high safety standards.[36] The safety-in-numbers phenomenon has been a point of discussion claiming that each pedestrian is safer if more pedestrians are there.[37] However, it could be argued that numbers are only protective if the infrastructure around is safer and road users adhere to safer behaviour. The insight from this

Table 4 Factors and loadings of the rotated factor matrix

Variable	Factor 1: Nature of land use around the road	Factor 2: Transport demand in relation to road design
V01 Presence of schools	0.4837	0.2197
V02 Presence of health centres	0.5905	0.2058
V03 Presence of markets	0.3822	0.2214
V04 Presence of retail shops	0.5725	0.1945
V05 Presence of taxi parks	0.6257	0.328
V06 Presence of fuel stations	0.5771	0.1617
V07 Presence of bars	0.3622	0.476
V08 Presence of commercial activities	0.6506	0.382
V09 Presence of worship places	0.6882	0.1886
V10 Presence of industries	0.6081	0.3209
V11Presence of residential land use	0.6447	0.2214
V12 Presence of highways	−0.0598	0.099
V13 Presence of arterial roads	0.185	0.334
V14 Presence of local roads	0.3713	0.2925
V15 Presence of by-passes	0.3432	0.1115
V16 Presence of flyovers	0.3378	0.0977
V17 Presence of junctions	0.0928	0.2751
V18 Presence of roundabouts	0.3407	0.247
V19 Presence of traffic lights	0.2355	−0.0525
V20 Presence of speed calming measures such as humps	0.4348	0.2911
V21 Presence of bends	0.2406	0.626
V22 Number of lanes	0.2875	0.4712
V23 Width of roads	0.1113	0.5282
V24 Population density	0.2169	0.7436
V25 Socio-economic status of an area	0.2509	−0.0311
V26 Vehicular volumes	0.1887	0.7673
V27 Pedestrian volumes	0.2243	0.7666
Eigenvalue	8.45	1.79
Percentage of the trace	76.01	16.07

finding is that the respondents look at the location of certain commercial, social and cultural activities located next to roads as contributing to pedestrian injury risk, which, from literature and experience in Kampala, could be related to interaction among trips generated and attracted or quality of safety in road infrastructure by which these locations are accessed.[38] Some of the built environment variables that closely related to this factor

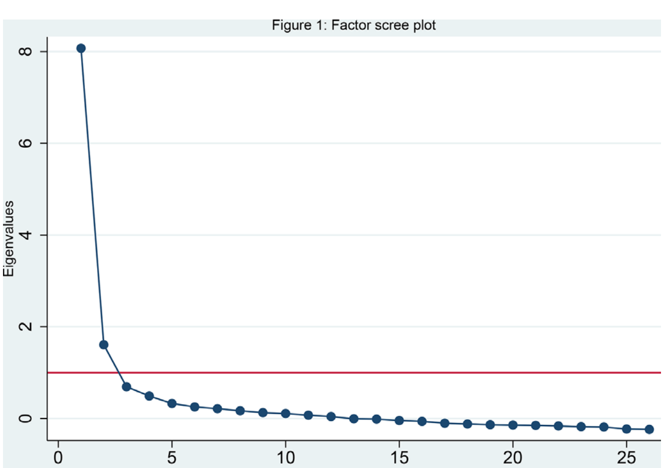

Figure 1 Factor scree plot.

may be based on the context in which the study was done. The essence of transport is to enhance the ability of these places to be reached safely,[36] but this consideration is not usually the case in this study's context. The above trip attractors and generators are generally designed in Kampala city without adequate safety consideration in their planning and development or the process of approval for the plans[38] despite the existence of guidelines.[39] In addition, they also have poor accessibility with inadequate consideration for pedestrians in terms of service, space and road infrastructure.[38] This situation contrasts with that obtained in some high-income countries, which have improved accessibility with pedestrian infrastructure present.[40]

Factor 2, 'structure of traffic flows', had vehicular volumes, pedestrian volumes and population density closely related to it followed by road width. This finding shows that respondents identified underlying issues related to amount, direction and interaction in traffic that could lead to injury risk to pedestrians. Overall, this factor points to ensuring safety in the flow of traffic as well as features of the road infrastructure such as road width that can increase risk, not only to pedestrians but also to other road users.[40] In the context of Kampala city, planning experience reveals shortcomings in planning for traffic flow. For example, most of the national road network comprises two-way single-carriageways, with no median to separate opposing traffic flows.[38] Kampala's transportation system is mostly dominated by a mix of pedestrians, private vehicles, taxis (matatu), motorcycles and heavy-duty vehicles due to shortage of public transport means.[28] This traffic mix, coupled with the ever-growing city population and poor traffic control methods, leads to crashes that sometimes result in permanent injuries and death.

A major limitation of this study was the omission of sidewalks and zebra crossings among the built environment factors to be ranked. This omission could have introduced information bias. We focused on the larger road infrastructure that would still create pedestrian risk, alluding to the quality of infrastructure at crossing points such as at junctions and intersections. The questionnaire also did not measure the direction of the relationship, whether the influence was perceived as positive or negative. This might have introduced a framing effect in the responses where people responded differently based on how they perceived the question. Another limitation is the use of convenience sampling, a non-random sampling technique that introduces the bias of the observer in selecting whom to interview. However, due to the transient nature of the study population and non-response, options such as quota sampling were not feasible. Finally, this study was conducted in a capital city in a low-income country, which could limit its external validity. While perceptions are useful, inferring risks from those perceptions may be incorrect in some settings.

Despite these limitations, this study makes a key contribution by providing community perspectives on the contribution of the built environment variables that have been associated with pedestrian injury risk through ranking on a Likert scale from highest to lowest. It also identifies the underlying pattern in the pedestrians' ranking of these built environment variables that contribute to pedestrian injury risk. While these rankings may not necessarily equate to actual risk, they are important in providing an understanding of pedestrian injury risk from the perspective of the community.

CONCLUSION

This study examined road users' rankings of the contribution of the built environment to pedestrian injury risk in Kampala city, Uganda. Factor analysis reduced 27 factors to two main factors, which were named ‘road adjacent trip generators and attractors’ and ‘structure of traffic flows’. These two factors explained 92% of the variance in road user responses. This study adds to existing research by assessing community perspectives through ranking within the context of a low-income setting at the scale of a city while incorporating many built environment variables.

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Contributors EB-Z is responsible for the overall content as guarantor and accepts full responsibility for the finished work right from the conduct of the study, access to the data, and controlling the decision to publish. EB-Z conceptualized the study, colducted data collection, analysis and writing the original manuscript draft. RN conducted analysis and reviewed the manuscript. MM supervised the study as well as reviewed the manuscript. All authors contributed to the writing of the paper.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Makerere University School of Public Health Research and Ethics committee and the Uganda National Council for Science and Technology under protocol number: HS960ES. Participants gave informed consent to participate in the study before taking part.

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Data availability statement Data are available upon reasonable request. The authors are pleased to share the dataset upon receiving a reasonable request. Interested parties may contact the corresponding author.

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