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Original Contribution

Injury patterns and mechanisms related to refrigerator and freezer utilization in the United States

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ABSTRACT

Introduction: Refrigerators and freezers (R/F) are a common household item and injury patterns associated with these appliances are not well characterized. We aimed to characterize the injury patterns, mechanisms, and affected body parts in patients treated in the emergency departments nationally, hypothesizing that injury patterns would differ by age group.

Methods: A retrospective review of the National Electronic Injury Surveillance System for all patients injured using R/F during 2010–2016 was performed. Patient narrative was reviewed for injury mechanism. Comparative and multivariable analyses were performed with effects reported as odds ratios with 95% confidence intervals (CI).

Results: During the study period (January 1, 2010-December 31, 2016) there were 6913 R/F related injuries. The study cohort was predominantly male 3734 (55%) and the median [IQR] age was 38 [22–56] years. The annual frequency of R/F related injuries was stable between years. The most common injury mechanism was falling while using R/F (31%) followed up injuries sustained while moving the appliance (25%). Teenaged patients more frequently struck the appliance compared to adults (39% vs 14%, $p < 0.001$). On regression, pediatric and elderly patients, mechanical fall mechanism, and cranial injury were risk factors independently associated with the need for hospitalization.

Conclusions: Falls in proximity to R/F were the most common injuries sustained and teenagers were more likely to strike/punch the appliance. Injury prevention efforts should support ongoing efforts of fall risk reduction for elderly populations.

Level of evidence: IV.

Study type: Retrospective.

1. Introduction

Pediatric and adult household injuries are not trivial. These unintentional injuries affect all age groups and represent a growing economic burden [1] with nearly 1.8 million household injuries reported annually [2]. Approximately half of injured patients will present to emergency departments [3] and the estimated annual unintentional injury costs ($25.2 million) are substantial [3, 4]. Unintentional household injuries contribute to an increased demand on healthcare resources but are also associated with premature mortality and substantial years of life lost per person [5]. While quality evidence evaluating household injury patterns exists [6, 7], these reports often lack details related to one of the largest and most common appliances – refrigerators and freezers.

Refrigerators and freezers (R/F) are large kitchen appliances with many households containing more than one unit [8]. Further, 3.6% of patients that sustained an injury due to R/F necessitated subsequent hospital admission [8]. The current paucity of data limits the appraisal of R/F injury patterns and mechanisms that are sustained by different age groups. In the present study, we evaluated and described specific R/F injury patterns and mechanisms. We hypothesized that different mechanisms of injury exist and that injury patterns would vary based on patient age group (pediatric, teenaged, adult, or >65 years).

2. Methods

2.1. Database and patient population

This is a retrospective study that incorporated data from an established and statistically valid injury surveillance system, the

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NEISS-AIP database (National Electronic Injury Surveillance System-All Injury Program) [9]. The NEISS-AIP database has been governed by the United States Consumer Product Safety Commission (CPSC) since 1972 with collaboration from the Centers for Disease Control (CDC) National Center for Injury Prevention and Control. The NEISS-AIP maintains information on non-fatal injuries and poisoning accidents from approximately 100 selected hospitals representative of the healthcare system nationally. Each included emergency department is continuously staffed and contains six or more beds. This database was selected as it provides cross-sectional sample estimates of injuries sustained by patients in the United States. Institutional review board approval was not required as the database is openly available to the public. This study is exempt from institutional review board approval.

2.2. Inclusion and exclusion criteria

In this study, we limited our analysis to patients that sustained injuries related to utilization of refrigerators and/or freezers. We utilized the CPSC product codes for freezers (263) and refrigerators (276) to query the NEISS for injuries during 2010–2016. No patients were excluded from this analysis.

2.3. Data abstraction and statistical analyses

Patient demographics, injury diagnosis code, anatomic location, injury locale, and treatment data were obtained. The patient narrative was queried to determine patients' mechanisms of injury (Table 1). All narratives were reviewed and categorized. The mechanisms of injury were utilized to further describe the injury diagnosis, anatomic location, and subsequent treatment provided. Warmer months were considered May–October and colder months were November–April. Age was categorized as pediatric (0–12 years), teenager (13–17 years), adult (18–64 years) and elderly (≥65 years).

Descriptive statistical analyses were performed. All normally distributed data were described using means with standard deviations (SD). Non-normally distributed data were reported using median with interquartile ranges [IQR]. Patients were compared and described between injury mechanisms and diagnoses using chi-square tests for categorical variables and independent *t*-tests for continuous variables. Non-parametric tests were used where parametric were inappropriate. A multivariable analysis to determine independent factors predictive of hospitalization was performed with effects reported as odds ratios (OR) with 95% confidence intervals (CI). CIs were calculated using likelihood ratio tests. Covariates were chosen based on being significant on univariate analysis ($p < 0.05$) or clinical relevance to the need for hospitalization. The models' sensitivity was described using the receiver operating characteristic (area under the curve, AUC) and calibration was reported using the Hosmer-Lemeshow test. Statistical significance was considered at a $p < 0.05$. Analyses were performed using JMP software version 13.0.0 (SAS Institute, Inc.).

Table 1
Injury mechanisms derived from patient narrative

Injury mechanism related to refrigerator or freezer	N = 6913
Punching, slamming, or hitting (with upper extremity)	1099
Pulling, moving, or lifting	1694
Cleaning	188
Climbing on or caught while jumping	152
Lifting or reaching items	716
Kicking	120
Closing or opening	579
Mechanical fall while using appliance	2163
Ingestion of products	34
Laceration	126
Electrical shock	24
Burn related injury	18

3. Results

3.1. Overall patient cohort

During the study period (January 1, 2010–December 31, 2016), there were 6913 R/F related injuries. The study cohort was predominantly male 3734 (55%) and the median [IQR] age was 38 [22–56] years. Injured patients in each age group included: 952 pediatric (0–12 years) patients (14%), 308 teenaged (13–17 years) patients (4%), 4366 adult (18–64 years) patients (63%) and 1287 elderly (≥65 years) patients (19%). During the study, the annual frequency of R/F related injuries was stable and the frequency of the six most common injury diagnoses did not change between years. Patient race (in descending order) consisted of White (n = 3354, 48.5%), not stated (n = 2254, 32.6%), Black/African American (n = 806, 11.6%), Hispanic (n = 392, 5.6%), Asian (n = 57, 0.8%), other (n = 37, 0.6%), American Indian/Alaskan Native (n = 10, 0.2%), and Native Hawaiian/Pacific Islander (n = 3, 0.1%). There were no considerable differences between groups based on race for injury mechanism, anatomy affected, or hospitalization.

3.2. Injuries in children

In children, injury mechanism differences based on sex, race, or time of year (cooler versus warmer months) were not observed. Among pediatric patients, the three most common injury mechanisms included 422 mechanical falls in proximity to R/F (44%), 189 injuries due to striking or hitting a R/F (20%), and 122 injuries that occurred while opening/closing a R/F (13%), Table 2. The most common sites of bodily injury included 290 injuries to the head (30%), 165 injuries to the face (17%), and 107 injuries to hands/fingers (11%). The majority of injuries (760, 80%) in pediatric patients occurred in a private residence. There were 10 crush injuries and a single occurrence of anoxia. Among children, 96% of patients received treatment at a hospital and were dismissed whereas six patients left against medical advice, 28 patients required

Table 2
Injury characteristics of children

Diagnosis	N = 952	Anatomic location	N = 952	Mechanism	N = 952
Laceration	375 (38)	Head	290 (31.3)	Mechanical fall	422 (44)
Internal organ injury	163 (17)	Face	165 (17)	Strike	189 (20)
Contusion, abrasion	144 (14)	Finger	107 (11)	Close/open	122 (13)
Other	59 (6.1)	Foot	83 (8.7)	Climb	58 (6)
Fracture	52 (5.5)	Toe	59 (6.2)	Pull/move	37 (4)
Strain/sprain	33 (3.5)	> 50% body	37 (3.9)	Shock	36 (4)
Poisoning	26 (2.7)	Hand	36 (3.9)	Lifting item	29 (3)
Concussion	16 (1.7)	Mouth	29 (3.1)	Kicking	29 (3)
Hematoma	13 (1.4)	Elbow	18 (1.9)	Ingestion	21 (2)
Ingestion object	10 (1.1)	Arm, lower	18 (1.9)	Burn	8 (1.7)
Crush	10 (1.1)	Leg, lower	17 (1.8)	Cleaning	1 (0.3)
Dislocation	9 (1)	Ankle	16 (1.7)		
Dental injury	9 (1)	Knee	14 (1.5)		
Thermal burn	7 (0.7)	Wrist	12 (1.3)		
Avulsion	7 (0.7)	Internal	11 (1.1)		
Burn scald	5 (0.5)	Shoulder	7 (0.7)		
Foreign body	4 (0.4)	Neck	7 (0.7)		
Burn electrical	2 (0.2)	Upper Trunk	4 (0.4)		
Aspiration	1(0.1)	Eye	4 (0.4)		
Puncture	1 (0.1)	Lower Trunk	4 (0.4)		
Anoxia	1 (0.1)	Ear	4 (0.4)		
Dermatitis	1 (0.1)	Upper arm	3 (0.3)		
		Not stated	3 (0.3)		
		Leg, upper	2 (0.2)		
		Pubis	1 (0.1)		
		25–50% body	1 (0.1)		

hospitalization, and a single patient expired. The expired patient narrative described a 1-month old male that suffered a traumatic head injury related to the R/F door but was diagnosed with sudden infant death syndrome.

3.3. Injuries in teenagers

Among teenaged patients, there were no considerable differences based on race, sex, or injuries during warmer or cooler months. The three most common injury patterns differed from pediatric patients. There were 117 patients (38%) that struck R/F, 94 that fell in proximity to a R/F (30%), and 34 patients that were injured while pulling or moving a R/F (11%), Table 3. Males more commonly struck R/F compared to females (48% versus 23%, $p < 0.001$). Conversely, females more frequently fell in proximity to R/F compared to males (40.3% versus 24.3%, $p < 0.001$). The most frequently injured anatomy included 158 injuries to the upper extremity (51%), 64 injuries to the head (21%), and 62 injuries to the lower extremity (20%). The most common diagnoses were contusions/abrasions (80, 26%), fractures (64, 21%), and lacerations (55, 18%). Injury locale included private residence (74%), not recorded (23%), public property (1.7%), school (1%), and a place of recreation (0.3%). In teenagers, there were four crush injuries and two patients that developed anoxia secondary to R/F. All patients were treated and dismissed to home however six patients required hospitalization and a single patient left against medical advice. There were no mortalities in this age group.

3.4. Injuries in adults

Among adults that sustained injuries associated with R/F, there were no substantive differences in injury mechanisms based on warmer versus cooler months or race, however, there were considerable differences noted between sexes. More males sustained injures related to pulling or moving R/F compared to females (44% versus 19%, $p < 0.001$). Furthermore, more females fell in proximity to R/F compared to males (32.3% versus 14.4%, $p < 0.001$). In adult patients the three most common injuries included 1504 injuries related to pulling or moving R/F (34%), 933 injuries related to falling in proximity to R/F (21%), and 737 injuries due to striking a R/F (16%). The most common diagnoses included strain/sprain (1051, 24%), contusion/abrasions (749, 17%), and other (748, 17%). The most common anatomic injury sites were the lower trunk (843, 19%), hand (735, 17%), and head (469, 11%), Table 4. There were forty crush injuries (1%) and three patients sustained anoxia (0.3%). Injuries occurred in the following locales private residence (3099, 71%), not stated (1197, 27%), public property (44, 1%), school (12, 0.3%), recreation place (8, 0.3%) and street (6, 0.3%). An overwhelming majority (95%) of patients were treated and sent home; however, 141 patients required hospitalization and sixty-one left against medical advice. There were no mortalities.

Table 3
Injury characteristics of teenagers

Diagnosis	N = 308	Anatomic location	N = 308	Mechanism	N = 308
Contusion, abrasion	80 (26)	Hand	108 (35)	Strike	117 (38)
Fracture	64 (21)	Head	49 (16)	Fall	94 (31)
Laceration	55 (18)	Finger	28 (0.9)	Pull/move	34 (11)
Internal organ	31 (10)	Foot	21 (6.8)	Lifting item	16 (5.2)
Other	27 (8.8)	Toe	21 (6.8)	Kicking	15 (4.9)
Strain/sprain	21 (6.8)	Face	12 (3.9)	Closing/opening	12 (3.9)
Concussion	8 (2.6)	Wrist	10 (3.5)	Cleaning	6 (1.9)
Avulsion	6 (1.9)	Knee	9 (2.9)	Shock	5 (1.6)
Crushing	4 (1.3)	Lower trunk	9 (2.9)	Climbing	4 (1.3)
Shock	2 (0.6)	All body	8 (2.6)	Ingestion	3 (0.7)
Poisoning	2 (0.6)	Upper trunk	7 (2.3)	Burn	2 (0.4)
Burn scald	1 (0.3)	Lower arm	7 (2.3)		
Dislocation	1 (0.3)	Lower leg	6 (1.9)		
Foreign body	1 (0.3)	Elbow	3 (0.9)		
Dental injury	1 (0.3)	Ankle	3 (0.9)		
Puncture	1 (0.3)	Shoulder	2 (0.6)		
Anoxia	1 (0.3)	Upper leg	2 (0.6)		
		Mouth	2 (0.6)		
		Ear	1 (0.3)		

Table 4
Injury characteristics of adults

Diagnosis	N = 4366	Anatomic location	N = 4366	Mechanism	N = 4366
Strain/sprain	1051 (24)	Lower trunk	843 (19)	Pull/move	1504 (35)
Contusion, abrasion	749 (17)	Hand	735 (16.9)	Fall	933 (21)
Other	748 (17)	Head	469 (10.7)	Strike	737 (17)
Fracture	604 (13.9)	Finger	383 (8.8)	Lifting item	552 (13)
Laceration	583 (13.3)	Upper trunk	321 (7.4)	Closing/opening	270 (6.2)
Internal organ	258 (5.9)	Shoulder	262 (6)	Cleaning	122 (2.8)
Concussion	77 (1.8)	Foot	239 (5.5)	Shock	73 (1.7)
Dislocation	54 (1.4)	Toe	173 (4)	Climbing	72 (1.6)
Nerve damage	50 (1.1)	Knee	131 (3)	Kicking	67 (1.5)
Crushing	40 (1)	Wrist	125 (2.9)	Burn	29 (0.6)
Avulsion	40 (1)	Face	122 (2.8)	Ingestion	7 (0.2)
Poisoning	23 (0.5)	Lower arm	94 (2.2)		
Hematoma	21 (0.5)	Lower leg	82 (1.9)		
Electric shock	21 (0.5)	Ankle	76 (1.7)		
Burn scald	11 (0.3)	Neck	69 (1.6)		
Foreign body	9 (0.2)	All body	59 (1.4)		
Burn chemical	5 (0.1)	Elbow	56 (1.3)		
Burn thermal	5 (0.1)	Upper arm	33 (0.8)		
Puncture	5 (0.1)	Upper leg	31 (0.7)		
Anoxia	3 (0.1)	Eyeball	26 (0.6)		
Dermatitis	3 (0.1)	Not stated	14 (0.3)		
Amputation	2 (0.1)	Pubis	9 (0.2)		
Dental injury	2 (0.1)	Mouth	8 (0.2)		
Burn electrical	1 (0.1)	Ear	6 (0.1)		
Hemorrhage	1 (0.1)				

3.5. Injuries in the elderly

Among the elderly, there were no injury mechanism differences based on sex, race, or time of year (cooler versus warmer months). Elderly patients sustained the following common injury mechanisms: 714 falls in proximity to R/F (55%), 175 injuries related to closing/opening a R/F (14%), and 119 injuries while moving/pulling a R/F (9%). The most common diagnoses included: fracture (281, 22%), internal organ injury (240, 19%), and contusions/abrasions (213, 17%), Table 5. Injured body parts included the head (498, 39%), trunk (361, 28%), and internal organs (215, 17%). There was a single crush injury and three patients developed anoxia. Similar to the other age categories, most patients were injured in a private residence and there were 153 injury locales not reported, thirty-eight on public property, one on a street, and one injury in a mobile home. Only 72% of patients were treated and dismissed to home whereas 348 patients required hospitalization, six left against medical advice, and a single patient expired. The patient was a 71 year-old male who experienced sudden cardiac arrest while moving a refrigerator; cardiopulmonary resuscitation was unsuccessful.

3.6. Uncommon R/F injuries

Overall, there were thirty-four (0.5%) ingestion-related injuries and the majority were in the pediatric population 24 (71%). Items that were ingested in the pediatric population included medicines ($n = 10$), magnets ($n = 8$), rodent poison ($n = 8$), refrigerant coolant ($n = 5$) and spoiled food ($n = 3$). Patients with ingestion-related injuries frequently had significant injuries involving the majority of their body ($n = 19$, 56%) or internal organs ($n = 8$, 24%). There were 0.3% of patients that sustained electrical shock injuries ($n = 24$) occurred predominantly while plugging or unplugging the refrigerator/freezer to

Table 5
Injury characteristics of elderly patients

Diagnosis	N = 1287	Anatomic location	N = 1287	Mechanism	N = 1287
Fracture	281 (22)	Head	390 (30)	Fall	714 (55)
Internal organ	240 (19)	Lower trunk	266 (21)	Closing/opening	175 (14)
Contusion, abrasion	213 (16.5)	Upper trunk	95 (7.4)	Pulling, moving	119 (9.2)
Laceration	181 (14.1)	Face	65 (5.1)	Lifting item	119 (9.2)
Other	171 (13.3)	Lower leg	48 (3.7)	Cleaning	59 (4.6)
Strain/sprain	108 (8.4)	Lower arm	44 (3.4)	Strike	56 (4.4)
Avulsion	30 (2.3)	Shoulder	40 (3.1)	Climbing	18 (1.4)
Hematoma	24 (1.9)	Knee	36 (2.8)	Shock	12 (1)
Concussion	11 (0.9)	Finger	36 (2.8)	Kicking	9 (0.7)
Dislocation	11 (0.9)	Foot	34 (2.6)	Burn	3 (0.2)
Nerve damage	4 (0.3)	Neck	34 (2.6)	Ingestion	3 (0.2)
Poisoning	4 (0.3)	Hand	33 (2.6)		
Anoxia	3 (0.2)	Shoulder	30 (2.3)		
Burn	1 (0.1)	Upper arm	28 (2.2)		
Burn chemical	1 (0.1)	Toe	25 (1.9)		
Burn therma	1 (0.1)	Upper leg	21 (1.6)		
Crush	1 (0.1)	Wrist	19 (1.5)		
Puncture	1 (0.1)	All body	16 (1.2)		
Hemorrhage	1 (0.1)	Elbow	15 (1.2)		
		Eyeball	4 (0.3)		
		Not stated	3 (0.2)		
		Ear	3 (0.2)		
		Mouth	2 (0.1)		

the electrical outlet. Two electrical injuries were due to touching exposed refrigerator/freezer wiring. The most uncommon injury pattern was burns (n = 18, 0.3%); patients were burned while defrosting the refrigerator using boiling water (n = 12), transporting hot liquids (n = 5), and changing a lightbulb (n = 1).

3.7. Results of the multivariable analysis identifying risk factors for hospitalization

Results of the multivariable logistic regression determined that the following factors were independently associated with requiring hospitalization: elderly age, mechanical fall in proximity to R/F, head injury, injuries within a private residence, and male sex (Table 6). The model demonstrated considerable sensitivity with an AUC (0.81), suggesting that these variables were independent risk factors associated with the need for hospitalization. The goodness of fit was appropriate; Hosmer-Lemeshow test (p = 0.38).

4. Discussion

Non-fatal injuries are responsible for a significant healthcare burden. In the present analysis, we set out to determine the frequency and patterns of injuries sustained by patients in the United States that involved R/F. The primary finding was that the most common injury mechanisms associated with R/F involved falls while patients were utilizing the appliances. Patient falls were associated with a variety of diagnoses and injured body parts. On regression, several risk factors (≥65 years, mechanical fall, male sex, head injury, and home location) were independently associated with the need for hospitalization. A majority of injuries took place within the home setting, highlighting that R/F owners must be aware of potential ongoing injury risk. Finally, we demonstrate that teenaged patients frequently struck R/F with patterns of significant injury to the upper extremities and that among teenagers, males more commonly struck R/F compared to females.

Table 6
Factors independently associated with need for hospitalization

Variable	Odds ratio with 95% CI	*p* value
Male sex	1.3 (1.02–1.6)	0.02
≥65 years of age	9.9 (8–12.3)	0.0001
Home locale	1.6 (1.2–2.1)	0.0008
Fall	2.2 (1.7–2.7)	0.0001
Head injury	1.3 (1.1–1.7)	0.009

Model sensitivity area under the curve 0.81 and the model indicated good fit (p = 0.38, Hosmer-Lemeshow test).

Unintentional injuries often occur within the household setting representing a significant problem for patients in all age groups [10, 11]. Falls are a leading cause of death and disability in several age groups [12], and the present study highlights that elderly patients >65 years old, as well as pediatric patients, fell more frequently. Alamgir et al. determined that mortality risk associated with falls increased with patient age [13]. In the present study, mortality risk was not able to be estimated since so few patients expired; however, falls were independently associated with hospitalization in addition to truncal injury and pediatric or elderly age groups. As the U.S. population ages, efforts to mitigate the risk of fall-related injuries must be considered [1]. Further, risk factors for mortality after injuries from falls in pediatric populations, such as intracranial injury, but not fall height, should be considered in triage criteria [14]. This study adds that in home settings, fall risk might be considered when patients utilize these appliances and that injury prevention awareness should be tailored to specific age groups [15].

Historically, crush asphyxia secondary to an appliance falling over or suffocation due to refrigerator entrapment was a source for child morbidity and mortality [16, 17]. Since the introduction of the Refrigeration Safety Act [18], the incidence of the entrapment and suffocation associated with R/F has declined [19]. This coincided with the addition of several additional laws that limited the internal R/F space as well as the requirements for discarding/abandoning these appliances [19]. Since R/F entrapment was and continues to be catastrophic in recent instances [20, 21], efforts to increase public awareness deserve continued merit. In an effort to ameliorate the need for R/F door seal and child self-extrication, children were simulated in R/F entrapment [22]. The authors determined that standard release mechanisms are sufficient for the majority of children who might become entrapped [22]. In the present study, several children experienced entrapment and developed anoxia; however, none expired from this injury mechanism. The low incidence of this injury pattern suggests that the passive changes implemented for R/F safety were effective.

Hand injuries are common in the pediatric population [23]. Shah et al., also utilizing the NEISS database, determined that pediatric hand injury prevention efforts should target the home environment as well as sport/recreational activities [23], but the authors excluded one of the common household appliances, R/F. In this study, we demonstrated that punch/slam/hit injuries were more frequent in the pediatric population. Teenagers 13 years or older appeared to have the highest incidence of punch/strike injury which coincided with hand/wrist injuries. Similar to Shah et al., we demonstrate that lacerations and contusions were also common pediatric upper extremity injuries. This study underscores the need for a thorough upper extremity inquiry in younger patients that present to the emergency room after striking or punching a refrigerator. Further, attention to patient psychiatric and mental health should be considered as well. Risk factors for pediatric hand injuries include positive psychiatric history including attention-deficit hyperactivity disorder, depression, and substance abuse [24]. While the NEISS does not provide detailed radiologic reports nor discharge diagnoses, identification of hand and wrist fractures can be nuanced and providers should remain vigilant for uncommon fracture patterns in this population.

There are several limitations to this study, foremost its retrospective nature. This impacted the present study by limiting the ability to granularly report the injury mechanisms as well as any other injuries sustained. Further, we were unable to account for the details regarding the few patients that required hospitalization or transfer. The number of injuries in this study that were associated with R/F was likely an underestimate of the true annual incidence in the United States. The NEISS database does not collect detailed information on all patients and remains

only a representative sample nationally. Patient narratives may not have provided the granular detail necessary to determine exact injury mechanisms. Finally, the NEISS is limited inherently by the documentation, extraction, and coding errors inherent to large databases. Despite these limitations, the present study addresses a critical gap in the scientific knowledge regarding injury patterns, diagnoses, and mechanisms associated with common household injuries.

5. Conclusion

This is the first investigation estimating the impact of injuries sustained by patients that were associated with R/F. Injuries were most commonly due to patient falls while using the R/F. The significant differences between age groups, such as teenagers being more likely to strike/punch the appliance, should guide injury prevention efforts.

Author contributions

MCH, JRA, JMA, EJF, NPM, and MDZ all contributed to the study idea, data acquisition and interpretation and provided writing as well as critical revisions for this manuscript.

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