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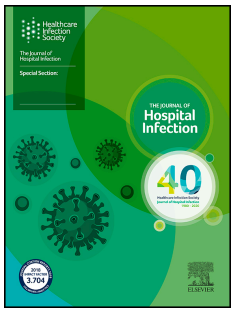

Influence of environmental temperature and heatwaves on surgical site infection after hip and knee arthroplasty: a nationwide study

Lauro Damonti, MD, Andrew Atkinson, PhD, Lionel Fontannaz, Jason P. Burnham, MD, Philipp Jent, MD, Nicolas Troillet, MD, MSc, Andreas Widmer, MD, MSc, Jonas Marschall, MD, MSc, for Swissnoso, the National Center for Infection Control

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Title: Influence of environmental temperature and heatwaves on surgical site infection after hip and knee arthroplasty: a nationwide study

Authors: Lauro Damonti, MD[1], Andrew Atkinson, PhD[1], Lionel Fontannaz[2], Jason P. Burnham, MD[3] Philipp Jent, MD[1], Nicolas Troillet, MD, MSc[4], Andreas Widmer, MD, MSc[5], Jonas Marschall, MD, MSc[1,3] for Swissnoso, the National Center for Infection Control

Affiliations

[1]Department of Infectious Diseases, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland

[2]Federal Office of Meteorology and Climatology MeteoSwiss, Bern, Switzerland

[3]Division of Infectious Diseases, Washington University School of Medicine, St. Louis, MO, U.S.

[4]Department of Infectious Diseases, Central Institute, Valais Hospital, Sion, Switzerland

[5]Division of Infectious Diseases and Hospital Epidemiology, University of Basel Hospitals and Clinics, Basel, Switzerland

Correspondence: Lauro Damonti, Department of Infectious Diseases, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland

Phone: +41 31 632 25 25. Email: lauro.damonti@insel.ch

Keywords: surgical site infection; temperature; season; heatwave; hip; knee; arthroplasty; prosthetic joint

Structured summary

Background: Previous studies reported higher incidence of surgical site infection (SSI) after procedures performed in summer or with high temperatures. However, no study used detailed climate data to assess this risk after hip and knee arthroplasty, and no study specifically investigated the role of heatwaves.

Aim: To assess the impact of higher environmental temperatures and heatwaves on SSI rates after hip and knee arthroplasty.

Methods: Data on hip and knee arthroplasty procedures performed between 01/2013 - 09/2019 in hospitals participating in the Swiss SSI surveillance were linked to climate data extracted from weather stations located in their vicinity. The association between temperature, heatwaves and SSI was studied using mixed effects logistic regression models fitted at the patient level. Poisson mixed models were fitted for both calendar year and month of the year to investigate the SSI incidence trajectory over time.

Results: We included 116,981 procedures performed in 122 hospitals. Significantly higher SSI rates were observed for procedures performed in the summertime (incidence rate ratio 1.39, 95% CI [1.20-1.60], p<0.001; reference: autumn) or in calendar months in which the mean temperature was above 20°C (reference 05-10°C; odds ratio 1.59, 95% CI [1.27, 1.98] p<0.001). We observed a slight but non-significant increase in the rate of SSI during heatwaves (1.44% versus 1.01%, p=0.2).

Conclusion: SSI rates after hip and knee replacement appear to increase with higher environmental temperature. To establish if, and to what extent, heatwaves increase the risk of SSI, studies involving geographical areas with larger variability in temperature are needed.

Introduction

Extreme climate events such as excessive heat and heatwaves are likely to become more frequent and more intense with human activity-induced climate change [1]. These events are associated with increased mortality and morbidity [2-4]. Recently, higher incidences of both community acquired [5-9] and healthcare-associated (HAI) [10-13] infections have been reported to occur in warmer months. Surgical site infection (SSI) is the most common and preventable HAI, and is associated with increased morbidity, mortality, and costs [14-16]. Risk factors associated with SSI include, but are not limited to, advanced age, frailty, diabetes mellitus, and complexity and length of surgery [17]. Recent reports showed a seasonal variation of SSI with higher incidence in the summer or in periods with higher temperatures. This association was demonstrated for the most common types of procedures [18-20], and specifically following spine surgery [21, 22], hip and knee arthroplasty [23] and implant-based breast reconstruction [24].

In this study, we investigate the impact of environmental temperature (hereafter simply referred to as "temperature" unless described otherwise) and heatwaves on the incidence of SSIs after elective hip and knee arthroplasty in Switzerland, using a large and representative nationwide surveillance database and a comprehensive network of meteorological stations. Our hypothesis was that the procedures performed in periods with higher temperatures or during a heatwave would be correlated with an increased risk of SSI. Since both the numbers of hip and knee replacement surgeries and heat-related extreme events are expected to increase over the coming years [25], a deferral of procedures ahead of anticipated heatwaves might thus prevent a relevant number of avoidable SSIs.

Methods

Surveillance data: In 2009, a national SSI surveillance program was introduced by the Swiss National Center for Infection Prevention (www.Swissnoso.ch) for surveillance, benchmarking and quality control purposes. Participating hospitals are required to record data of three types of surgeries in a catalogue of five eligible areas of surgery (abdominal surgery and bariatric procedures; cardiac surgery; hip and knee arthroplasty; laminectomy; caesarean section and hysterectomy). As of 30 September 2019, 486,000 procedures have been included. The definitions used in the surveillance program are based on the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) criteria [26]. Patient follow-up is by telephone interview, 30 days after the index procedure for all procedure types, and again after 1 year for those procedures that included implants. The entire process has been described in detail elsewhere [27]. For this study, we considered elective hip and knee arthroplasty among all inpatients in the period from 1 January 2013 to 30 September 2019. We focused on hip and knee arthroplasty because these procedures are mostly elective and can generally be postponed if needed. Per this surveillance system's criteria, a procedure is considered "elective" if it was the reason for a planned admission. Arthroplasties with presence of previously implanted prosthetic material, those performed immediately after a fracture or within 30 days after an infiltration, and in cases of pre-existing infection at the time of surgery as ascertained by chart review, were not included.
Variables collected in the surveillance and considered in this study included: patient age and sex; National Nosocomial Infections Surveillance (NNIS) risk index (derived from *a.* American Society of Anesthesiologists (ASA) physical status classification system, *b.* length of surgery and *c.* class of contamination); date of procedure; timing of the first antibiotic prophylaxis; length of hospitalization and destination post-discharge; date and classification of the SSI, causative microorganism (if cultures were obtained) and all-cause mortality.

Climate data: since 1864, climate data in Switzerland have been collected by the Swiss Federal Office of Meteorology and Climatology (MeteoSwiss, www.meteoswiss.admin.ch) in dedicated weather stations of the National Basic Climatological Network (Swiss NBCN). Throughout the study period (1 January 2013 to 30 September 2019), 67 dedicated weather stations that cover all major climatic regions of Switzerland have continuously collected daily data on temperature (°C, min, max, and mean), sunlight (hours per day), precipitation (mm/24 hours) and relative air humidity (%, min, max, and mean).

Definition of heatwave: The definition of heatwave varies across countries and organizations, and which definition should be used in health outcomes research is still a matter of debate [28]. For our analysis, we used the criteria currently employed by the Federal Office of Meteorology and Climatology (Meteoswiss), established

in collaboration with the Swiss Tropical and Public Health Institute (Swiss TPH). According to these criteria, a heatwave is declared once the daily *mean* temperature is equal to or above 25°C (77°F) for at least three days in a row [29].

Data merging: To link climate and surveillance data, the weather station nearest to the participating hospital was selected (usually located in the same city), and its measurements integrated with the surveillance dataset. Following the merging process, data were aggregated to calendar month to investigate the influence of the average monthly temperature on the outcome. However, to investigate the primary endpoint (i.e. presence or absence of a heatwave on the day of the procedure), we used the specific calendar day.

Statistical analyses: 30 day and 1 year SSI rate was the primary endpoint of this study, while the primary exposure was the presence of a heatwave, as defined above, on the day of the procedure. Our main hypothesis was that heatwave periods correlated with the SSI rate. The primary analysis compared the crude SSI rate for procedures performed during heatwave periods versus non-heatwave periods using a chi-square test. Uni- and multivariable mixed effects logistic regression models were then fitted at the patient level to estimate risk factors for SSI (the dependent variable) with independent variables: presence or absence of a heatwave, mean temperature (either as a continuous variable or as categories), sex, age, length of surgery, ScoreT ("overlong operation", i.e. the duration of surgery is above the 75th percentile of the benchmark for this particular surgery across all captured procedures in Switzerland), ASA score, number of individual prophylactic antibiotic agents, timing of first antibiotic prophylaxis, and hospital size. A random intercept effect was included for each hospital. Analogously, unadjusted Poisson mixed models were also fitted for both calendar year during the study (2013-2019) and month of the year (Jan-Dec, for all years) to investigate the SSI incidence trajectory over time. The numerator for these models was the total number of SSIs and denominator the total number of procedures in the respective month. Again, a random intercept for each hospital was included, with a cubic spline fitted for the respective timescale (6 knots placed at equidistant points of the respective distribution). For this analysis, we did not consider other meteorological parameters such as humidity. Humidity is indirectly accounted for by using the mean average temperature to define heatwave (the primary exposure in our study) [29].

All analyses were performed with R (version 4.0.2). P values < 0.05 were considered statistically significant. The analysis is in compliance with the STROBE guidelines for observational studies [30].

Ethics statement: As the analysis has been performed on anonymized non-genetic surveillance data, ethical consent was not required according to the Swiss law for research on humans (Article 33, Paragraph 2, Human Research Act).

Results

During the study period, 116,981 procedures of elective hip and knee arthroplasty were included from 122 hospitals, located in proximity of 46 weather stations; with 1.02% (N=1190) of them complicated by SSI. Overall, 975 (0.8%) procedures were performed during a heatwave. Baseline characteristics of patients with and without SSI are listed in Supplementary Table A1. Supplementary Figure A1 illustrates the average monthly temperature recorded in the climate stations linked to the hospitals. In terms of the primary analysis, we observed a non-significant increase in the rate of SSI during heatwaves, compared to other times (1.44% versus 1.01%, p= 0.2). Table 1 displays the crude number of procedures and the rates of SSI, stratified by five mean monthly temperature intervals. About 7% of the procedures were performed on days of a given calendar month in which that month's temperature was above 20°C. A significant increase of the SSI rate was observed in this group (reference 05-10°C; OR 1.59, 95% CI [1.27, 1.98] p<0.001). Of note, in a subset of patients with a BMI ≤25 kg/m² this association disappeared (OR 1.05, 95% CI [0.51, 2.01], p=0.9, with 5-10°C as a reference). Moreover, when the microbiology information was available (in about 50% of SSIs), an increased odds ratio of SSI to be caused by Gram-negative bacteria (as opposed to Gram-positive bacteria) was observed for mean temperatures above 16°C (reference 05-10°C; OR 2.85, 95% CI [1.41, 6.07], p=0.005 for the group interval 16-20°C and OR 3.10, 95% CI [1.37, 7.21], p=0.007 for the group interval >20°C). A sub-analysis showed that SSI after hip arthroplasty drove this increase (OR 3.42, 95% CI [1.55, 8.23], p=0.003 for the group interval 16-20°C and OR 3.89, 95% CI [1.59, 10.0], p=0.004 for the group interval >20°C). After knee arthroplasty, no difference was found (Supplementary Table A2 and Supplementary Table A3).

Figure 1 plots temporal trends in the incidence of SSI (as the number of episodes per 1000 procedures) alongside aggregated monthly temperature levels (in °C). In *Panel A*, the seasonal fluctuation of SSI rates reveals a degree of correlation with the peaks of maximum temperature, although summertime was not always associated with higher incidence. *Panel B* plots monthly incidence and mean monthly temperature indicating a general trend of higher incidence of SSI with higher temperatures. Table 2 summarizes estimated risk factors for SSI from fitted uni- and multivariable logistic regression models. In the multivariable adjusted model, male sex, hip arthroplasty (versus knee), ASA level ≥3 and prolonged length of surgery were all significantly associated with an increased risk of SSI. Heatwaves were not associated with increased odds of an SSI (adjusted OR 1.4, 95% CI [0.9-2.22], p=0.12). The Poisson model revealed that procedures performed in the summer were at higher risk of developing SSI than if performed in other seasons (IRR 1.39, 95% CI [1.20-1.60], p<0.001).

Discussion

Our nationwide surveillance study demonstrated seasonal variation in SSI rates after hip and knee arthroplasty, with increased incidence during the summer and with higher environmental temperatures at the time of the procedure, as previously observed for this type of surgery [23] as well as non-orthopaedic procedures [19, 20]. A unique aspect of our study is that we used data collected in a capillary network of weather stations located in the vicinity of the participating hospitals, a methodology that - to the best of our knowledge - has never been used to specifically investigate the impact of climate factors on SSI after hip and knee arthroplasty. As hip and knee arthroplasties are usually elective procedures, postponing them during heatwaves (also a partially predictable event), could have practical implications for infection prevention measures and SSI rates. Using our categorization of heatwaves, defined as a minimum of three days with mean temperatures of at least 25°C (77°F), we did not find an association between heatwaves and SSI. However, this might be related to the heatwave definition we used, and could also be explained by the fact that, in our latitudes, the temperatures recorded during a typical summer differ only marginally from those recorded during heatwaves.

The underlying pathophysiological mechanism behind the increase in SSIs with warmer temperatures is not well understood. Changes in the skin microbiome with warmer and more humid environments have been hypothesized to be drivers [31]. In our study, no association between temperature and SSI was found in the group of patients with a BMI of less than 25 kg/m², which might, to some extent, corroborate this hypothesis. A decrease in sweat glands and sweat secretions in elderly patients could partially explain lower SSI rates in populations observed in some studies [24] (including ours, where SSI rates were lower among patients aged 65 years and older). Among culture-positive infections, SSIs were predominantly caused by Gram-positive bacteria; however, increased rates of SSI after hip (but not knee) arthroplasty due to Gram-negative bacteria were associated with higher temperatures, as previously observed in a study on several types of surgical procedures [32]. This could be explained by the vicinity to the groin and anal region. Of note, a metagenomics study showed that the skin microbiome remains overall stable over time, despite exposure to variable conditions in the external environment [33], but variability was more pronounced at moist sites (such as the groin region). Perioperative hypothermia may increase [34] and preoperative warming may lower [35] the risk of SSI, while a post-operative local warming had no effect in a single-blinded randomized controlled trial [36]. Current guidelines recommend maintaining normothermia in the perioperative period [16, 37], which is (albeit not captured by this surveillance) standard across the institutions participating in our study, where the temperature in operation rooms is pre-set, controlled and immediately re-established in case of disruption. Therefore, since operating room temperature is a near-constant, the temperature outside the operating room is likely to be much more relevant, as, for instance

in hospital rooms with no conditioned air or in the immediate postoperative period spent outside of healthcare facilities. Of note, in Switzerland air conditioning systems are rarely installed outside operating rooms and intensive care units, which makes it difficult to cool these patient rooms in the summer or during heatwaves. Our results suggest that procedures performed in the summer and with higher environmental temperature are associated with higher rates of SSI. However, we could not demonstrate a significant impact of heatwaves, arguably due to the limited number of procedures performed during a heatwave, as per the definition used here. Moreover, heatwaves are extreme events that usually occur during periods with higher baseline temperature (themselves independently associated with higher SSI rates). This may mask their true influence in the analysis. To better differentiate the risk attributable to the heatwave from the underlying risk increase, a larger variation between temperature extremes and warm season temperatures is needed.

Given the expected increase of both elective arthroplasty surgeries and heat-related extreme events in the near future, it is critical to assess the appropriateness of procedures performed on particularly hot days and heatwaves. Further studies addressing this subject are therefore needed and may have to involve geographical areas with larger variability in temperatures.

Our study has some limitations. First, our national data may not be generalizable to other countries, especially where air conditioning systems are standard on hospital wards. The association between increased temperature and SSI, however, has been observed globally, and we therefore expect our conclusions to be generalizable at least to some extent. Second, we used a definition of heatwave that may differ from definitions used in other countries and in other health outcomes research. This highlights the need for a universal and standardized definition of heatwave in exposure studies. Third, the distances between hospitals and weather station were not available. However, due to the closely-knit network of the weather stations in Switzerland and the fact that the vast majority of them are located in the same city as the hospital, this should not strongly influence our findings. Fourth, due to the surveillance nature of this study, we could not identify possibly relevant confounders such as the temperature inside a given hospital or in rehabilitation facilities, as well as the presence of air conditioning systems; and lastly, some relevant data, such as microbiological data and relevant patient-level risk factors were incomplete or missing.

Conclusions:

SSI rates after hip and knee replacement increase with higher environmental temperature. To establish if, and to which extent, heatwaves increase the risk of SSI, studies involving geographical areas with larger variability in temperatures are needed.

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Conflict of interest: none

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Other statements

Ethics statement: As the analysis has been performed on anonymized non-genetic surveillance data, ethical consent was not required according to the Swiss law for research on humans (Article 33, Paragraph 2, Human Research Act).

Data availability: The datasets generated during and/or analysed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Authors' contributions: LD, AA and JM conceived the study. LD cleaned and, under AA's supervision, analysed the data. AA analysed the data. LF provided the data from MeteoSwiss and double-checked the validation results LD wrote the first draft of the manuscript. AA, LF, JB, PJ, NT, AW and JM substantially contributed to the interpretation of the data and provided critical inputs to the manuscript. All authors read and approved the final manuscript.

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331 Table 1 Outcome according to mean environmental temperature, in °C, stratified by five average monthly
332 temperature intervals

Temperature (°C)	<5	05-10	11-15	16-20	>20	overall
crude numbers						
Interventions (N/%)	36502 / 31%	25608 / 22%	23100 / 20%	23086 / 20%	8685 / 7%	116981
SSI (N/%)	354 / 30%	231/ 19%	234 / 20%	247 / 10%	124 / 10%	1190
OR, (95% CI) p-value	1.08 [0.91, 1.27] p=0.4	1.00 Reference	1.12 [0.94, 1.35] p=0.2	1.19 [0.99,1.98] p=0.06	1.59 [1.27, 1.98] p<0.001	
with pathogen	171	119	114	124	62	590
gram-positive	147	107	97	94	46	491
gram-negative	24	12	17	30	16	99
Rates per 1000 OP						
SSI rates	9.7	9.0	10.1	10.7	14.3	10.2
with pathogen	4.7	4.6	4.9	5.4	7.1	5.0
gram-positive	4.0	4.2	4.2	4.1	5.3	4.2
gram-negative	0.7	0.4	0.7	1.3	1.8	0.8
GN-SSI OR, (95% CI) p-value	1.46 [0.71, 3.13] p=0.3	1.00 Reference	1.56 [0.72, 3.51] p=0.3	2.85 [1.41, 6.07] p=0.005	3.10 [1.37, 7.21] p=0.007	

333

334 **Legend**: OR: odds ratio; CI: confidence interval; intervention; GN; gram negative
335 Since the average maximum temperature over the whole study period was 9.4 °C, the interval 05-10°C was chosen as the reference
336

337 Table 2 Estimated risk factors for SSI from the fitted uni- and multivariable logistic regression models.

Characteristic N (%) / median [IQR]	Univariable			Multivariable*		
Endpoint = SSI (0/1)	Odds ratio	95% CI	p-value	Adjusted Odds ratio	95% CI	p-value
Main exposure:						
Heatwave						
no	1 (reference)					
yes	1.4	[0.9, 2.2]	0.12	1.4	[0.9, 2.2]	0.12
Mean temperature (per 5 degrees C)	1.1	[1.0, 1.1]	0.06	nE		
Monthly mean Temperature (C°)				-		
<5	1.1	[0.9, 1.3]	0.4			
5 – 10	(reference)					
11 – 15	1.1	[0.9, 1.4]	0.2			
16 – 20	1.2	[1.0, 2.0]	0.06			
>21	1.6	[1.3, 2.0]	<0.001			
Sex – female	0.7	[0.6, 0.8]	<0.001	0.7	[0.6, 0.8]	<0.001
Age (10 year steps)	1.0	[0.9, 1.0]	0.1			
Age >65	0.9	[0.8, 1.0]	0.03	0.8	[0.7, 0.9]	0.03
Age >75	1.0	[0.9, 1.1]	0.8			
Procedure Type						
- Hip	1 (reference)					
- Knee	0.7	[0.6, 0.9]	0.006	0.7	[0.6, 0.8]	<0.001
Duration of procedure (per 30 minutes longer)	1.1	[1.1, 1.1]	<0.001	1.0	[1.0, 1.1]	0.02
Overlong operation (ScoreT)	1.7	[1.4, 2.1]	<0.001	1.6	[1.3, 2.0]	<0.001
ASA levels						
1/2	1 (reference)					
3/4/5	1.8	[1.5, 2.1]	<0.001	1.9	[1.5, 2.2]	<0.001
Number of prophylactic antibiotics given				-		
None	1 (reference)					
1	1.3	[0.5, 3.5]	0.7			
2	0.8	[0.2, 2.8]	0.7			
>3	1.2	[0.4, 3.6]	0.7			
Timing of first antibiotic (30 minute steps)	1.0	[1.0, 1.1]	0.3	-		
Hospital size (beds)						
<200	1 (reference)					
200-499	1.1	[0.8, 1.7]	0.5	1.1	[0.8, 1.5]	0.7
500+	1.7	[1.3, 2.2]	<0.001	1.4	[1.1, 1.7]	0.01

338
339 **Legend**: Heatwave was defined as a period in which the mean temperature was equal or above 25°C for at 3 days or more.
340 ASA: American Society of Anesthesiology score; nE: not estimated (colinear with heatwave);
341 *variables were included via forwards selection then backwards deletion with p<0.1 as inclusion criteria
342

Table 1: Outcome according to mean environmental temperature, in °C, stratified by five average monthly temperature intervals

Temperature (°C)	<5	05-10	11-15	16-20	>20	overall
crude numbers						
Interventions (N/%)	36502 / 31%	25608 / 22%	23100 / 20%	23086 / 20%	8685 / 7%	116981
SSI (N/%)	354 / 30%	231/ 19%	234 / 20%	247 / 10%	124 / 10%	1190
OR, (95% CI) p-value	1.08 [0.91, 1.27] p=0.4	1.00 Reference	1.12 [0.94, 1.35] p=0.2	1.19 [0.99, 1.98] p=0.06	1.59 [1.27, 1.98] p<0.001	
with pathogen	171	119	114	124	62	590
gram-positive	147	107	97	94	46	491
gram-negative	24	12	17	30	16	99
Rates per 1000 OP						
SSI rates	9.7	9.0	10.1	10.7	14.3	10.2
with pathogen	4.7	4.6	4.9	5.4	7.1	5.0
gram-positive	4.0	4.2	4.2	4.1	5.3	4.2
gram-negative	0.7	0.4	0.7	1.3	1.8	0.8
GN-SSI OR, (95% CI) p-value	1.46 [0.71, 3.13] p=0.3	1.00 Reference	1.56 [0.72, 3.51] p=0.3	2.85 [1.41, 6.07] p=0.005	3.10 [1.37, 7.21] p=0.007	

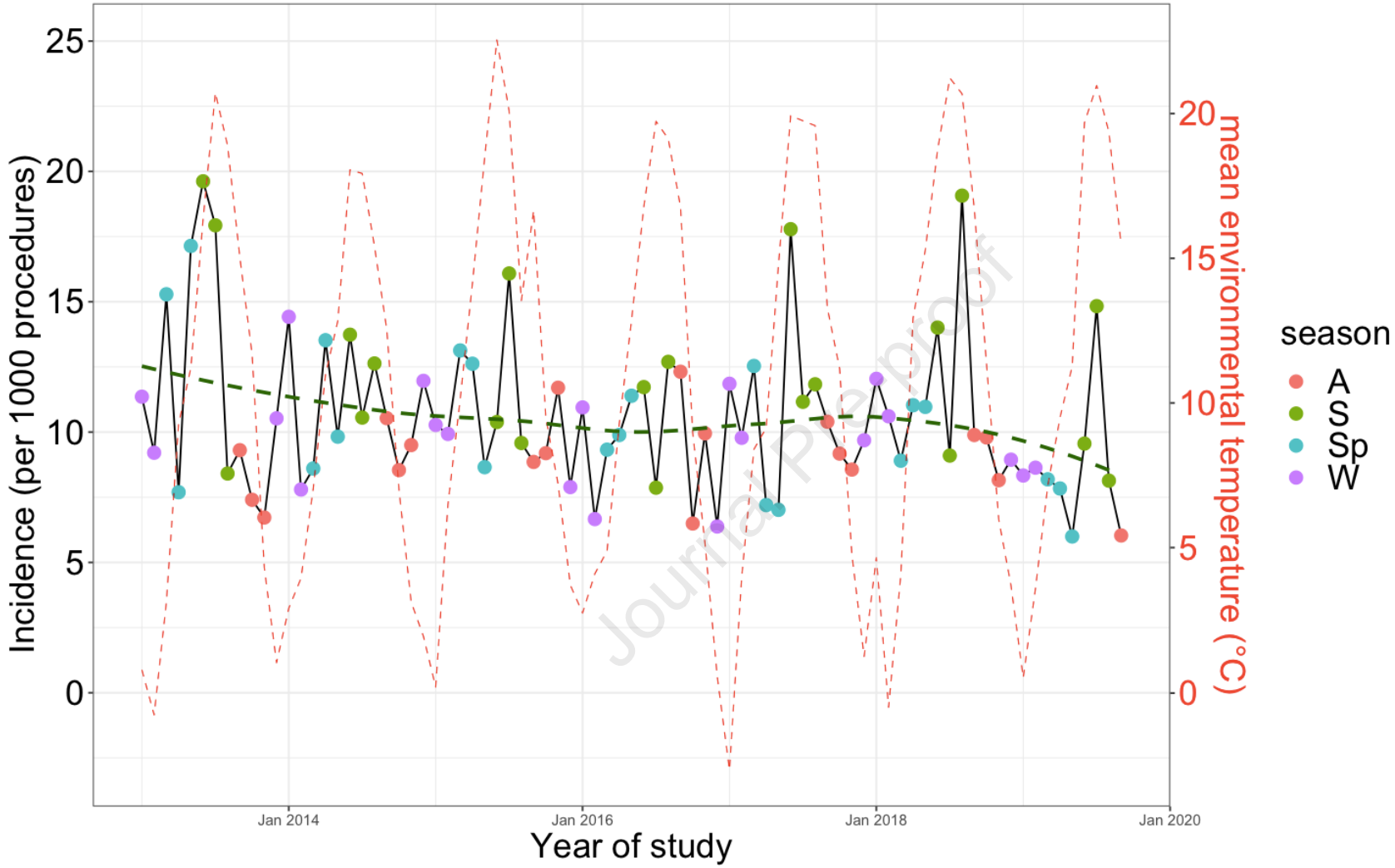
Legend: OR: odds ratio; CI: confidence interval; intervention; GN; gram negative
Since the average maximum temperature over the whole study period was 9.4 °C, the interval 05-10°C was chosen as the reference

Table 2. Estimated risk factors for SSI from the fitted uni- and multivariable logistic regression models.

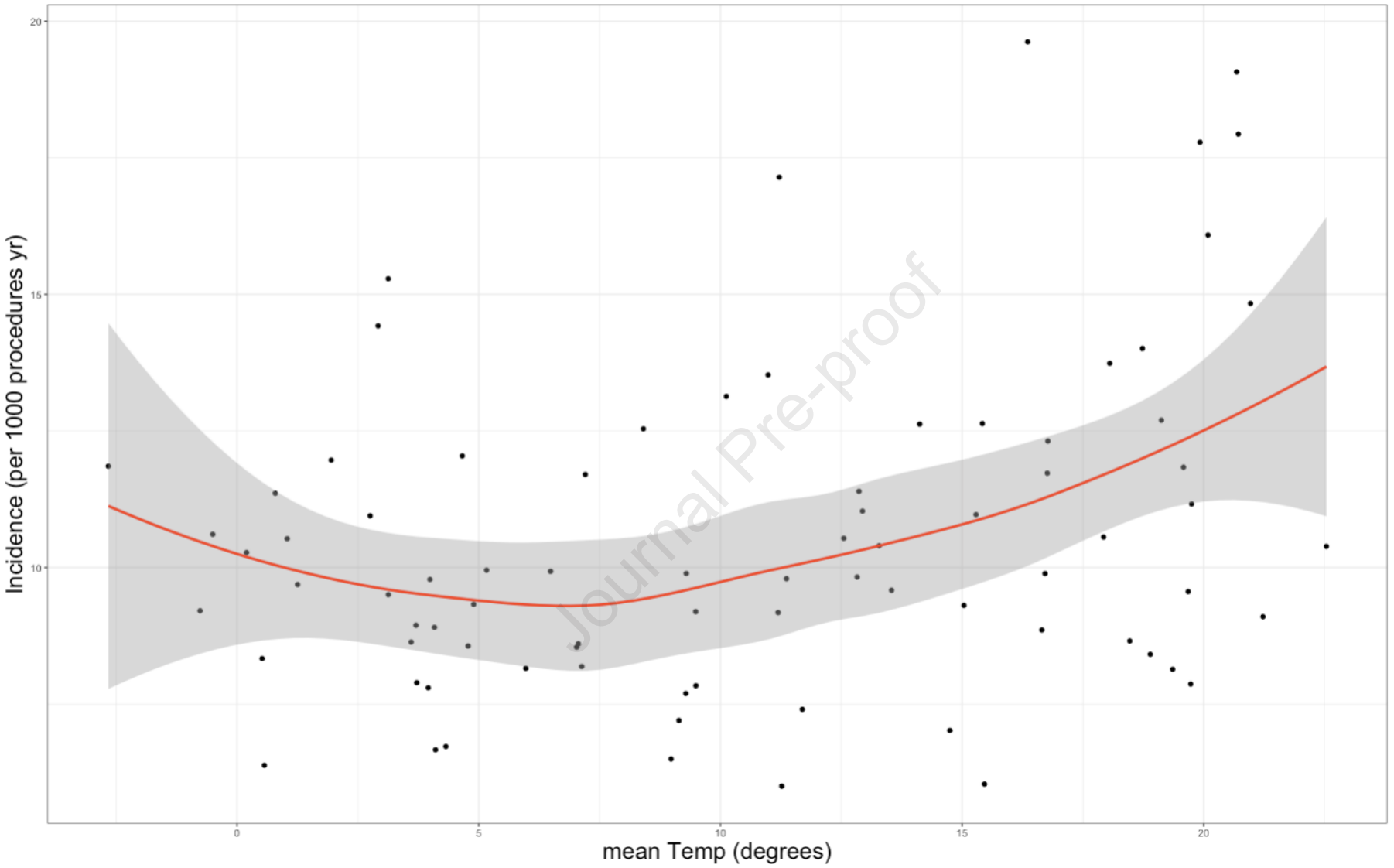
Characteristic **N (%) / median [IQR]**	**Univariable**			**Multivariable***		
Endpoint = SSI (0/1)	Odds ratio	95% CI	p-value	Adjusted Odds ratio	95% CI	p-value
Main exposure:						
Heatwave						
no	1 (reference)					
yes	1.4	[0.9, 2.2]	0.12	1.4	[0.9, 2.2]	0.12
Mean temperature (per 5 degrees C)	1.1	[1.0, 1.1]	0.06	nE		
Monthly mean Temperature (C°)				-		
<5	1.1	[0.9, 1.3]	0.4			
5 – 10	(reference)					
11 – 15	1.1	[0.9, 1.4]	0.2			
16 – 20	1.2	[1.0, 2.0]	0.06			
>21	1.6	[1.3, 2.0]	<0.001			
Sex – female	0.7	[0.6, 0.8]	<0.001	0.7	[0.6, 0.8]	<0.001
Age (10 year steps)	1.0	[0.9, 1.0]	0.1			
Age >65	0.9	[0.8, 1.0]	0.03	0.8	[0.7, 0.9]	0.03
Age >75	1.0	[0.9, 1.1]	0.8			
Procedure Type						
- Hip	1 (reference)					
- Knee	0.7	[0.6, 0.9]	0.006	0.7	[0.6, 0.8]	<0.001
Duration of procedure (per 30 minutes longer)	1.1	[1.1, 1.1]	<0.001	1.0	[1.0, 1.1]	0.02
Overlong operation (ScoreT)	1.7	[1.4, 2.1]	<0.001	1.6	[1.3, 2.0]	<0.001
ASA levels						
1/2	1 (reference)					
3/4/5	1.8	[1.5, 2.1]	<0.001	1.9	[1.5, 2.2]	<0.001
Number of prophylactic antibiotics given				-		
None	1 (reference)					
1	1.3	[0.5, 3.5]	0.7			
2	0.8	[0.2, 2.8]	0.7			
>3	1.2	[0.4, 3.6]	0.7			
Timing of first antibiotic (30 minute steps)	1.0	[1.0, 1.1]	0.3	-		
Hospital size (beds)						
<200	1 (reference)					
200-499	1.1	[0.8, 1.7]	0.5	1.1	[0.8, 1.5]	0.7
500+	1.7	[1.3, 2.2]	<0.001	1.4	[1.1, 1.7]	0.01

Legend: Heatwave was defined as a period in which the mean temperature was equal or above 25°C for at 3 days or more.
ASA: American Society of Anaesthesiology score; nE: not estimated (colinear with heatwave);
*variables were included via forwards selection then backwards deletion with p<0.1 as inclusion criteria

Figure 1: Surgical site infection after hip and knee arthroplasty: temporal trends in crude SSI incidence and maximum temperature



Panel A: Black solid line: crude incidence per 1000 person years; red dotted line maximum temperature in °C; green dashed line locally weighted smoothing (LOESS); A = autumn, Su = summer, Sp = spring, W = winter.



Panel B: Correlation plot between SSI incidence per month and environmental mean temperature (Celsius); red solid line locally weighted smoother (LOESS) with 95% confidence intervals (shaded grey); Pearson's correlation ρ = 0.31 (p-value = 0.04).