

Incidence of Swimming-Induced Pulmonary Edema



A Cohort Study Based on 47,600 Open-Water Swimming Distances

Maria Hårdstedt, MD, PhD; Linda Kristiansson, MD; Claudia Seiler, MD; Annika Braman Eriksson, MD; and Josefin Sundh, MD, PhD



BACKGROUND: Despite increasing awareness of swimming-induced pulmonary edema (SIPE), large population-based studies are lacking and the incidence is unknown.

RESEARCH QUESTION: What is the incidence of SIPE in a mixed group of competitive and recreational swimmers during a large open-water swimming event?

METHODS: In four consecutive years (2016-2019), a prospective cohort study was conducted during Sweden's largest open-water swimming event, Vansbrosimningen. All swimmers seeking medical care with acute respiratory symptoms were eligible for the study. SIPE diagnosis was based on clinical findings in 2016 and 2017 and pulmonary edema assessed by lung ultrasound in 2018 and 2019. Data on patient characteristics, clinical findings, and information about the race were collected.

RESULTS: Based on 47,573 consecutive swimming distances, 322 patients with acute respiratory symptoms (0.68%; CI, 0.61%-0.75%) were treated at the mobile medical unit. Of these, 211 patients (0.44%; CI, 0.39%-0.51%) received a diagnosis of SIPE. The annual incidence of SIPE was 0.34%, 0.47%, 0.41%, and 0.57%, respectively, from 2016 through 2019. Most patients diagnosed with SIPE were women (90%), despite about equal percentages of men and women participating (47% men and 53% women). The incidence of SIPE overall was 0.75% in women and 0.09% in men. The incidence increased with age, from 0.08% in the youngest age group (18-30 years) to 1.1% in the oldest age group (≥ 61 years). Based on multiple logistic regression analysis, the adjusted odds for SIPE occurring was 8.59 times higher for women compared with men and 12.74 times higher for the oldest age group compared with the youngest age group.

INTERPRETATION: The incidence of SIPE over 4 years during a large open-water swimming event in Sweden was 0.44%. The incidence was higher in women than in men and increased with age.

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KEY WORDS: immersion pulmonary edema; incidence; lung ultrasound; SIPE; swimming; swimming-induced pulmonary edema

FOR EDITORIAL COMMENT, SEE PAGE 1594

ABBREVIATIONS: IPE = immersion pulmonary edema; LUS = lung ultrasound; MMU = mobile medical unit; SIPE = swimming-induced pulmonary edema; SpO_2 = peripheral oxygen saturation

AFFILIATIONS: From the Center for Clinical Research Dalarna-Uppsala University (M. Hårdstedt and C. Seiler), the Department of Anesthesiology and Intensive Care (C. Seiler), Falun Hospital, Falun, the School of Medical Sciences (M. Hårdstedt, L. Kristiansson, C. Seiler, and J. Sundh), Faculty of Medicine and Health, Örebro University, the Department of Respiratory Medicine (J. Sundh), Örebro University Hospital, Örebro, the Vansbro Primary Health Care Center (M. Hårdstedt, A. Braman Eriksson), Vansbro, the Center for Research and Development (L. Kristiansson), Uppsala University/Region Gävleborg, Gävle, and the Sandviken North Primary Health Care Center (L. Kristiansson), Sandviken, Sweden.

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CORRESPONDENCE TO: Maria Hårdstedt, MD; email: maria.hardstedt@regiondalarna.se

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Take-home Points

Study Question: What is the incidence of swimming-induced pulmonary edema (SIPE) in a large mixed group of competitive and recreational swimmers during a large open-water swimming event?

Results: Based on 47,600 swimming distances, the overall incidence of SIPE was 0.44%, with higher incidence for women (0.75%) and with higher age (1.1% in the group older than 61 years compared with 0.08% in the youngest age group comprising those 18-30 years of age).

Interpretation: We present unique epidemiologic data of an underreported condition that can help organizers of open-water swimming events predict the need of health care resources.

Open-water swimming has become increasingly popular worldwide, demanding increased awareness of potential risks involved. Acute pulmonary edema, as the result of immersion and swimming in cold water, was described first in the late 1980s.^{1,2} Swimming-induced pulmonary edema (SIPE) is characterized by acute onset of cough and dyspnea while swimming in open water, sometimes accompanied by exhaustion, excessive sputum and hemoptysis, or a combination thereof.^{3,4} SIPE typically occurs in otherwise healthy individuals.^{2,5,6} The condition usually resolves spontaneously with interruption of swimming, but may result in serious illness.³ In diving, fatal accidents of immersion pulmonary edema (IPE) have been reported.⁷ The

pathophysiologic and individual risk factors of the condition are not understood fully. Exercise in cold water resulting in central pooling of blood, increased pulmonary arterial pressure, capillary damage, and subsequent pulmonary edema is assumed to be the predominant mechanism.⁸⁻¹¹ SIPE is considered fairly uncommon, but the true incidence is virtually unknown.^{12,13} In previous studies of SIPE incidence, the study populations often are small and highly selected, including younger individuals, military trainees or triathletes, and predominantly men.^{5,6,14} The criteria for SIPE diagnosis also vary highly in the literature. Some studies define SIPE merely based on respiratory symptoms during swimming in open water, whereas others demand a set of clinical findings suggesting pulmonary edema or radiologic evidence of edema. A broad range of diagnostic checkpoints for SIPE diagnosis have been suggested.³ We recently presented a clinical algorithm for SIPE diagnosis based on lung ultrasound (LUS) findings of pulmonary edema in 158 open-water swimmers.¹⁵ Based on this algorithm, peripheral oxygen saturation of $\leq 95\%$ or lung auscultation of crackles identified pulmonary edema with a sensitivity of 97% and a specificity of 86% in patients seeking medical care with acute respiratory symptoms after swimming in cold open water.¹⁵

The aim of this study was to determine the incidence of SIPE in a large heterogeneous population of open-water swimmers. A prospective cohort study was conducted over 4 years during Sweden's largest open-water swimming event, including 47,600 swimming distances.

Methods

Vansbrosimningen is the largest open-water swimming event in Sweden, attracting approximately 11,000 swimmers annually. Participants are of all ages (> 10 years), of both sexes, and include competitive as well as recreational swimmers. The event takes place during a 3-day weekend in July and consists of swimming distances of 1,000 m, 1,500 m, or 3,000 m in cold (15-20°C) open-water rivers. The first 2,000-m distance is downriver in the river Vanån, followed by an upriver distance of 1,000 m in the river Västerdalälven; shorter distances start closer to the finish. Vansbro is located 78 km from the nearest emergency hospital. A growing number of participants over the years have expanded the prehospital health care organization on site, now consisting of a first aid team along the riverside, two ambulances, and a temporary mobile medical unit (MMU) with experienced physicians and nurses at the finish area. Only a handful of patients every year require referral to hospital.

Study Population and Data Collection

This prospective cohort study was conducted during Vansbrosimningen in 2016, 2017, 2018, and 2019. All participants 18

years of age or older seeking medical attention at the MMU because of cough, dyspnea, or both with onset during or directly after swimming in cold open water were eligible for the study. In 2016, limited data were gathered anonymously in a pilot study.¹⁶ In 2017, 2018, and 2019, a more extensive dataset was collected with written informed consent from all participants. Ethical approval was received from the regional ethical review board in Uppsala, Sweden (Dnr 2017/216 with amendment 2017/216/1).

Medical history, information concerning the swimming race, symptoms, and clinical findings were collected for all patients from 2017 through 2019. Symptoms were reported as cough, dyspnea, increased sputum, hemoptysis, or a combination thereof. Lung auscultation findings were reported as normal breathing sounds, crackles, rhonchi, or other findings. Peripheral oxygen saturation was measured with a pulse oximeter (Oximax N-65; Nellcor). In 2018 and 2019, the body temperature was measured with an ear thermometer (Braun Welch Allyn Pro 4000/6000). LUS was performed at the MMU using machines aimed for point-of-care examinations (Flex Focus 500 with a curved probe [type 8823] of 2-6 MHz; BK Medical). As described previously, patients were scanned sitting in the upright position for four left and four right chest

TABLE 1] The Criteria Used for SIPE Diagnosis over the 4 Years of the Study

Year	Criteria for SIPE diagnosis
2016	Patients treated for SIPE at the MMU (n = 46). Criteria based on clinical findings by physician on site: crackles on lung auscultation and hypoxia.
2017	Diagnostic algorithm based on clinical findings (n = 59) ^a
2018	Pulmonary edema on LUS (n = 46); diagnostic algorithm based on clinical findings (n = 1) ^a
2019	Pulmonary edema on LUS (n = 56); diagnostic algorithm based on clinical findings (n = 3) ^a

LUS = lung ultrasound; MMU = mobile medical unit; SIPE = swimming-induced pulmonary edema.

^aAlgorithm published by Hårdstedt et al.¹⁵ Combination of clinical criteria for SIPE diagnosis: peripheral saturation \leq 95% and findings of crackles on lung auscultation at admission (n = 34); saturation \leq 95%, but no crackles (n = 22); saturation $>$ 95% and crackles (n = 4); and missing data regarding saturation and crackles at admission (n = 3).

regions: upper and basal anterior and upper and basal lateral.¹⁵ Bilateral or unilateral presence of two or more regions with positive findings, that is containing three or more B-line artifacts, was defined as pulmonary edema.¹⁵

SIPE Diagnosis

In 2016, SIPE diagnosis was based on clinical findings of physicians on site (Table 1). In 2017, our previously published diagnostic algorithm for SIPE diagnosis was applied retrospectively to identify cases of SIPE (e-Fig 1).¹⁵ In 2018 and 2019, SIPE diagnosis was based on findings of pulmonary edema on LUS.¹⁵ For five patients in 2018 and 2019 with missing LUS data, the algorithm retrospectively defined SIPE in four patients (Table 1).

Statistical Analysis

Descriptive continuous data are presented as mean \pm SD or median (interquartile range), and categorical data are presented as number (percentage). Cumulative incidence is presented as

percentage, with number of individuals with SIPE diagnosis as numerator and number of swimming distances as the denominator. Number of swimming distances was defined as number of started distances. Age is presented as number of years by the year of participation. CIs for incidence measures were estimated using the Clopper-Pearson exact test. Simple and multiple logistic regression analysis were performed for all participants over the 4 years with SIPE diagnosis as the dependent variable and sex (female or male) and age groups (18-30 years, 31-40 years, 41-50 years, 51-60 years, and $>$ 61 years) as independent variables. Comparison of peripheral saturation between years was performed using Kruskal-Wallis test; post doc analysis was carried out with Dunn's postdoc test. IBM SPSS Statistics for Windows version 25.0 software (IBM Corp.) and GraphPad Prism version 7.00 software (GraphPad Software) were used for statistical analysis and graphic presentation. A *P* value of $<$.05 was considered statistically significant.

Results

Altogether, 45,913 participants 18 years of age or older swam 47,573 distances during Vansbrosimningen in 2016, 2017, 2018, and 2019. Of these, 27,097 individuals participated in 1 year, 4,764 individuals participated in 2 years, 1,604 individuals participated in 3 years, and 1,119 individuals participated in all 4 years. The mean age of all adult participants was 40.4 years; 47% were men and 53% were women. Information on distances swum and age and sex groups of all participants is presented in e-Table 1. To complete an open swimming race of Vansbrosimningen at a speed of less than 20 min/km was required to be considered a competitive swimmer. Over the 4 years, 7,701 of the races (16%) were swum at a speed of less than 20 min/km, 39,607 of the races (83%) were swum at a speed of 20 min/km or more, and 265 of the races (1%) were not finished (e-Table 1).

The water temperature was on average $17.3 \pm 1.5^\circ\text{C}$ and air temperature $18.3 \pm 6.8^\circ\text{C}$ (e-Table 1). The warmest water and air temperatures were measured in 2018

(water, 19.5°C ; air, 21.8°C) and the coldest in 2019 (water, 15.9°C ; air, 15.5°C) (e-Table 1).

Respiratory Symptoms at the MMU

In total, 405 admissions (individuals \geq 18 years of age) were registered to see a physician at the MMU in 2016 through 2019 (Fig 1). Most of these (n = 322 [80%]) demonstrated acute respiratory symptoms corresponding to an incidence of 0.68% (CI, 0.61%-0.75%). Patients with respiratory symptoms in 2017 through 2019 reported the following symptoms at admission: cough only (23%), dyspnea with or without cough (54%), or cough, dyspnea with excessive sputum, hemoptysis, or a combination thereof (23%; data not shown).

Altogether, 313 participants (\geq 18 years of age) with respiratory symptoms were included in the further analysis and seven participants were excluded (Fig 1). Individuals with recurrent episodes of respiratory symptoms at different years were included both years (n = 2), whereas individuals seeking medical attention

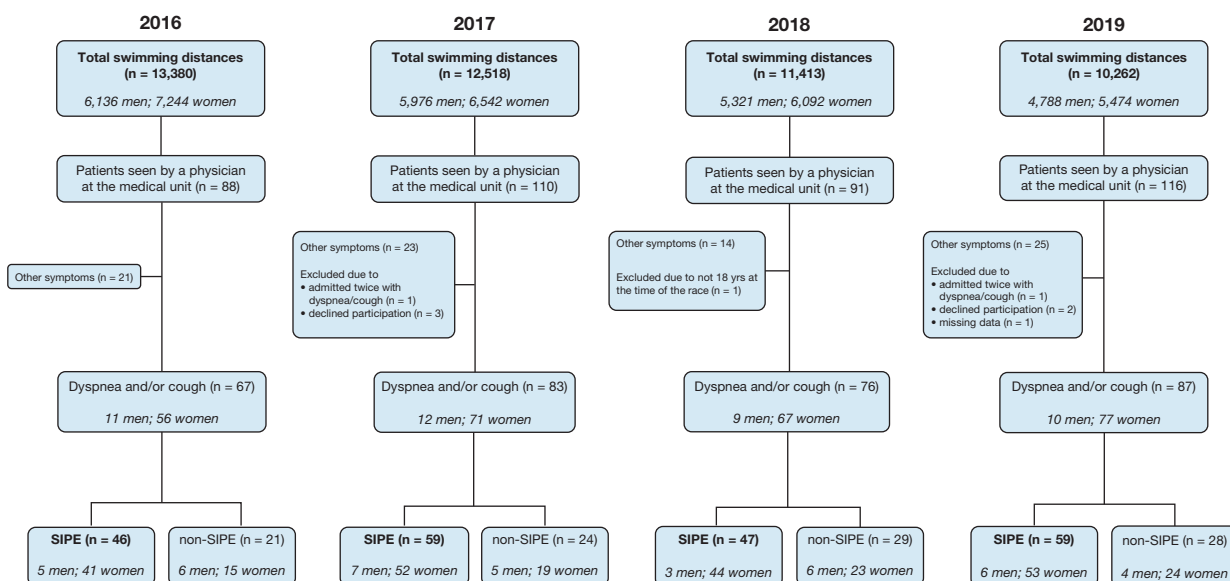


Figure 1 – Study flow chart showing the total number of swimming races (by those ≥ 18 years of age) during Vansbrosimningen in 2016, 2017, 2018, and 2019. Patients seeking medical attention for respiratory symptoms (dyspnea, cough, or both) were eligible for the study. The numbers of patients who received a diagnosis of SIPE are reported together with sex distribution for each year. SIPE = swimming-induced pulmonary edema.

twice the same year were accounted for once ($n = 2$). In addition to the mentioned adult patients, six individuals younger than 18 years were admitted because of respiratory symptoms; none were diagnosed with SIPE.

Incidence of SIPE

The number of patients (≥ 18 years of age) diagnosed with SIPE in 2016 through 2019 were 211, corresponding to an incidence of 0.44% (CI, 0.39%-0.51%) (Fig 1). The annual incidence of SIPE was 0.34%, 0.47%, 0.41%, and 0.57%, respectively in 2016, 2017, 2018, and 2019. Ninety percent of patients ($n = 190$) with SIPE were women and 10% ($n = 21$) were men (Fig 1). The incidence of SIPE for women was 0.75%, compared with 0.09 % for men (Fig 2A). The incidence of SIPE increased with higher age from overall 0.08% in the youngest age group (18-30 years of age) to 0.26% (31-40 years of age), 0.65% (41-50 years of age), 0.76% (51-60 years of age), and 1.1% in the oldest age group (> 61 years of age) (Fig 2B). Adjusted for age group, women showed a 8.59 times higher odds of developing SIPE compared with men (Table 2). Compared with the youngest age group (18-30 years of age), the adjusted odds of developing SIPE was 3.48 for those 31 to 40 years of age, 8.07 for those 41to 50 years of age, 9.90 for those 51 to 60 years of age, and 12.74 for those 61 years of age or older. Multiple regression analysis including age as a continuous variable, together

with sex, found no interaction effect between age and sex for the outcome of SIPE diagnosis (data not shown).

Further demographics, medical history, factors concerning the swimming race, and clinical findings for patients with SIPE in 2017 through 2019 are presented in Table 3. Asthma and hypertension were the most commonly reported comorbidities in women, and hypertension was the most commonly reported comorbidity in men. A vast majority of swimmers wore a wetsuit (98%); only three patients in the warmest year of 2018 did not. Only two patients diagnosed with SIPE were reported to be disoriented at admission; the remaining patients were fully awake. Self-reported aspirations, such as inhaling or swallowing of water, were common (45%) (Table 3). Overall, this referred to minor aspirations; only one patient might have experienced a more severe aspiration. The median peripheral saturation for patients who received a diagnosis of SIPE in 2016 through 2019 was 91% (interquartile range, 88% to 94%) and improved over the 4 years studied ($P = .0023$) (Fig 3).

Discussion

We reported 211 patients with SIPE among 45,915 swimmers, together completing 47,576 distances of 1,000 to 3,000 m, in cold open water. This corresponds

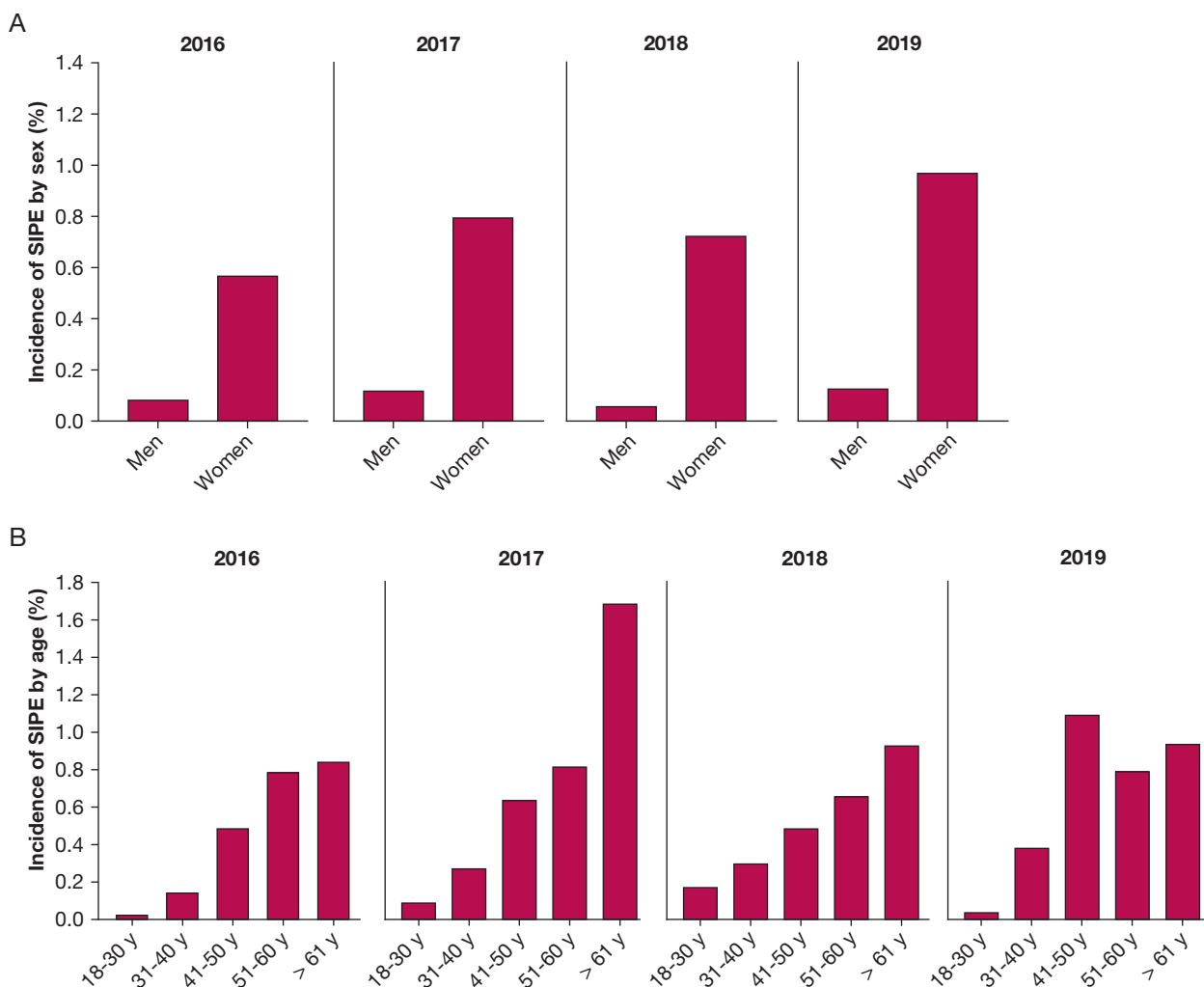


Figure 2 – A, B, Age- and sex-dependent incidence of SIPE. Cumulative incidence reported for men and women (A) and by age group (B) as follows: 18 to 30 years, 31 to 40 years, 41 to 50 years, 51 to 60 years, and 61 years or older. SIPE = swimming-induced pulmonary edema.

to an incidence of 0.44% in a mixed group of competitive and recreational swimmers of both sexes and all ages (≥ 18 years of age). The incidence of SIPE was strikingly similar over the 4 years studied. A higher incidence was associated with female sex and higher age. To the best of our knowledge, this is the largest population-based study of SIPE incidence in the literature.

Previous estimates of the SIPE incidence during open-water swimming have varied greatly (0.01%-60%). The large differences presumably depend on study design, population, diagnostic criteria, settings (ie, water temperature, level of physical exercise), how recurrent episodes were dealt with, and the denominator used.^{5,6,14,17,18} Most studies are based on strenuous training programs during military training including

young men.^{5,6,14,19} In two of the first case series from military training, including 30 and 35 individuals, the incidence reported was surprisingly high: 27% and 60%, respectively.^{5,6} Overhydrating before the race might have contributed to the high occurrence of SIPE in one of these studies.⁶ In the other study, each individual swam five distances over a 2-month period, and recounting the incidence using the number of distances, rather than the number of individuals, as the denominator resulted in an incidence of 17%, instead of 60%.⁵ In both studies, respiratory symptoms were the basis for SIPE diagnosis. Later, Adir et al¹⁴ reported an incidence of 1.8% based on 70 cases of SIPE during military training over a 3-year period; in that study, the number of swimming distances was the denominator. Symptoms together with signs of pulmonary edema on physical examination were the criteria for diagnosis.

TABLE 2] Logistic Regression Analysis of the Association of Sex and Age With SIPE Among All Participants in Vansbrosimningen 2016 Through 2019

Variable	Simple Logistic Regression		Multiple Logistic Regression ^a	
	Unadjusted OR (95% CI)	P Value	Adjusted OR (95% CI)	P Value
Age group y^b				
18-30	1	...	1	...
31-40	3.21 (1.62-6.37)	< .0001	3.48 (1.76-6.92)	< .0001
41-50	7.44 (3.96-13.95)	< .0001	8.07 (4.30-15.15)	< .0001
51-60	8.78 (4.63-16.64)	< .0001	9.90 (5.22-18.78)	< .0001
≥ 61	10.84 (5.15-22.81)	< .0001	12.74 (6.05-26.84)	< .0001
Sex^c				
Male	1	...	1	...
Female	7.98 (5.09-12.53)	< .0001	8.59 (5.47-13.49)	< .0001

SIPE = swimming-induced pulmonary edema.

^aNagelkerke $R^2 = 0.092$.

^bAge divided in age groups, with the youngest group (18-30 years) used as reference group.

^cMale sex used as the reference for sex.

Recently, an incidence of 5% was presented in a cohort of 2117 United States Navy Sea, Air, and Land Teams over 15 months based on radiologic findings.¹⁹ One previous report from United States Experimental Diving Unit indicated a cumulative incidence of 1.78% among their trainees over 12 months; however, because of missing data, the definition of SIPE diagnosis was questionable.²⁰ In military training programs, the level of exertion often is extreme. The degree of physical activity previously was associated with a higher risk of IPE in scuba divers.²¹ Another group frequently discussed in the context of SIPE is triathletes.^{18,22} In a large questionnaire-based study of triathletes, the prevalence of individuals reporting “cough productive of pink frothy or blood-tinged secretions” during swimming in open water was 1.4 % of 1,400 swimmers answering the survey.¹⁸ To our knowledge, no prospective population-based study of SIPE incidence during a mass-participation swimming event has been presented. One report on SIPE incidence during triathlon events in the United Kingdom from 2011 through 2016 was published as a conference abstract in 2017.²³ This study retrospectively identified SIPE cases through chart review and reported an incidence of 0.007% in a mixed population of elite and nonelite triathletes swimming 400 to 1,500 m in cold open water.²³

Different diagnostic criteria contribute to the discrepancy in reported incidence of SIPE. Acute onset of cough, dyspnea, and breathlessness during open-water swimming often are the basic criteria, sometimes limited to sputa or hemoptysis.^{3,12} However, objective clinical findings indicative for

pulmonary edema, for example, desaturation, auscultation, or radiologic findings of edema, are not always presented. Because SIPE most frequently occurs during open-water swimming events, a set of criteria to use at the river or seaside would be preferable. We recently suggested a diagnostic algorithm for SIPE based on clinical findings of crackles on lung auscultation and peripheral saturation of $\leq 95\%$.¹⁵ The rapid development of flexible ultrasound equipment makes LUS an attractive addition to on-site diagnostics. A uniform set of criteria for SIPE diagnosis would advance knowledge of SIPE by comparison between populations and settings.²⁴ In the presented data, the diagnostics of SIPE varied from 2016 through 2019. The lesson learned in 2017 was the presence of auscultation of crackles over the anterior chest in swimmers with SIPE.¹⁵ In 2018 and 2019, we concluded that desaturation of $\leq 95\%$ was associated with pulmonary edema on LUS, even without auscultation of crackles.¹⁵ LUS apparently is more sensitive than the human ear in detecting pulmonary edema. Using the algorithm, patients with desaturation of $\leq 95\%$ will be characterized as having SIPE, which minimizes the risk to missing patients with severe pulmonary edema. The consistency of SIPE incidence over the 4 years of this study strengthens the data, despite differences in diagnostics. In 2019, the low temperatures probably contributed to a higher incidence. A lower water temperature is believed to trigger SIPE by enhanced peripheral vasoconstriction.^{2,4,14,25} SIPE is known as a

TABLE 3] Background Characteristics and Clinical Findings for Patients With SIPE From 2017 Through 2019

Variable	Patients With SIPE (n = 165)	
	Women (n = 149)	Men (n = 16)
Age, y	48 ± 10	53 ± 11
Age group, No (%)		
18-30 y	9 (6)	0
31-40 y	22 (15)	3 (19)
41-50 y	63 (42)	2 (13)
51-60 y	42 (28)	6 (38)
> 61 y	13 (9)	5 (31)
Weight, kg	66 (62-74) ^a	80 (79-86) ^b
Length, m	168.3 ± 5.6 ^a	181.3 ± 6.1 ^b
BMI, kg/m ²	23.1 (21.7-25.9) ^a	24.9 (24.1-27.4) ^b
Medical history, No (%)		
Smoker	1 (1)	1 (6)
Asthma	29 (19)	1 (6)
Heart disease	5 (3)	1 (6)
Hypertension	16 (11)	6 (38)
Factors concerning the race, No (%)		
Wearing a wetsuit, any type	145 (98) ^b	16 (100)
Distance, No (%)		
1,000 m	66 (44)	0 (0)
1,500 m	17 (11)	3 (19)
3,000 m	66 (44)	13 (81)
Discontinuation of the race	65 (44)	8 (50)
Distance swum before discontinuation, m	750 (450-1,700)	875 (500-1,475)
Aspiration or swallowing of water during the race ^c	67 (45) ^b	7 (44)
Symptoms, No. (%)		
Cough only	23 (16)	0
Dyspnea with or without cough	78 (54)	11 (73)
Increased sputum and/or hemoptysis	46 (32)	4 (27)
Clinical findings		
Body temperature, °C	36.0 (35.0-36.6) ^d	36.7 (35.7-37.1) ^e
SpO ₂ , %	92 (89-95) ^f	90 (89-92) ^b
Crackles on lung auscultation, No. (%)	120 (81) ^b	11 (69)

Continuous data are presented as mean ± SD, or median (interquartile range). Categorical data are presented as No (%). SIPE = swimming-induced pulmonary edema; SpO₂ = peripheral oxygen saturation.

^aData missing for four swimmers.

^bData missing for one swimmer.

^cThe patients reported if they experienced a "kallsup" (in Swedish) during the race, which translates to both aspiration and swallowing of water.

^dData missing for 58 swimmers.

^eData missing for seven swimmers.

^fData missing for two swimmers.

transient condition, usually resolving within 24 to 48 h.³ In our data, the number of distances defined a person at risk and was the denominator in incidence calculation. Recurrent episodes of SIPE within days could reflect lack of recovery between races and were not counted.

Vansbro and the open water swimming event of Vansbrosimningen provide a unique setting to study the incidence of SIPE. Because of the long distance to the nearest emergency hospital, swimmers in need of medical attention will turn to the on-site MMU. In the present study, we included patients seeking, or being

referred to, the on-site MMU with respiratory symptoms. Pulmonary edema also occurs in asymptomatic athletes during exercise, shown in divers, marathon runners, and triathletes.^{26,27} In our experience, the symptoms of SIPE can vary from an innocent cough to rare, but severe, events with desaturation and unconsciousness. Unless all participants during a swimming event are examined, the true incidence of SIPE may be underestimated because of mild or absent symptoms. However, beyond a pathophysiologic interest, asymptomatic patients have little clinical relevance. Launching a research study during Vansbrosimningen has increased knowledge of SIPE in the organization of health care and first aid surrounding the event. We believe that first aid personnel along the riverside provide more encouragement for swimmers with respiratory symptoms to interrupt the race now than previously. This may explain the trend of fewer patients with severe hypoxia over the 4 years studied, despite an overall similar incidence of SIPE.

Although most reported cases of IPE and SIPE in the literature are in men, a few studies have indicated dominance in women.^{16,18,28-30} At Vansbrosimningen from 2016 through 2019, patients with pulmonary edema predominantly were women, despite an equal number of swimmers of both sexes. Sex difference in lung anatomic features, cardiopulmonary response to exercise and stress, endothelial function, as well as cardiovascular morbidity all could predispose women to SIPE.³¹⁻³³ Lower lung mass and differences in lymphatic anatomic features were demonstrated in individuals susceptible to high-altitude pulmonary edema and IPE.³⁴ Lower FVC and lower forced expiratory flow between 25% and 75% of vital capacity were found in men who later experienced SIPE.⁵ This theoretically may be a reflection of small airways disease, but is more likely a reflection of lower lung volumes.³⁵ Pulmonary hemodynamics during exercise are linked closely to left and right ventricular function.^{10,36} Women show a higher incidence of stress-induced cardiomyopathy, pulmonary arterial hypertension, and age-dependent diastolic heart dysfunction than men.³⁷ It has been shown that women have a higher systolic and diastolic left ventricular elastance (stiffness) compared with men at a given age, and this difference is accentuated with higher age.³⁸ Higher incidence of IPE in divers with increasing age has been reported by others, and changes in cardiorespiratory function with age are well

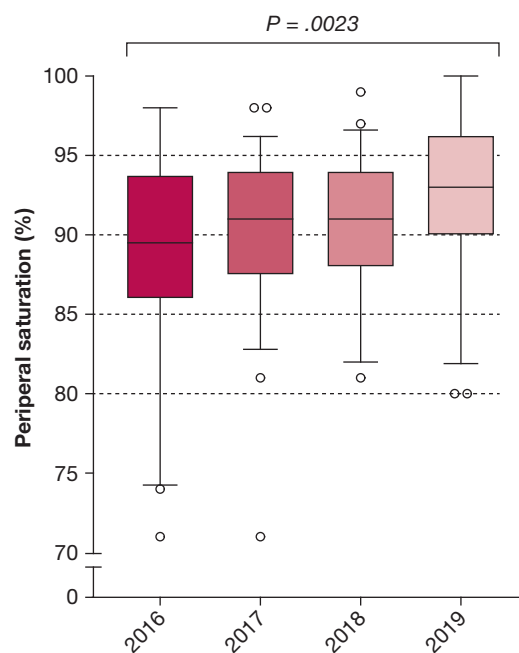


Figure 3 – Box-and-whisker plot showing the peripheral saturation (%) presented for all patients who received a diagnosis of swimming-induced pulmonary edema at the mobile medical unit in 2016, 2017, 2018, and 2019. Peripheral saturation measured by pulse oximeter at admission. Overall comparison between years made by Kruskal-Wallis test ($P = .0023$). P values for postdoc analysis was carried out using Dunn's test: $P = .002$ (2016 vs 2019), $P = .049$ (2017 vs 2019), $P = .062$ (2018 vs 2019), and $P > .100$ (2016 vs 2017, 2016 vs 2018, and 2017 vs 2018).

known.^{18,33,39} Increased stiffness of the myocardium and higher prevalence of hypertension over the life span contribute to elevated end-diastolic pressure and lower ability to increase cardiac output during exercise, resulting in higher arterial pulmonary pressure.^{40,41} Hypertension is the most frequently reported comorbidity in literature in both IPE and SIPE.^{18,39,42} Hypertension also was the most common comorbidity, besides asthma, in our otherwise healthy population of recreational swimmers. Although the end-diastolic limitation is an attractive explanation to the higher incidence of SIPE in women and with higher age, the individual predisposing factors to pulmonary edema developing during swimming or diving in open water most likely is multifactorial and needs to be explored further.

An obvious strength in the present study is the large mixed population, including most nonelite swimmers. Our data potentially can help organizers of large open-water swimming events to plan for health care resources on site. A limitation in the conclusion of age and sex as independent risk factors for SIPE is the lack of data on all potential confounders for swimmers not seeking medical care. However, female sex and higher age

consistently have been overrepresented in patients with SIPE over the years, and we believe this association will withstand future cohort studies of similar settings. Overall, knowledge on SIPE pathophysiology, potential risk factors, and long-term individual consequences is lacking, which calls for further studies. To standardize future research, we suggest that LUS findings of pulmonary edema according to the previously presented protocol become the gold standard for SIPE diagnosis.¹⁵ Herein, bilateral or unilateral presence of two or more positive regions with B-lines of four examined was defined as pulmonary edema. In the absence of equipment and skills for LUS examination, the

previously published diagnostic algorithm based on peripheral saturation and lung auscultation of crackles can be applied (e-Fig 1).¹⁵

Interpretation

We report on an incidence of SIPE of 0.44% in a large heterogeneous group of competitive and recreational swimmers during an open-water swimming event. This study provides unique epidemiologic data on an underreported condition and quantifies the association of SIPE with female sex and higher age.

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Author contributions: M. H. takes responsibility for the content of the manuscript, including the integrity of the data and data analysis. M. H. and A. B. E. initiated the study. M. H., L. K., C. S., and A. B. E. took active part in study design, logistics, and data collection. M. H. wrote the first draft of the manuscript with help of L. K., C. S., and J. S. All authors contributed to methodology and presentation and interpretation of the data and approved the final manuscript.

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Additional information: The e-Figure and e-Table can be found in the Supplemental Materials section of the online article.

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