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Prospective analysis: does ice bathing harden against COVID-19 and is B RhD- the least viral resistant blood group in Polish ice bathers?

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A – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

Summary **Background.** Amateur ice bathing has recently become very popular, with studies revealing health benefits, including enhanced viral resistance. Such interest in this issue has been heightened even more due to the COVID-19 pandemic. The study predates widespread COVID-19 vaccination in Poland.
Objectives. The aim of the study was to investigate the effect of short-term cold-water immersion on COVID-19 resistance in Polish ice bathers. Additionally, a possible relation between the ABO blood group and RhD antigen of winter swimmers and COVID-19 incidence was also studied.
Material and methods. A survey was conducted on 2,534 Polish ice bathers who were questioned about their demographic data, ice bathing habits, ABO and RhD antigens, symptoms of infection and SARS-CoV-2 RT-PCR test results. For prospective statistical analysis, a Bayesian prediction was carried out to accommodate for missing COVID-19 RT-PCR test data following the selected explanatory clinical covariates. Furthermore, a taxonomic method was used to cluster the ice bathers.
Results. In experienced ice bathers, a 7% higher resistance to COVID-19 has been estimated compared to beginners. Additionally, the probability of COVID-19 infection in ice bathers with blood group B RhD- is predicted to be the highest, while group O RhD+ and A RhD+ tend to be more resistant against the virus.
Conclusions. There is an increasing immunological resistance of ice bathing, especially in O RhD+ and A RhD+ carriers, against COVID-19, although this does not appear to be strong. Our findings suggest that ice bathing should be considered as an additional means to enhancing the resistance to infection.
Key words: COVID-19, blood group antigens, immunity.

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Background

Scientific literature provides ample evidence of the benefits of the remarkably healthy properties that short-term immersion in cold water can have on the human body. This applies to many organ systems, including the circulatory, endocrine, immune system and psyche, and there is also convincing scientific confirmation of its health benefits. Due to the framework limitation, instead of developing a paragraph on the pros and cons of ice baths, we direct readers to comprehensive reviews such as articles written by Knechtle et al. [1] and Bleakley et al. [2], treating the studied hobby and sports activity in a wide range of physiological, metabolic, clinical and immunological contexts, as well as the public health effects, e.g. combating modern world diseases such as hypertension, obesity and diabetes (the citations include reviews of a total of several hundred studies conducted in the field of research on ice bathing and the impact on ice bathers).

Ice bathing in Poland

In the past, ice bathing in Poland may have been more closely associated with groups indulging in eccentric behavior. However, the number of enthusiasts for this form of physical activity grew quickly, and formal clubs of swimmers, commonly referred to as 'walruses' ('morsy' in Polish), began to emerge. The first such club in Poland was the Gdanski Klub Morsow (Gdansk Walruses Club) [3], established in 1975. Due to the increase in the number of clubs and the growing interest in the discipline, an initiative was taken to organize an international winter sea rally in Mielno, Poland. The first such rally took place in 2004, when 120 participants got into the water. Over the following years, their number grew rapidly to reach the impressive number of 6,000 participants during the 17th International Walruses Rally. During two recent rallies, the Guinness World Record for the number of people bathing in one place at the same time was broken twice. In 2010, 1,054 'walruses' entered the water, and 1,799 in 2015. Nevertheless, on December 13, 2015, the Guinness World Record for the number of 'walruses' bathing in the same place at the same time was broken, when 3,717 people entered the water simultaneously [4].

In the era of the COVID-19 pandemic, due to temporarily closed sports and recreational facilities, ice bathing became extremely popular in Poland and could be considered the new 'national' sport of Poles.

There are many health-promoting properties that have been attributed to ice bathing, one being the strengthening of the immune system and increasing resistance to infections, which gained special importance after the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) pandemic, due to the virus spreading worldwide [5]. Despite large-scale vaccination, the search for new sources of immunity became, and still is, an important weapon in the fight against this dangerous disease, as well as many other infectious diseases [6]. Such scientific knowledge is also important to Poland, where officially, since the beginning of the pandemic, more than 6.26M cases have been reported, and over 117K citizens have died due to COVID-19 [7].

Objectives

Due to the still ongoing pandemic, all research pointing to the mechanism of infection, as well as methods and factors for reducing the risk of infection, are very valuable. Despite this interest, no one, to the best of our knowledge, has so far studied the possible immunological impact of ice bathing on resistance to COVID-19.

The aim of the study was to investigate the influence of cold-water activity (number of swimming seasons, frequency of ice bathing and time spent in cold water) on COVID-19 resistance in Polish ice bathers. Additionally, on the basis of the information received from collected questionnaires that were freely filled in by participants, we tried to establish possible relations between the ABO blood groups of ice bathers and COVID-19 incidence.

Material and methods

Material

Prior to conducting the research, we obtained approval from the bioethics committee of the Medical Chamber in Zielona Gora (No. 03/139/2021) waiving a written informed consent of each participant which was obtained online. A disclaimer message was given before the questionnaire, and every participant (and legally authorized representatives in case of minor patients below 18 years of age) filled out their personal details and confirmed their consent to participate in the research. Consent, however, was not merged with the questionnaire but was collected as separate file; therefore, the participants gave their answers anonymously. All the procedures followed were in accordance with the Declaration of Helsinki.

The research is registered and posted on the ClinicalTrials.gov site under the identifier: NCT04817280.

The study material was based on our own questionnaire, presented on the Google Drive platform [https://forms.gle/QZvQnpVnadhnzRTQ6] from December 1, 2020, to January 17, 2021 (the questionnaire is also translated into English and can be found at the link attached: https://student.cloud.umw.edu.pl/index.php/s/jnTixaXTyXpZNZA). The survey was conducted in Poland among the "short-term cooling down" persons practicing ice bathing (individually and associated with the clubs). We contacted the participants via social media and electronic mail (the co-author of this study is also a longtime ice bather, and a short video of his winter activity can be found at the link attached: https://student.cloud.umw.edu.pl/index.php/s/66gKeTm3gTszsTc). The end of the survey was dictated by a sudden drop in responses in mid-January 2021. Until then, 2,534 respondents answered the questionnaire (practicing ice bathing was the only inclusion criterion, and no exclusion criteria were used for the selection of participants). Out of those, 676 reported a SARS-CoV-2 (COVID-19) Real-Time Polymerase Chain Reaction (RT-PCR) test result, and 1,057 provided their confirmed blood group. The demographic, ice bathing activity, and clinical characteristics of the surveyed ice bathers are described in Table 1. The study was designed as prospective in its nature. During the data collection period, there was no available COVID-19 vaccine for the general population. Therefore, none of the study participants were vaccinated against COVID-19 at the time of the study.

Table 1. Demographic, ice bathing activity, and clinical characteristics of ice bathers in Polish COVID-19 survey

Characteristics	Statistics	
Sex	males = 48%, females = 52%	
Age (years)	41.3 ± 10.6 (10–87)	
Number of seasons	3.6 ± 3.5 (1–47)	
Frequency	twice a week = 1,070 (42%) weekly = 1,247 (49%) less often = 217 (9%)	
Bath time	9'36" ± 4'36" (1–30')	
Contact with COVID-19 (declarative)	no = 459 (18%) don't know = 941 (37%) yes = 1,134 (45%)	
Level of restrictions	no = 275 (11%) rather no = 285 (11%) so-so = 827 (33%) rather yes = 884 (35%) yes = 263 (10%)	
COVID-19 (PCR tested data) (*n* = 676)	negative = 380 (56%) positive = 296 (44%)	
Treatment location (*n* = 2534)	nowhere = 2,047 (81%) at home = 483 (19%) in hospital = 4 (0%)	
Blood group (*n* = 1057)	O RhD- = 77 (7%) O RhD+ = 293 (28%) A RhD- = 73 (7%) A RhD+ = 289 (27%) AB RhD- = 20 (2%) AB RhD+ = 87 (8%) B RhD- = 54 (5%) B RhD+ = 164 (16%)	
Reported symptoms (*n* = 2534)	fever	211 (8%)
	chills	137 (5%)
	dyspnea	73 (3%)
	rhinorrhea	309 (12%)
	cough	253 (10%)
	sinusitis	112 (4%)
	blepharitis	40 (2%)

Table 1. Demographic, ice bathing activity, and clinical characteristics of ice bathers in Polish COVID-19 survey

Characteristics	Statistics	
	anosmia	261 (10%)
	hypogeusia	201 (8%)
	nausea	61 (2%)
	vomiting	24 (1%)
	diarrhea	95 (4%)
	headache	438 (17%)
	sore throat	161 (6%)
	muscle pain	225 (9%)
	back pain	252 (10%)
	spine pain	252 (10%)
	arthralgia	135 (5%)
	abdominal pain	68 (3%)
	numbness in hands	100 (4%)
	skin rash	51 (2%)
	memory impairment	74 (3%)
	syncope	5 (0%)
	cardiological disorders	31 (1%)
	none of above symptoms	1,393 (55%)

Based on the statistics in Table 1, it can be said that taking part in ice bathing is spread equally between the genders of the participants, and most of the respondents were middle-aged. One can also note that the declared activity indicators (especially the number of bath seasons) are quite asymmetrical, and the frequency of bathing given by participants is certainly noteworthy (over 90% of the ice bathers reported themselves as having at least one ice bath a week). The high fraction of COVID-19 infections among the RT-PCR tested participants (296/676 = 44%) may indicate a feeling of being unwell (i.e. feeling symptoms suggestive of infection) that had forced the carriers to undergo testing. The alleged high resistance to viral diseases by the ice bathing population is certainly evidenced by the fact that only 4 out of more than 2.5 thousand people required hospital treatment, and 4 out of 5 people did not undergo any therapeutic regime. As well as this, every second ice bather did not experience any symptoms that are characteristic of a COVID-19 infection.

Based on data in Table 1 and a Pearson's χ^2 test (p-value = 0.2426), we identified a linear correlation between the observed blood group distributions among the ice bathers and the expected frequencies in the Polish population (O RhD- = 6%, O RhD+ = 31%, A RhD- = 6%, A RhD+ = 32%, AB RhD- = 1%, AB RhD+ = 7%, B RhD- = 2%, B RhD+ = 15%) [8, 9]. Moreover, the calculated Pearson's product-moment correlation $r > 0.99$ ($p < 0.0001$) and Kendall's rank correlation $\tau = 0.93$ ($p = 0.0017$) between these fractions allow us to consider the research group as statistically representative and quasi-randomized.

Methods

Bayesian prediction

Due to a relatively small fraction of ice bathers who were tested with RT-PCR towards COVID-19 infection (626/2534 = 27%, nearly 3 out of 4 individuals would have been discarded if we had used complete case analysis), the estimate of unrecorded COVID-19 test results in ice bathers was based on Bayesian predictions. Outcome values were simulated from the posterior predictive distribution (PPD). Since Bayesian methods naturally accommodate missing data for inference, they can be used as optimal predictors in forecasting, optimal classifiers in classification problems, imputations for missing data, and they are also important for checking goodness of fit of the model [10]. The idea of using PPDs for making statistical inferences is well-established in Bayesian statistics. For example, Stern and Cressie [11] used PPD obtained by reanalyzing data without suspecting small area numbers to assess whether the observed count in the area is consistent with the model.

In the missing response data mechanism, for binary indicator of COVID-19 outcome (Y), which can be partitioned into $Y = (Y^{observed}, Y^{missing})$, and confounder (= covariate/risk factor) x, a model of interest:

$f(Y^{observed}, Y^{missing} | x, b, \sigma^2)$, where b and σ^2 are independent parameters,

is the likelihood specified for fully observed response Y, whereas estimating the missing responses $Y^{missing}$ is equivalent to posterior prediction from the model fitted to the observed data (the Bayesian approach treats missing data as additional unknown quantities for which a posterior distribution can be estimated) [12].

In the specification of a joint model (for observed and missing data, the missing data indicator and the model parameters), for each individual $i = 1, \ldots, 2534$, a random effects' multivariate logistic regression which was assumed in all analyzed infection symptoms (i.e. fever, chills, dyspnea, rhinorrhea, cough, sinusitis, blepharitis, anosmia, hypogeusia, nausea, vomiting, diarrhea, headache, sore throat, muscle pain, back pain, spine pain, arthralgia, abdominal pain, numbness in hands, skin rash, memory impairment, syncope and cardiological disorders = 24 independent covariates).

$Y_i \sim$ Bernoulli (p_i), where p_i = probability of COVID-19 infection of the ith subject,

logit $(p_i) = \beta_0 + {}_{j=1}{}^{z}\Sigma \beta x_{ij} + b_i$, with $z = 24$ $(x_{i1}, \ldots, x_{ip})$ covariates, and b_i representing the random effect for subject i.

A stochastic approximation of the PPD was provided by the Markov chain Monte Carlo (MCMC) sampler in WinBUGS software [13]. A number of burn-in 1,000 samples and the following 10,000 production-run cycles of the Gibbs sampler were used to estimate each quantity of interest of the model given above.

The quality of the Bayesian prediction was assessed using accuracy coordinate ((true positive cases + true negative cases)/n = 676).

Binary logistic regression

On the available RT-PCR test (676) respondents and the remaining (2,534 - 676 = 1858) RT-PCR untested persons with a predicted COVID-19 status present, the univariate binary logistic regression was used to study the relation with selected risk factors. The results were expressed by a classical odds ratio (OR) and 95% confidence interval (95% CI).

Taxonomy

To study non-regression relationships between ice bathing and COVID-19, a cluster analysis was used based on the original taxonomic metric proposed by Marczewski and Steinhaus [14]. In this simple approach, a symmetric taxonomic distance (D) between subjects (A, B) is proposed and defined as: D = |A - B|/ max(A, B), where the nominator is the modulus of A - B, and the denominator is the maximum distance between A and B (the metric was successfully used in a few previous studies, see e.g. [15]).

In the conducted taxonomy analysis, a three-dimensional set of the collected classification factors has been proposed to measure a taxonomic distance between the ice bathers, i.e. age, sex, and the arithmetically calculated ice bathing activity index equals the sum of the normalized numbers of declared ice bathing seasons, frequency and time of inundating.

ANOVA

For the established clusters, descriptive statistics was given, and one-way parametric and non-parametric analysis of variance was conducted (ANOVA).

All statistical data and WinBUGS codes are available upon request.

Results

As a result of the conducted Bayesian prediction, the accuracy of cases in the RT-PCR tested subjects was 0.851 (> 85%), and the number of positive COVID-19 outcomes from the starting 294 PCR tested cases increased by 154 cases in the RT-PCR untested (2,534 - 676 = 1,858) subpopulation (with the remaining 1,704 COVID-19 negative individuals).

Using the rule of product of the probability of an intersection of independent events A and B: P(AÇB) = P(A) × P(B), the obtained precision of Bayesian prediction implicated all subsequent statistically significant ($p < 0.05$) estimates, giving their probability level higher than 0.85*(1–0.95)*100% > 80% (put it simply, in this study, all the $p < 0.05$ COVID-19 estimates are more than 80% likely).

According to the RT-PCR tested and COVID-19 predicted data (296 + 154)/2,534 = 18% of the Polish ice bathers were infected during the study period.

The statistically significant ($p < 0.05$) logistic regression estimates for RT-PCR tested (n = 676) + COVID-19 (n = 1858) predicted outcomes in relation to a COVID-19 contact, restriction attitude and (n = 1,057) blood groups are reported in Table 2.

Table 2. Statistically significant estimates ($p < 0.05$) of the logistic regression analysis of COVID-19 infection (based on RT-PCR tested + COVID-19 predicted results) in relation to age, social behavior and blood groups in Polish ice bathers

Risk factor	OR	95% CI	p
Age	0.987	(0.977, 0.997)	0.0081
Contact: no	1.00	(ref.)	–
Contact: don't know	1.89	(1.19, 3.02)	0.0072
Contact: yes	7.66	(4.98, 11.8)	< 0.0001
Restriction level	1.17	(1.07, 1.29)	0.0009
B RhD- vs O RhD+	2.20	(1.14, 4.27)	0.0194
B RhD- vs A RhD+	2.06	(1.07, 3.99)	0.0316
RhD+ vs RhD-	0.69	(0.48, 0.99)	0.0435

Following the results reported in Table 2, it can be established that COVID-19 infections decrease with the age of ice bathers (OR < 1). Next, it is possible to find a significant increase in the risk of viral infection (almost twofold) for those in contact with an uncertain carrier versus a negative contact (reference group). The lack of contact (negative contact) with COVID-19 carriers reported by the participants did not completely exclude such contact, and the declaration was based solely on the fact that the participant did not know or suspect such contact. This classification was in line with the criteria for suspicion of SARS-CoV-2 infection announced by the Polish Ministry of Health, which were consistent with the criteria applicable around the world. If they were convinced that there was contact with persons positive for COVID-19, the risk increased over seven and a half times. Surprisingly, an increase in the severity of a restrictive attitude on the ordinal scale (towards from "no" and "rather no" through "so-so" and "rather yes" to "yes" level) resulted in an elevated risk of viral infection almost one and two tenths of a fold with each level of restriction. Moreover, the incidence of COVID-19 is at least twice as high in those with the B RhD- blood group compared to O RhD+ and A RhD+ groups (it is of note that A RhD+ is the most frequent blood group among the Polish population) [8, 9]. Finally, carriers of the RhD+ antigen are less exposed to infection by (1–0.69)*100% = 31%, which is nearly by a third, than RhD- antigen owners. It is of note that no other relationships in the other blood antigen system provided statistically significant results, as well as for the ABO blood type with RhD antigen status calculated separately.

For the collected chosen three classification factors (age, sex and ice bathing activity index), the main four types of individuals were segregated (a taxonomical dendrogram is presented in Figure 1).

Following the particular individual "I" numbers, the identification of ice bathers was performed within the main ("1", "2", "3" and "4") taxonomic clusters. Additional demographic, ice bathing and clinical descriptive statistics of the established clusters was then conducted using one-way parametric and non-parametric analysis of variance (ANOVA). The ANOVA results are reported in Table 3.

From the results reported in Table 3, it can be seen that the conducted taxonomy grouped all the selected demographic, ice bathing and clinical factors with a statistical significance ($p < 0.05$), or at least on the border of statistical significance ($p < 0.1$), for the majority of the selected explanatory variables. Thus, the genders were allocated in separate clusters, i.e. collections "1", "2" & "4" are only males, and cluster "3" are only females. The oldest ice bathers belong to cluster "1", while the youngest, by around 30 years of age, are males in cluster "4". The means of ice bathing activity, i.e. the declared number of seasons attended, frequency of ice bathing per week and inundating time in clusters were presented graphically in Figure 2, Panels A, B, and C, respectively, while the COVID-19 incidence plot (based on RT-PCR tested and COVID-19 predicted data) is

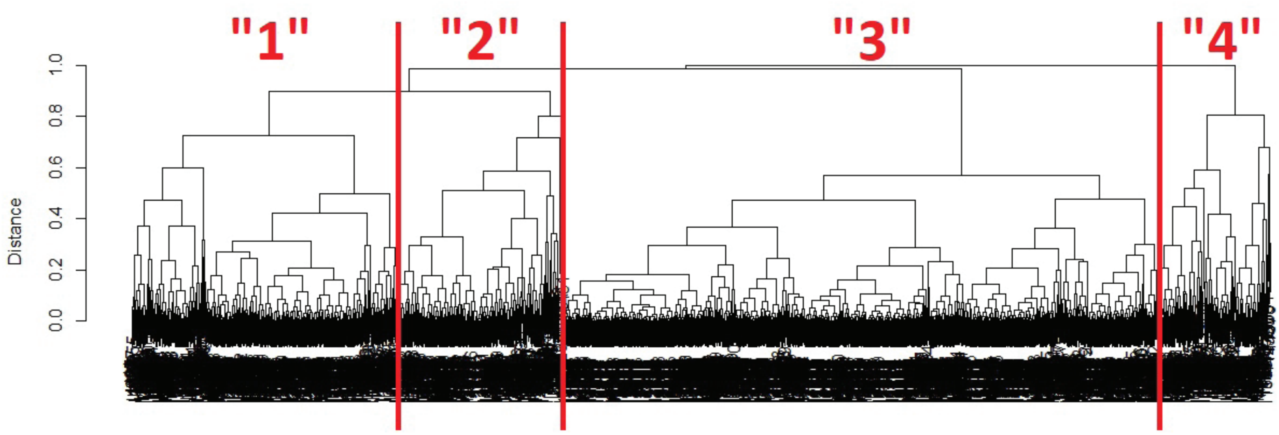

Figure 1. Classification dendrogram of ice bathers based on age, sex and ice bathing activity (n = 2534). The displayed dendrogram can be described as follows: particular individuals (coded by "I" numbers) from up to down are hierarchically aggregated in separated branches that are represented by separate leaves of the dendrogram. In this way, four main clusters ("1", "2", "3" and "4") of ice bathers can be distinguished in the created classification tree.

Table 3. Demographic, ice bathing and clinical characteristics of ice bathers in established taxonomic clusters with one-way parametric and non-parametric ($p < 0.05$ & $p < 0.1$) ANOVA test

Cluster:	1	2	3	4	*p*
n =	591	371	1320	252	
Sex	males	males	females	males	
Age (years)	48.0 ± 9.4	40.0 ± 5.9	41.1 ± 10.4	29.1 ± 6.4	< 0.0001
No. of seasons	5.2 ± 5.2	3.2 ± 2.4	3.2 ± 2.6	2.8 ± 2.0	< 0.0001
Frequency (per 1 week)	1.7 ± 0.5	0.9 ± 0.2	1.3 ± 0.5	1.5 ± 0.5	< 0.0001
Bath time (min)	10.8 ± 4.8	8.2 ± 3.6	9.5 ± 4.6	9.6 ± 4.9	< 0.0001
COVID-19	16%	23%	17%	18%	0.0338
Fever	9%	12%	7%	8%	0.0181
Dyspnea	10%	15%	11%	19%	0.0990
Rhinorrhea	4%	2%	3%	3%	0.0005
Sinusitis	3%	5%	5%	3%	0.0816
Blepharitis	1%	1%	3%	0%	0.0016
Nausea	1%	1%	4%	1%	0.0012
Headache	9%	16%	22%	13%	< 0.0001
Sore throat	3%	6%	8%	6%	0.0029
Back pain	8%	13%	10%	10%	0.0754
Spine pain	9%	8%	12%	8%	0.0460
Abdominal pain	2%	1%	4%	2%	0.0069
Numbness in hands	3%	2%	5%	2%	0.0270
Skin rash	2%	1%	3%	0%	0.0402
Memory impairment	2%	2%	4%	2%	0.0577
Cardiological disorders	2%	0%	1%	1%	0.0196
None of above symptoms	60%	52%	54%	56%	0.0437

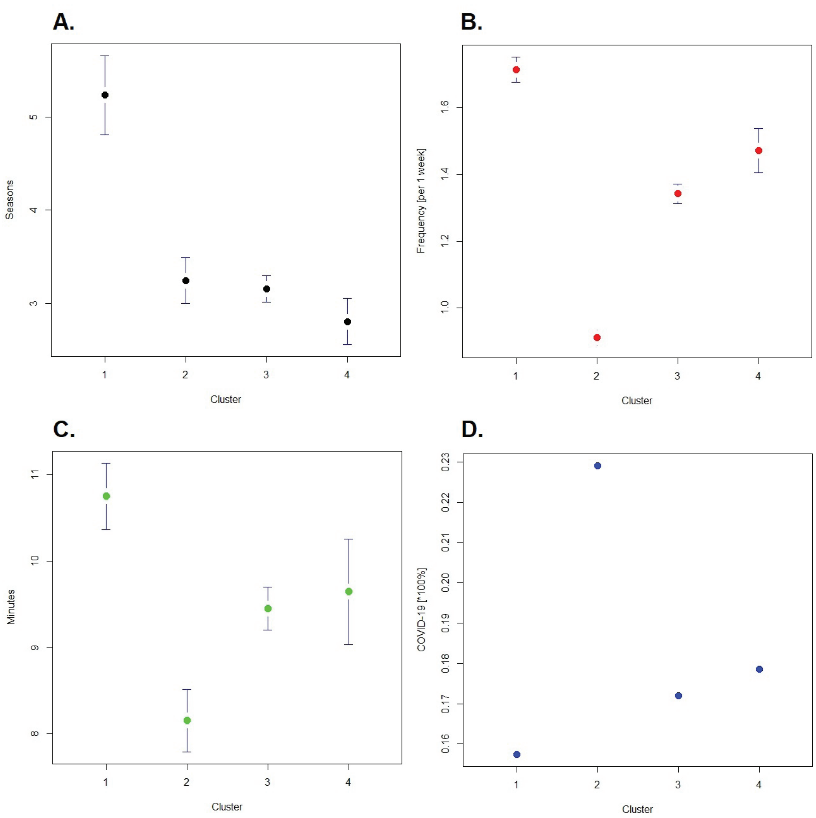

Figure 2. Means of number of seasons, frequency per 1 week, ice bathing time and COVID-19 incidence in taxonomic clusters (Panel A = Number of seasons; Panel B = Frequency per 1 week; Panel C = Time of ice bathing; Panel D = COVID-19 incidence)

The computation was performed with the *R* statistical platform [16] and 'cluster' *R* packages [17].

shown correspondingly in Panel D. Fever was mostly observed in the "2" cluster but was less experience by women (cluster "3"), etc.

Based on the statistically significant ($p < 0.05$) statistics of ice bathing activity and COVID-19 incidence in male taxonomic clusters, it can be stated that between the most experienced ice bathers (cluster "1") and the beginners (cluster "2"), there is a (23 - 16) = 7% difference in population resistance to COVID-19, in favor of advanced bathers (see Table 3 and Figure 2 for a better visualization).

Discussion

In this investigation, we conducted a survey amongst ice bathers who practice this increasingly popular sport. One of our main findings is that amongst ice bathers, the risk of being COVID-19 positive is inversely related to age (Table 3). This result, however, is not consistent with the review of 70 studies made by Romero Starke et al. (2021) [18], clearly indicating that the risk of COVID-19 disease severity due to the isolated effect of age increases by age year, and no specific age threshold was observed.

One possible explanation might be longer exposure to ice bathing being responsible for the stronger possible immunomodulating effect, and additionally, Pearson's linear correlation $r = 0.33$, $p < 0.0001$ may justify this thesis, indicating a statistically significant and positive association between the age of ice bathers and the number of ice bathing seasons attended.

Some studies have proposed a protective mechanism suggesting that a greater number of leukocytes and monocytes activated in the marginating pool. As a result, ice bathers have better non-specific immunity and are less susceptible to infections [1, 2]. This falls in line with research carried out by other scientists and is related to the hardening of the human organism [19]. Moreover, a study of a small group of people who participated in a 150-meter cold water swimming competition showed that it causes a significant change in complete blood counts (CBC) compared those who are not involved in the activity. There was a statistically significant increase in the level of erythrocytes, leukocytes and platelets which could not be explained by hemoconcentration due to fluid loss [20]. As another potential mechanism for the improved resistance to infection, another study showed that in experienced ice bathers, plasma levels of interleukin 6, resting leukocytes and monocytes were significantly higher than in inexperienced ice bathers [21]. Thus, it seems that both short-term and the long-term changes occur in blood homeostasis and hormone levels in people who regularly partake in ice bathing. This might explain our findings, where ice bathers with higher exposure in terms of frequency and duration of baths reported less COVID-19 infections. The result of this study therefore supports the thesis of viral hardening in people who rationally use cold baths.

Our study also demonstrates that possible contact with an infected person increases the likelihood of a positive COVID-19 test result. This is consistent with previously conducted research and proves that such a distinction of contact based only on the patient's knowledge of its occurrence, and not its objective exclusion, is a sufficient criterion affecting the likelihood of contracting COVID-19 [22]. However, in contrast to existing studies, which proved a significant positive correlation between compliance with restrictions, our findings show the opposite (Table 2). The more carefully the restrictions were followed, the higher the risk was of getting COVID-19, which is an interesting and unusual phenomenon if compared with Bouchnita et al. [23], Głąbska et al. [24], Gomez et al. [25] and Tang et al. [26], for example.

First of all, we can explain this anomaly by attributing it more to the emotional behavior of the respondents. It might be a case of psychological self-defense in people who tried to excuse themselves while knowing that they had had contact with an infected person or instinctively felt that they were COVID-19 positive. On the other hand, it would be worth considering comparing it with the information on exposure to SARS-CoV-2 taking into account people's occupation. It seems reasonable that people who are at high risk of SARS-CoV-2 infection, e.g. doctors, nurses and paramedics, get sick more often than the rest of the population [27, 28], despite following rules about hygiene and using personal protective equipment [22]. Despite following the restrictions, the risk of infection is also dependent on the viremia of the target patient, as well as the nature, timing, proximity, duration and amount of potentially dangerous contacts.

Another issue that may explain this phenomenon is the quality of compliance with the restrictions. According to other authors, wearing masks and frequent hand washing reduces the risk of transmission of the infection, and the more correctly these procedures are followed, the more effective they are. Education about the proper use of masks and hand hygiene is essential all the time [29].

Before we move on to the analysis of the disease in the context of blood groups, it is worth noting that the remarkably high correlation found between the blood group counts in ice bathers within the Polish population indicates a very high statistical representativeness of the analyzed statistical sample. It also reflects the credibility and quality of the statistical outcomes obtained in the study.

Analyzing the results in relation to the influence of the blood group set out in the ABO system and the RhD antigen on the susceptibility to SARS-CoV-2 infection, we can see that that the risk of infection in group B RhD- is twice as high as in types O RhD+ and A RhD+ (Table 2), while no other statistically significant differences between the remaining blood groups have been found. Moreover, the COVID-19 incidence in ice bathers with a positive RhD antigen is almost a third lower than in carriers with a negative RhD antigen. These results indicate the need for caution in people with the indicated blood group in regard to the weakest immunological resistance, despite the extreme thermal activity they partake in.

The association between the susceptibility to COVID-19 infection and blood group has already been the subject of many previous studies that seem to be discrepant with each other. For example, some researchers report that blood group O is associated with the lowest risk of developing COVID-19 [30–34], while also showing a protective effect, both in terms of the risk of infection and the severity of the disease; however, others found that its positive RhD antigen increases that risk [30] and that (followed by A RhD-) it was more frequently found in patients who tested positive for COVID-19 [35]. In turn, there are studies indicating that blood groups A and B may play a role in increased susceptibility to COVID-19 infection and that blood group AB may also be somewhat protective [31, 32, 36], but according to a meta-analysis conducted in China, blood group AB did not increase the risk of SARS-CoV-2 infection [37]. To complicate this, taking into question all the conclusions from the studies mentioned above, some authors have recently reported that in people who have already been infected, the blood group does not appear to influence COVID-19 infection or the clinical outcome at all [38].

As briefly shown above, considerable scientific efforts have been made worldwide to decipher the immune response triggered upon COVID-19 infection and its preferences for specific blood groups, and even after all these studies, there is still no consensus by researchers investigating these questions. We believe that our study is one more contribution to the studies of the inflammatory processes involved in critical illnesses caused by COVID-19, which is of high importance.

Conclusions and suggestions

We conclude that amateur ice bathing may have influenced population immunity against COVID-19. In particular, in our study, in the male ice bathers who were exposed to ice bathing the longest, the population resistance to infection was 23–16%, which is 7% higher compared to beginners. In addition, the B RhD- blood group seems to be the most infected by COVID-19, compared to O RhD+ and A RhD+ groups, as well as RhD positive antigen carriers are less likely to develop the disease than RhD negative individuals. These observations indicate that extreme thermal activity like ice-bathing is undoubtly not raising the immunological resistance against COVID-19 as much as vaccination do. However, it could have an additional effect on overall resistance.

Our results are not a breakthrough in the knowledge of COVID-19, but they do point to additional immune mechanisms that work against this dangerous disease. However, they require further scientific verification, and vaccination must be always the first line of defense with COVID-19. Our findings should be treated as additional means for enhancing the immune system and suggest that ice bathing should be considered as an additional means to enhancing the immune system.

limitations of the study

The main problem is the lack of a control group. However, it would be difficult to compare the studied ice bathing activity in a situation where all the data on this subject would have to be zeroed. It seems to us, however, that the group of beginners can be treated, in a sense, as a control group, as they constitute a significant share in the entire statistical sample (who only just started their physical activity) and measurably differ from the other ice bathers studied. Moreover, a selection bias is considered if including only those participants who used web applications and ignoring the persons from the general population not connected to electronic media.

It is crucial to highlight that additional risk factors, in the form of comorbidities, contribute to an increased incidence of COVID-19 and elevate the risk of a severe course of the disease. Unfortunately, we did not collect information on these factors from the study participants. The absence of this data could significantly impact the results and their interpretation.

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