Examining the First Decision-Making in Response to Symptoms of Acute Myocardial Infarction:

Symptom Awareness, Reaction to the Symptoms, Cardiac Symptom Attribution, and Proficiency in Cardiopulmonary Resuscitation

Thesis

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Abstract

Background: Ischemic heart disease impacts 126 million individuals worldwide, underscoring the critical need to explore strategies for reducing mortality and morbidity in cases of acute myocardial infarction (AMI). One potential step is to promote awareness of the symptoms, cardiac symptom attribution, and the appropriate response, as this can shorten the time from symptoms onset to reperfusion. At the same time, proficiency in cardiopulmonary resuscitation (CPR) is crucial, as well as the self-efficacy of bystanders to perform it in an emergency.

Methods: At the global level, understanding of symptoms and cardiac symptom attribution was examined through a systematic review, encompassing all relevant studies between January 2008 to August 2019 utilizing four electronic databases. Cardiac patients and the general population were compared, and results were presented using knowledge scores, crude means, and weighted means. Additionally, an online study conducted between 2020 and 2021 surveyed 633 participants from four German states with low and high AMI mortality rates. We analyzed knowledge scores by linear regression and calculated the prevalence ratio for binary outcomes. Univariate and multivariable regressions were used to identify health-related and sociodemographic factors associated with knowledge, symptom response, and CPR skills.

Results: The systematic review included 86 studies with a total sample size of 354,497 participants. Cardiac patients demonstrated a broader knowledge base compared to the general population (69.5% vs. 42.1%, with a maximum of 100%). However, 45.1% of patients did not attribute the symptoms to the heart when experiencing their AMI. The cross-sectional study revealed that German participants had better knowledge compared to the global level but still lacked awareness of common symptoms. When faced with realistic scenarios, respondents mostly chose an inappropriate response. The majority lacked confidence in performing CPR in an emergency. Regional differences within Germany regarding the first-decision making did not explain the varying mortality rates.

Conclusion: This work demonstrates that internationally, despite a broad knowledge base about symptoms, cardiac patients mostly do not attribute their symptoms to cardiac origin. Psychological factors and symptom incongruence are presumed contributors. Inadequate knowledge of atypical symptoms in the population disproportionately affects women and the elderly due to their more frequent atypical symptom presentation. German study participants struggled to apply their knowledge in everyday scenarios, suggesting that educational campaigns should use a more practical approach to convey awareness. We recommend repetitive CPR training in Germany, which would particularly benefit the older population.

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Referat

Hintergrund: Die ischämische Herzkrankheit betrifft weltweit 126 Millionen Menschen, was den Stellenwert verdeutlicht, Wege zur Reduzierung von Mortalität und Morbidität nach einem akuten Myokardinfarkt (AMI) zu finden. Eine Herangehensweise ist die Verbesserung des Wissens über die Symptome, die Zuordnung zu einer kardialen Ursache und die angemessene Reaktion, da dies die Zeit von Symptombeginn zu Reperfusion verkürzen kann. Gleichzeitig ist die Kenntnis über kardiopulmonale Reanimation (CPR) zentral, sowie dass sich Beistehende dies im Notfall zutrauen.

Methoden: Der weltweite Kenntnistand über die Symptome und die kardiale Symptomattribution wurden mittels einer systematischen Übersichtsarbeit untersucht unter Einschluss aller relevanten Studien von 01.2008 – 08.2019 unter Verwendung von vier elektronischen Datenbanken. Kardiale Patienten und die Allgemeinbevölkerung wurden verglichen und die Ergebnisse mittels Wissens-Scores, ungewichteten und gewichteten Mittelwerten dargestellt. Gleichfalls befragten wir in einer Online-Studie zwischen 2020 und 2021 633 Teilnehmer aus vier deutschen Bundesländern mit niedrigen und hohen AMI-Mortalitätsraten. Wir analysierten Wissens-Scores mittels linearer Regression und berechneten Prävalenzraten. Mittels uni- und multivariabler Regressionen wurden gesundheitsbezogene und soziodemografische Faktoren gefunden, die eine Assoziation mit Wissen, der Reaktion auf Symptome und Fähigkeiten in CPR zeigen.

Ergebnisse: In der systematischen Übersichtsarbeit wurden 86 Studien mit insgesamt 354.497 Teilnehmern eingeschlossen. Die kardiologische Gruppe wies im Vergleich zur Allgemeinbevölkerung einen breiteren Kenntnisstand auf (69,5% bzw. 42,1%, mit einem Höchstwert von 100%). Die kardiale Symptomattribution war unzureichend (45,1%). Die Querschnittsstudie zeigte einen höheren Wissensstand deutscher Studienteilnehmer im internationalen Vergleich, dennoch waren auch geläufige Symptome unzureichend bekannt. Die gewählte Reaktion auf die Beschreibung eines AMI-Szenarios war größtenteils inadäquat. Die Mehrheit traute sich nicht zu, eine CPR im Notfall auszuführen. Die festgestellten Unterschiede zwischen den vier deutschen Regionen konnten die verschieden hohen Mortalitätsraten nicht erklären.

Fazit: Diese Arbeit zeigt, dass kardiale Patienten international trotz eines breiten Kenntnisstandes über die Symptome, ihre eigenen Symptome mehrheitlich nicht auf einen kardialen Ursprung zurückführen. Psychologische Faktoren und Symptominkongruenz sind hier anzunehmen. Die unzureichende Kenntnis atypischer Symptome in der Bevölkerung wirkt sich insbesondere auf Frauen und älteren Menschen negativ aus aufgrund ihrer häufigeren atypischen Symptompräsentation. Deutsche Studienteilnehmer hatten Schwierigkeiten, ihr Wissen in alltagsnahen Szenarien anzuwenden. Dies impliziert, dass Aufklärungskampagnen die Wissensvermittlung praxisnah gestalten sollten. Wir empfehlen repetitives CPR-Training in Deutschland, wovon vor allem die ältere Bevölkerung profitieren würde.

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List of abbreviations

IHD	ischemic heart disease
AMI	acute myocardial infarction
OECD	organization for economic co-operation and development
COVID-19	Coronavirus disease 2019
CVD	coronary vascular disease
ACS	acute coronary syndrome
STEMI	ST-elevation myocardial infarction
CPR	cardiopulmonary resuscitation
HBM	health belief model
SCT	social cognitive theory
EPPM	extended parallel process model
TPB	theory of planned behavior
CSM	common-sense model
HeReCA	health related beliefs and healthcare experiences in Germany
PRISMA	preferred reporting items for systematic reviews and meta-analyses
OHCA	out-of-hospital cardiac arrest
T-CPR	telephone-assisted cardiopulmonary resuscitation
AI	artificial intelligence

1. Introduction and objectives

1.1 Importance of reducing mortality and morbidity of acute myocardial infarction

Ischemic heart disease (IHD) affects around 126 million people worldwide (1,655 per 100,000) with an increasing prevalence globally. (1) With a prevalence of 3.5% in Germany in 2020 and a death toll of 102.4 deaths per 100,000 for IHD and 38.7 deaths per 100,000 for acute myocardial infarction (AMI), chronic IHD is the leading cause of death in Germany. (2, 3) This health burden has been identified as a significant contributor to the modest improvement in life expectancy in "Organization for Economic Co-operation and Development" (OECD) countries from 2011-2019, particularly evident in Germany compared to other OECD nations. (4) While various factors such as trends in obesity, diabetes, socio-economic disparities, migration, and the impact of "austerity" measures following the 2008 economic recession may contribute to the slowdown in life expectancy improvements, heart disease, and stroke have been identified as contributing the most, according to an assessment from Public Health England. (4, 5)

Amid the Coronavirus disease 2019 (COVID-19) pandemic, there is a heightened importance in informing the public about the urgency of seeking help when experiencing IHD symptoms. A study by Porter et al. revealed a 48% increase in the likelihood of dying at home from IHD during the pandemic study period, underscoring the critical need for more awareness. (6) Additionally, COVID-19 has been established as a risk factor for various forms of coronary vascular disease (CVD), including IHD, exhibiting a comparable impact to traditional cardiovascular risk factors. (7) These findings emphasize the increasing importance of devising strategies to reduce mortality and morbidity in acute coronary syndrome (ACS) and AMI, both in Germany and globally.

While primary prevention typically concentrates on the general population and risk groups, secondary prevention involves addressing patients already diagnosed with established CVD or who have experienced an AMI. (8) Similarly, comprehensive prevention encompasses public awareness campaigns and direct communication from healthcare providers to inform both the general public and cardiac patients about the appropriate response when experiencing AMI symptoms. (9) Enhancing understanding of AMI and empowering patients, as well as their families, friends, and bystanders, to react promptly and correctly when witnessing related symptoms can significantly reduce pre-hospital delay. This reduction is crucial since evidence indicates that minimizing the time from symptom onset to reperfusion leads to smaller infarct sizes, diminished adverse clinical outcomes, and reduced morbidity and mortality. (10–13) To comprehend patient delay, the time from symptom onset to seeking help, it is pivotal to analyze the initial decision-making process. This involves knowledge of symptoms, the ability to attribute them to the heart during emergencies, and awareness of the correct reaction and urgency. (14–16)

Despite various awareness campaigns in Germany, as organized by the "Deutsche Herzstiftung e. V.", in 2012, the median pre-hospital delay time for AMI patients in Germany was 184 minutes, with a time to the first medical contact of 128 minutes among ST-elevation myocardial infarction (STEMI) patients. (14, 17–19) Data from the Augsburg Myocardial Infarction Registry in southern Germany indicated that, for 40% of AMI patients, the time from symptom onset to hospitalization exceeded four hours. (20) This illustrates that the majority of German patients do not receive treatment within the critical period, mirroring the global situation, and emphasizing the potential to reduce mortality by minimizing patient delay. (21)

Furthermore, the survival of patients during the pre-hospital period can be increased by improving the public's proficiency in cardiopulmonary resuscitation (CPR). Consequently, it is crucial that the public possesses sufficient confidence in their CPR skills, enabling them to effectively administer CPR or guide others to perform it during emergencies.

1.2 Theoretical background

1) Health Belief Model

The Health Belief Model (HBM) serves as a foundational framework for understanding individuals' health-related behaviors. (22) Developed in the 1950s by social psychologists Hochbaum, Rosenstock, and others, the HBM posits that people's health-related actions are influenced by their perceptions of susceptibility to a health threat, the severity of the threat, the perceived benefits of taking action, and the perceived barriers to action. (23) Additionally, cues to action, such as symptoms or external stimuli, prompt individuals to engage in health-protective behaviors. (22) In the context of experiencing symptoms of an AMI, the HBM can help elucidate the factors influencing individuals' decision-making processes during a cardiac event, and the likelihood of seeking timely medical assistance. Similarly, during educational campaigns targeting the public and cardiac patients, their perceptions of AMI as a severe health threat will influence how well they retain the campaign's message and recognize symptoms in the future.

2) Social Cognitive Theory

Social Cognitive Theory (SCT), developed by psychologist Albert Bandura, emphasizes the role of observational learning, social influence, and self-efficacy in shaping behavior. (24) According to SCT, individuals learn by observing others' actions and the consequences of those actions, leading to the acquisition of knowledge, skills, and attitudes. Moreover, self-efficacy, or one's belief in their ability to perform a specific behavior, plays a crucial role in determining whether

individuals engage in health-promoting actions. This is relevant in emergency situations such as performing CPR or making the decision to call an ambulance promptly, as it requires not only a sense of urgency but also confidence in one's ability to recognize and respond to the situation effectively. Similarly, exposure to educational campaigns or witnessing the experience and response of an individual during an AMI can enhance individuals' self-efficacy and contribute to better decision-making in similar situations.

3) Extended Parallel Process Model

The Extended Parallel Process Model (EPPM), proposed by communication scholars Kim Witte and Mike Allen, focuses on individuals' responses to fear-inducing messages about health threats. (25) According to the EPPM, individuals' responses to fear appeals depend on their perceptions of the severity and susceptibility of the threat, as well as their perceptions of the efficacy of recommended responses. If individuals believe they are susceptible to a severe health threat and perceive the recommended response as effective, they are more likely to engage in the recommended behavior. However, if individuals perceive the recommended response as ineffective or perceive high barriers to action, they may engage in defensive avoidance or denial. Consequently, in the case of an AMI, patients will be more likely to call an ambulance, firstly, if they recognize the symptoms as belonging to an AMI (cardiac symptom attribution) and, secondly, judge an AMI as a threatening emergency that can be tackled by immediate medical help.

4) Theory of Planned Behavior

The Theory of Planned Behavior (TPB), proposed by psychologists Icek Ajzen and Martin Fishbein, posits that individuals' intentions to engage in behavior are influenced by their attitudes toward the behavior, subjective norms, and perceived behavioral control. (26, 27) Attitudes refer to individuals' positive or negative evaluations of the behavior, subjective norms reflect perceived social pressure to perform or not perform the behavior, and perceived behavioral control refers to individuals' perceptions of their ability to perform the behavior under different circumstances. Intentions, in turn, are strong predictors of actual behavior. For the decision-making process in the case of an AMI, it is essential to what degree an individual perceives social pressure to call an ambulance for himself or another person when feeling unwell. Likewise, while there exists societal expectation to administer CPR during emergencies, individuals may encounter personal and social obstacles, particularly when providing aid to someone of a different gender.

5) Symbolic Interactionism

Symbolic Interactionism is a sociological perspective that focuses on the role of symbols and interactions in shaping human behavior and perceptions. (28, 29) Rooted in the work of theorists such as George Herbert Mead and Herbert Blumer, this framework suggests that individuals create and interpret symbols to assign meaning to their experiences and interactions. In the context of the decision-making process in AMI, it emphasizes the influence of family members and friends who are often consulted as well as bystanders in a public space. In one study by Alonzo of 1102 patients, 93% of patients who suspected an episode of acute CVD were not alone when they experienced the symptoms and in 78% of cases, the witnesses were family members. (30) Dracup et al. used the theory of symbolic interactionism to describe four phases in the shared decision-making process: the act of decision, the individual's self-concept, the counter roles, and the periodic evaluation. (31) While the counter roles depend on the setting and could be people or input from the internet, the periodic evaluation depicts the phase in which a shared or unilateral decision is made on seeking help, postponing help, or self-treatment.

6) Acute Myocardial Infarction Coping Model

Introduced by Nancy Reynolds and Angelo Alonzo, the AMI Coping Model is a midrange theory looking at the decision-making process in the case of an AMI that sees individuals as active problem solvers who consciously and intentionally engage in cognitive and behavioral efforts to manage external or internal demands. (32) Key assumptions include the desire for a stable social identity and the involuntary nature of emotions, which influence perception and situational responses. The model incorporates concepts such as coping, emotions, cumulative stress, and phases of AMI coping, including impulse recognition, cognitive processing, overt action, and assessment. The AMI Coping Model proposes that coping mechanisms centered around emotions could hinder an individual's capacity for correct symptom attribution. This has been confirmed by Fox-Wasylyshyn et al. and explains why a previous AMI is not necessarily a predictor for a correct and timely reaction. (33) In fact, engaging in activities to divert attention from the symptoms, or ignore or downplay AMI symptoms results in extended patient delay. (34, 35)

7) Leventhal's Common-Sense Model of Illness Representation

Leventhal's common-sense model (CSM) of illness representation suggests that individuals form cognitive and emotional representations of illness based on their experiences and understanding. It emphasizes how individuals perceive the identity, cause, timeline, consequences, and controllability of their illness, which in turn influences coping behaviors. (36, 37) The CSM posits

that individuals develop a "common-sense" understanding of their illness to make sense of their experiences and guide their behaviors. This understanding includes an expectation of the symptoms regarding location, duration, as well as severity. A higher symptom congruence, meaning the degree to which the expectation aligns with the experience, has been shown to be associated with a higher cardiac symptom attribution and a lower patient delay. (38–41) Fox-Wasylyshyn found that especially experiencing more severe symptoms or chest pain contributed to a higher degree of symptom congruence. (42)

1.3 Research question

To our knowledge, as of 2020, there was no systematic global overview of the knowledge levels among the general population and cardiac patients. Moreover, correct symptom attribution, referring to AMI or ACS patients attributing their symptoms to the heart before receiving a medical diagnosis, had not been assessed internationally. Recognizing this gap, we conducted a systematic review encompassing four databases, including pertinent studies over the preceding decade (January 1, 2008, to August 1, 2019). (43) This review provided insights into AMI awareness in Germany compared to other nations and allowed us to draw general conclusions about the knowledge levels of cardiac patients in contrast to the general population. Additionally, it enabled both a German and global examination of the initial attribution of symptoms. The review further facilitated an assessment of knowledge variations regarding different symptoms and possible implications of insufficient knowledge on the initial decision-making process, particularly for atypical symptom presentations. Lastly, we compared results obtained through different assessment formats, including open- and closed-ended question formats.

During 2020 and 2021, we conducted a cross-sectional study using an online survey to assess the knowledge of AMI symptoms, the first decision-making process, and competency in CPR among 633 respondents in four regions in Germany. (44) This investigation aimed to compare these factors in regions with high (Saxony-Anhalt) and low (Baden-Wuerttemberg, North-Rhine Westphalia, Schleswig-Holstein) mortality rates, which, to our knowledge, had not been previously assessed. While previous literature confirmed that a higher number of risk factors in Saxony-Anhalt contributes to the differences, we sought to examine behavioral and awareness-related factors. (45) Therefore, we explored predictive variables for higher knowledge, CPR proficiency, and the appropriate reaction in case of witnessing an AMI. Besides identifying gaps in understanding, the findings allowed us to provide recommendations regarding the targeting of educational campaigns and CPR training.

1.4 Methods

Regarding our systematic review, we looked for studies examining the knowledge levels of the symptoms of AMI and cardiac symptom attribution. Our search covered four databases - PubMed, CINAHL, Embase, and Cochrane Library - and relevant studies were identified using the PubMed search algorithm: “myocardial infarction”[mesh] AND (“chest pain” OR symptom* OR “warning signs”) AND (“recognition” OR “awareness” OR interpretation* OR perception* OR incongruence* OR congruence* OR expectation* OR “knowledge” OR “understanding” OR “community intervention” OR “educational intervention” OR campaign*). The search algorithm was appropriately adjusted for the other databases to meet their specific requirements. (43)

Following a screening process conducted by two reviewers, a quality assessment was carried out using an adapted version of the Newcastle Ottawa scale. This scale is recommended for evaluating the quality of nonrandomized studies in meta-analyses and has been employed in a similar review previously. (46, 47) In particular, we examined two factors separately, the representativeness of the sample and response proportion, as we found these factors to be most relevant for our assessment.

For data analysis and reporting, we standardized knowledge scores for comparison and summarization. The standardized score, termed the overall knowledge score, represents the mean knowledge score within a group, divided by the maximum achievable value, and multiplied by 100%. In calculating the crude arithmetic mean, each sample's overall knowledge score carried equal weight. Conversely, when computing the weighted arithmetic mean, the weight of each sample's overall knowledge score was determined by the number of participants in that sample.

Our cross-sectional study was embedded in the “Health Related Beliefs and Healthcare Experiences in Germany” (HeReCa) online panel, which was reviewed by the ethical commission of the Medical Faculty of the Martin Luther University Halle-Wittenberg (reg. nr.: 2019-044). HeReCa is described in detail elsewhere. (48, 49) We applied the questionnaire on symptom attribution in a sample of participants who registered for the HeReCa study after a postal reminder. Initially, addresses of 10,000 individuals per federal state were obtained from the local registration offices. We sent a first invitation to these individuals, and they filled out a different questionnaire. Upon non-response, we followed up with reminders sent to 35,835 individuals. Of these, 857 completed the questionnaire for the present study, but only 633 participants were included in the analysis after excluding observations with missing values for any of the examined variables. (44)

For evaluating the knowledge of symptoms, we employed a list of 10 commonly used symptoms drawn from previous studies, as described in our systematic review. As a “trap” symptom, we used 'sudden visual disturbances’ which is frequently utilized in the literature because participants commonly tend to confuse symptoms of stroke and AMI. (43)

Participants' responses to encountering an individual exhibiting symptoms of AMI were evaluated via the description of a hypothetical phone scenario featuring a female person that the participant is close with. This 60-year-old woman expressed concern over sudden chest pain in one scenario and escalating abdominal discomfort over the past hour in another. By asking half of the participants about the prevalent symptom of chest pain and the other half about the less recognized symptom of abdominal pain, we sought to enhance the external validity of our assessment beyond a mere checklist of symptoms. Participants were presented with four potential reactions to the phone call, with one option deemed the most appropriate and assessed as correct in the subsequent analysis. Additionally, they had the choice of selecting "do not know" or "none of the above," which, in turn, enabled them to provide an answer in a free-text field.

Similarly, we investigated the reactions of first responders when faced with a potential AMI scenario, where they are the first witnesses to discover a person collapsed on the floor of a department store. Furthermore, we assessed the initial decision-making process by directly asking participants what they would do first if they suspected someone was experiencing an AMI. Another aspect evaluated CPR proficiency by presenting five options representing varying levels of self-efficacy and skill.

In our statistical analyses, we utilized linear regressions to examine knowledge scores. Additionally, we conducted both univariable and multivariable regressions to identify factors that might be associated with various outcomes. In all models, age was incorporated as a linear term. For the regression analyses, we considered socio-economic, biological, health-related, and educational factors, alongside knowledge scores and location, as potential predictors for the outcomes under investigation.

1.5 Reducing pre-hospital delay time

1.5.1 Knowledge of symptoms

After screening 1419 records, in accordance with “Preferred Reporting Items for Systematic Reviews and Meta-Analyses” (PRISMA) guidelines, we included 86 pertinent studies from 34 different countries in our systematic review. (50) Relevant data were extracted from each record for analyses. The quality assessment indicated mostly high representativeness and response proportion. Only one study established comparability between respondents and non-respondents’ characteristics.

Our systematic review revealed an overall knowledge score of 42.1% in the population group, employing a weighted mean. This means that, on average, participants correctly recognized 42.1% of all AMI symptoms from a list of symptoms. Comparatively, our cross-sectional study in

Germany found a higher mean knowledge score of 7.3/11, indicating that participants correctly attributed 7.3 symptoms to AMI, constituting a proportion of 66.4%.

Globally, cardiac patients appeared to have a higher level of knowledge (69.5%) than the population, utilizing a weighted mean. Both cardiac patients and the population exhibited a substantially better knowledge of six symptoms 'chest pain or discomfort', 'shortness of breath', 'pain or discomfort in arms or shoulders', 'feeling weak, lightheaded, or faint', 'pain or discomfort in the jaw, neck, or back', and 'sweating' (49.8 - 88.5%), compared to the remaining symptoms. The remaining symptoms, namely 'stomach or abdominal discomfort', 'nausea or vomiting', and 'headache' were less well-known in both groups, but still better known by cardiac patients (23.4 - 36.7%) than the general population (8.7 - 28%). 'Feeling of anxiety' was exclusively assessed in the population and similarly not well known (23.7%).

The weighted mean knowledge of the trap symptom 'sudden trouble seeing in one or both eyes' or 'visual impairment' was 32.2% in the general population compared to 33% in the cardiac group which means that in both groups around one-third mistook a stroke symptom for a cardiac symptom. It can also point to the possibility that participants had a tendency to tick off more items on the list of symptoms. (51, 52) In the German general population, 44.5% incorrectly attributed the symptom 'sudden visual disturbances.' (44) Although this percentage surpasses the international average, the consequences of this finding may be mitigated by the fact that 'sudden visual disturbances', while not indicative of AMI, still necessitate prompt professional assistance.

Participants demonstrated higher symptom recognition when presented with a list of symptoms to tick off (closed-ended question) compared to an open-ended question format that required them to recall AMI symptoms from memory. These findings are consistent with previous research. (51, 52) Using a symptom checklist may enhance external validity, as it necessitates recognition rather than recall, akin to real-life symptom recognition during an AMI event. (53) However, in practical scenarios, the role of symptom congruence becomes pivotal, insofar as the appearance of unexpected symptoms might confuse the patient. (42) The patient may entertain various potential causes when experiencing symptoms, adding complexity to the task of attributing them clearly to the heart and recognizing them with a sense of urgency.

1.5.2 Cardiac symptom attribution

In our systematic review, the investigation of cardiac symptom attribution involved three distinct groups: studies specifically considering STEMI patients, studies focusing on ACS patients excluding the STEMI group, and a group that included all studies (ACS and STEMI). When utilizing all studies, 45.1% (weighted mean) of all patients attributed their symptoms to the heart.

Within the STEMI group, this weighted mean was 49.8%, and in the ACS group excluding STEMI patients, it was 43.2%. The higher proportion of correct symptom attribution in the STEMI group might be driven by their more typical symptom presentation, particularly 'chest pain or discomfort', which is easier to recognize. (54) In fact, analyzing the National Registry of Myocardial Infarction of the United States, Canto et al. found that non-STEMI (vs. STEMI) was the strongest predictor of experiencing atypical symptoms. (54)

Interestingly, less than half of patients attributed their symptoms to the heart, despite our systematic review's finding that the six best-known symptoms were known by at least 49.8% of patients. Similarly, a systematic review by Van Oosterhout et al. found that the vast majority of AMI patients, 79% of men and 74% of women, presented with chest pain in ACS, and at the same time the symptom was recognized by 88.2 - 88.5% of participants in a closed-ended question format. (43, 55) In an open-ended question format, 74.3 - 82.0% of participants remembered it as a symptom of AMI. (43) This suggests that knowledge, while crucial, is just one of several factors influencing the recognition of an AMI.

Consistent with the global average, two German studies reported a correct cardiac symptom attribution of 50.2% and 50.3% for first-time AMI patients. (56, 57) Unlike international studies, the correct symptom attribution was lower among STEMI patients (45.1%) compared to non-STEMI patients (53.9%). (56) This discrepancy might be influenced by the composition of countries in the global review and the lack of a direct comparison between STEMI and non-STEMI patients in international studies.

While in international samples non-STEMI patients show more atypical symptoms, Kirchberger et al. found several differences in symptom presentation in the German sample, notably that STEMI patients presented more often with 'vomiting', 'dizziness', and 'diaphoresis'. (54, 56) At the same time, they were less likely to experience 'dyspnea' or 'pain in the throat/ jaw'. Given that our cross-sectional study found 'dyspnea' to be the third best-known symptom (84.4%), a lack thereof might have contributed to a lower correct symptom attribution. (44) These variations in symptom presentation impact symptom congruence, thus influencing symptom recognition.

Additionally, in the above-mentioned study, patients with STEMI were significantly younger, more likely to be smokers, and less likely to have a history of hypertension or sleep disturbances compared to those with non-STEMI. (56) Past literature has generally found young and middle-aged patients to be more knowledgeable while we found no differences in our analysis. (44, 58–61). Similarly, in our cross-section study, we did not identify hypertension or being a smoker as predictors for a higher knowledge score or a correct response.

1.5.3 Reaction to the symptoms

The appropriate response when experiencing symptoms of AMI is to promptly call an ambulance. This action is crucial because the early intervention of a doctor in the ambulance enables timely AMI detection through an electrocardiogram, facilitating proper medication administration and informing a nearby catheter lab in advance of the incoming patient. In cases of cardiac arrest or unexpected events, the attending doctor can also initiate resuscitation and respond appropriately. Calling an ambulance contributes to reducing both the symptoms-onset-to-balloon time by facilitating fast transport and the door-to-balloon time (time from entering the hospital to intervention) by providing advance notification to the hospital. Contrarily, if a layperson opts to transport the individual, they might choose an inadequate hospital lacking a catheter lab, resulting in longer transport times.

Concerning the initial reaction, the German public generally demonstrates awareness of the correct answer in a closed-ended question format, with 94.2% indicating they would call an ambulance, while only 2.1% would transport the person to the hospital themselves. Other responses, such as recommending consulting a physician (0.9%) or contacting a family member (0.8%), were less common. A small percentage (2.1%) indicated they would choose a different course of action (refer to supplemental table 1 of our cross-sectional study). (44)

To further assess the awareness of the correct reaction, participants were confronted with a phone scenario, either of an elderly woman with sudden ‘chest pain’ or with escalating ‘abdominal pain’. To avoid priming the participants, we made no explicit mention of AMI. Among the possible options, the sole recommended correct response was to persuade the woman to call an ambulance. In the chest pain scenario, 64.6% of participants chose the correct reaction, while only 35.4% did so in the abdominal pain scenario. (44)

Considering that in the same survey, 98.9% recognized the AMI symptom ‘chest pain/ pressure’, 52.1% recognized ‘abdominal pain’, and 94.2% of participants would call an ambulance, it is remarkable that in the phone scenario, the correct response was chosen insufficiently. This illustrates the limitations of asking participants directly rather than using the description of a real-life scenario. Additionally, participants might have not felt an awareness of the severity and urgency of the scenario and therefore shown an inadequate response. (44, 57, 62, 63)

1.6 Proficiency in cardiopulmonary resuscitation

A prior study revealed that 4.7% of AMI patients experienced out-of-hospital cardiac arrest (OHCA). (64) Furthermore, in ACS, as outlined by Bell et al., “early recognition of cardiac arrest and prompt initiation of bystander CPR are the most important factors associated with

improved survival." (65) This emphasizes the importance of implementing widespread proficiency in CPR as well as enhancing the self-efficacy of bystanders to apply these skills in emergencies. Thus, in our cross-sectional study, we evaluated the current CPR skillset in four German regions.

Our findings indicate that 37.9% of all participants possessed practical CPR knowledge and would confidently perform it or guide someone else. Meanwhile, 31.8% had theoretical knowledge but lacked the confidence to execute CPR. In 28%, both theoretical and practical knowledge were deficient, despite having received training. Only 2.4% reported never having learned or known how to perform CPR (refer to Figure 3 of our cross-sectional study). (44)

As per CPR guidelines in Germany, telephone-assisted cardiopulmonary resuscitation (T-CPR) is standard protocol upon dialing the emergency number. Over the phone, dispatchers assess the situation and guide callers through the required CPR steps. (66) Since the introduction of T-CPR, there has been a significant rise in laypeople providing first aid for sudden cardiac arrest. (67, 68) Nonetheless, having a fundamental grasp of CPR is still advantageous for following the dispatcher's instructions effectively. Given that the usage of CPR in Germany lags behind many other European countries, there is a critical need to improve CPR skills in the German population. (69) Nationwide CPR education initiatives like "Resuscitation Week" and "Kids Save Lives" are steps in the right direction, but further implementation of regular CPR training, as seen in the Netherlands and Scandinavia, is recommended. (67, 70)

1.7 Predictors of the examined factors in a cross-sectional survey

Since knowledge of the symptoms is relevant for attributing the symptoms to the heart and seeking help, identifying factors that drive higher knowledge is crucial for promoting appropriate reactions. (63, 71, 72) Through an analysis of health-related and sociodemographic factors among German participants, we aimed to gain insights into the qualities associated with increased awareness, a correct response to AMI, and skills in CPR.

Notably, a general interest in health emerged as a driving factor, potentially explaining why cardiac patients demonstrated broader knowledge in our systematic review. Predictors for better knowledge included being female, knowing someone with heart disease, and being an ex-smoker compared to those who never smoked. While the two former factors align with previous studies, the latter factor has not been previously documented. (53, 58–60, 73) One plausible explanation for the higher knowledge in ex-smokers may be their greater interest in adopting a healthy lifestyle. Knowing someone with heart disease can be explained by the observational theory of SCT, specifically if the individual was close to the person experiencing an AMI.

Regarding the phone scenario, higher knowledge scores were associated with a greater likelihood of calling an ambulance for both symptoms. This aligns with previous studies demonstrating that higher knowledge is linked to appropriate reactions. (72) In the abdominal pain scenario, older age emerged as a positive predictor, suggesting that older participants considered abdominal pain a more severe symptom requiring immediate medical attention.

While we found no association between age and a higher knowledge score of the symptoms, most previous studies have identified young and middle-aged adults to be the most knowledgeable. (58–61) In the same scenario, individuals residing in federal states characterized by low AMI mortality rates were less inclined to persuade the woman to call an ambulance, in contrast to those in Saxony-Anhalt, which has the highest AMI mortality rate. This result included the null effect which could be attributed to the small sample size and should be further examined in future studies. This contradicts the assumption that Saxony-Anhalt shows worse help-seeking behavior than other federal states and might point toward the success of educational campaigns in Saxony-Anhalt. (44)

The likelihood of administering CPR was associated with better knowledge of symptoms, male gender, and younger age. Individuals without a degree or still in training were less inclined to engage in CPR compared to those with a Master's, diploma, or doctorate. (44) Partly, this aligns with international studies that found that female sex was a barrier to CPR as well as low socio-economic status. Better skills in CPR, recent CPR training, as well as a higher CPR self-efficacy have been found to promote the use of CPR in an emergency. Similarly, a bystander age of less than 50 years has been found to be beneficial. (74)

When assessing CPR skills, male participants were more likely to consider themselves capable of performing CPR or instructing someone else to do so compared to female participants. Similarly, a higher knowledge was identified as a predictor. This is a noteworthy observation since we found that women were more knowledgeable, but they still were less likely to dare to perform CPR or guide someone else. A possible explanation is that men generally tend to rate themselves as more self-confident in their skillset and as more self-efficient, potentially indicating a form of self-overestimation. (75)

One research question addressed whether variances in knowledge, response to AMI, or CPR skills might account for the varying mortality rates across the four federal states. As no significant differences were observed, we posit that sociodemographic, health-related, and structural disparities rather than awareness or CPR skills contribute to the differing mortality rates. (45)

2. Discussion

2.1. Comparison of the general population and cardiac patients

As previously outlined, our systematic review found that cardiac patients displayed a broader knowledge of the symptoms of AMI than the general population. However, atypical symptoms were generally less well-known, internationally as well as in Germany. (43)

The expanded knowledge base among cardiac patients may result from heightened interest, successful educational campaigns, or guidance from their treating physicians. This knowledge is deemed beneficial for reducing delay times, as previous studies have identified that the time-saving impact of knowledge in cardiac patients is primarily attributed to awareness of atypical symptoms. (19) This positive effect is driven partly by symptom congruence, as an aspect of the illness representation in the CSM. (33, 42) Patients with a more comprehensive understanding of symptoms, including atypical ones, are more likely to attribute their experiences to cardiac issues, reducing confusion associated with unknown symptoms. Symptom congruence has been proven beneficial for cardiac symptom attribution, with a higher level significantly associated with a shorter pre-hospital delay. (33, 40, 76, 77)

Despite cardiac patients' extensive knowledge of symptoms, fewer than half attributed their ACS (mostly AMI) to the heart during its occurrence, underscoring the importance of psychological factors. This shows that besides knowledge, other variables are driving factors for correct symptom attribution, particularly emotional elements. (57, 63, 78) One study has noted lower knowledge scores in STEMI patients with a history of AMI or stent placement, possibly due to factors such as denial and trauma caused by the initial attack. (19) Atypical symptoms in a second AMI did not predict longer delay times, which might be understood under the assumption that a history of AMI increases symptom congruence. (42, 79) These observations align with previous findings that a history of angina, AMI, or heart failure does not translate into a shorter delay time. On the contrary, a history of angina or heart failure significantly increases delay time in cases of ACS which can be explained by a form of post-traumatic stress reaction according to the AMI Coping Model. (32, 80)

This emphasizes the importance of not solely informing patients about atypical symptoms to enhance symptom alignment but, perhaps more crucially, preparing them psychologically. Cognitive and psychological factors associated with delayed response times include denial, a feeling of being able to cope with or control symptoms, a lack of perceived seriousness of symptoms, a lack of perceived susceptibility to heart disease, and fear of troubling others. (43, 62) Consequently, we recommend that educational initiatives not only concentrate on imparting symptom knowledge but also address strategies for overcoming psychological hurdles. (43)

2.2 Training in cardiopulmonary resuscitation

The observation that male participants perceive themselves as more skilled in CPR underscores the critical need to enhance the self-efficacy of women, given its substantial impact on the survival rates, especially of women, experiencing OHCA. Currently, men exhibit a 23 percent higher likelihood of survival in OHCA, partly because bystander CPR is administered to men in 45% of cases, as opposed to 39% for women. (81) This observation has been consistently confirmed in previous studies showing that female gender of the patient and sex difference with the patient pose a barrier to CPR. Men appear to grapple with societal beliefs and concerns that impede life-saving actions, including fears of inappropriate physical contact with women or the potential of being wrongly accused of sexual harassment or assault. According to Perman et al., the reasons were first, sexualization of women's bodies; second, women are weak and frail and therefore prone to injury; and third, misperceptions about women in acute medical distress. (82) This illustrates the importance of preparing the public in advance that it is not only acceptable but compulsory to administer CPR to all people and to tackle their reservations in CPR training. According to the TPB, addressing social expectations and enhancing the self-efficacy of females should help to increase the use of CPR administration. (26, 27)

In our cross-sectional study, we observed that younger age emerged as a favorable indicator for engaging in CPR, possibly influenced by the German system where younger individuals are more likely to have received recent CPR training. Previous research has established that having undergone CPR training within the last five years is a positive factor associated with the willingness to perform CPR. (74) Although certain professions in the medical and educational fields necessitate regular CPR training, a significant proportion of Germans typically undergo CPR training during young adulthood, often in connection with obtaining a driver's license. Notably, there is currently no mandate for individuals to undergo a CPR refresher course once they have obtained their driver's license. Therefore, we recommend recurrent CPR training which would especially benefit the CPR proficiency in middle-aged adults and the elderly.

2.3. Awareness in Germany in the international comparison

In our cross-sectional study, German participants demonstrated the highest or second-highest knowledge across all symptoms compared to other countries assessed in our systematic review, except for 'pain or discomfort in the jaw, neck, or back', which was only recognized by 36.5% of participants, compared to a weighted average of 49.8% internationally.

The United States and Lebanon exhibited the highest levels of knowledge in the international comparison, alongside Germany. Notably, our study's findings substantially surpassed those of a

previous German study conducted in 2006. (53) Although our research was confined to four federal states, we assume that the results may be extrapolated to Germany as a whole, given the absence of significant differences among federal states with varying mortality rates. However, while the improvement from 2006 to 2020 could be attributed to the efficacy of health education initiatives, disparities in assessment methodologies should be acknowledged. The previous study utilized face-to-face interviews as part of the European Consumer Study 2007, whereas we utilized online surveys, necessitating participants' internet literacy. Notably, past literature has observed that web-based studies do not introduce distortions when compared to paper-based studies. (83–85) Nevertheless, our study's lower response rate of 2.4% might lead to bias while the previous study from 2006 employed systematic sampling to minimize sampling bias.

When examining knowledge across all nine countries assessed in 2006, Germans demonstrated the highest recognition of symptoms, followed by Austrians. Conversely, Italy, Spain, Poland, and Russia exhibited the lowest recognition rates. Comparing German participants' knowledge in 2006 to our cross-sectional study, participants in 2020 demonstrated an average increase of 21.95% in recognizing the seven symptoms assessed in both studies (46.74% vs. 68.69%). Possibly, participants in our cross-sectional study were primed to consider 'chest pain or discomfort' (98.9% vs. 85%) or 'stomach or abdominal discomfort' (52.1% vs. 9.5%) as AMI symptoms, as these symptoms were introduced in the phone scenario with the woman. Still, when excluding these two symptoms and comparing the remaining five, the difference remained at 19.28% (46.54% vs. 65.82%).

Compared to the international average, ‘abdominal discomfort’ stood out most in our cross-sectional study, with a recognition rate of 52.1%, significantly higher than the international weighted mean of 10.7%. (43, 44). This notable difference contrasts with findings from a German study conducted in 2006, which observed a recognition rate of only 9.5%, and another study involving STEMI patients in Germany with a recognition rate of 36.7%. (19, 53) Internationally, among cardiac patients, studies from China and Jordan reported an awareness of 2% and 10%, respectively. (86, 87) Even though ‘indigestion’ and ‘stomach or epigastric pain’ are more often displayed by women, it has to be considered an atypical symptom with a frequency of 8 - 20%. (55)

In our cross-sectional study, 44.5% of participants mistakenly identified ‘sudden visual disturbances’ as a symptom of AMI, which is higher than the weighted mean of 32.2% from the three studies that assessed an ocular trap symptom in our systematic review. The discrepancy could imply a propensity in our online survey to indiscriminately attribute symptoms to the heart, potentially inflating their knowledge assessment compared to 2006. This inclination might be mitigated during face-to-face interviews.

2.4 Best and least known symptoms in the international comparison

Chest pain remains the most crucial symptom to recognize in both men and women, given its prevalence in 79% and 74% of AMI cases, respectively. (55) According to our systematic review, we found participants in Spain (65.3%), Italy (66.5%), and Greece (71.8%) to be the least aware of chest pain when assessed in a closed-ended question format. (53, 88) However, this comparison only included a limited number of developing countries and excluded studies that were not considered representative or focused solely on cardiac patients. In a systematic review by Sharma et al. from 2021, which applied different inclusion and exclusion criteria, the lowest knowledge of chest pain was found in Kenya (2%) and Tanzania (3%). (89)

While the 2006 German study reported relatively good knowledge of chest pain at 85%, the Netherlands (87.5%), the United Kingdom (90.9%), and the United States (92.0%) demonstrated the highest awareness among the general population. (53, 59)

Among European countries, the symptoms ‘feeling of anxiety’ (21.4%), ‘intense nausea and dizziness’ (21.2%), ‘headache’ (12.0%), and ‘stomach pain’ (7.5%) were the least recognized. (59) In the same study, German participants demonstrated particularly higher recognition of ‘feeling of anxiety’ (51.2%) and ‘intense nausea and dizziness’ (40.7%) displaying the best knowledge among all examined European countries. (53)

Since 'headache', 'jaw/neck/back pain', and 'nausea or vomiting' emerged as the least known symptoms in our cross-sectional study, it is essential to consider their frequency of presentation. While 'headache' is uncommon in AMI cases among the German population, approximately one-third of patients experience 'jaw/neck/back pain' (throat/jaw pain: 31.1%, pain between shoulder blades: 27%), and similarly, 'vomiting/nausea' (vomiting: 13%, nausea: 36.3%). (56) This highlights the importance of enhancing community awareness by specifically educating individuals about these less-recognized symptoms.

2.5 Implications of atypical symptom presentation

Given the limited awareness of atypical symptoms both in Germany and internationally, these findings carry significant implications for delay time, particularly affecting women and the elderly, who are more likely to exhibit an atypical symptom presentation. (55, 90–92) While there is a substantial symptom overlap between genders, men more frequently present with well-known symptoms such as 'chest pain' and 'sweating'. (55) Conversely, women more commonly manifest non-chest pain discomfort, such as ‘jaw, neck and back pain’, or exhibit symptoms like ‘nausea or vomiting’, a category we found to be insufficiently known. (55, 93, 94) In particular, Black and Hispanic women present with more atypical symptoms than White women. (95) At the same time,

the elderly and women are less knowledgeable about atypical symptoms which contributes to their extended patient delay and increased mortality. (19, 21, 43, 96, 97)

Due to their symptom presentation when calling for help, women have a reduced chance of receiving an emergency dispatch, contributing to their increased 30-day mortality rates. (98) A Danish study found that 24% of AMI patients were not correctly recognized with an acute life-threatening disease when calling emergency services. Especially patients without chest pain or who were not unconscious were less recognized over the phone. (99) Interestingly, Møller et al. found that providing ambulances to non-chest pain AMI patients was not associated with improved survival, partly attributed to a lower administration of acetylsalicylic acid. (100) An Australian study compared emergency services responses to female and male patients with chest pain and found women to be less likely to receive a "priority 1" (lights and sirens) ambulance response, possibly because they additionally presented more often with 'vomiting'. (94, 101)

While the differing symptom presentations have been attributed to variances in pathophysiology between sexes, the assessment method may also play a role in these disparate findings. Women tend to report more atypical symptoms than men in open-ended inquiries, while men tend to report more 'chest pain' in response to closed-ended questions compared to open-ended. (94, 102–104)

Given that women tend to experience more prodromal symptoms than men, educating them about warning signs could lead to earlier care-seeking behavior. This would be particularly beneficial for Black and Hispanic women who report experiencing more prodromal symptoms than White women. (95) The most commonly reported prodromal symptoms, in descending order, include 'unusual fatigue', 'sleep disturbances', 'anxiety', 'shortness of breath', and 'arm, back, or chest pain'. (105–107) Over 50% of women experienced disrupted sleep patterns within four weeks of their AMI, compared to 32% of men who reported similar sleep disturbances. (106, 108)

2.6 Educational campaigns

A systematic review and meta-analysis by Baharak et al. from 2023 compared different interventions among the elderly who were at risk of myocardial infarction. (109) Comparing the effect on knowledge, belief, decision-making, rate of calling emergency services, and mortality, they examined eight different approaches: nurse-based case management, direct mail, innovation methods, tricked intervention promoting memory and concern, tailored education, structured education, community-based, and multi-group health education.

Nurse-based case management involved regular home visits and phone calls by a nurse for three years for discharged AMI patients. (110) While the intervention focused on individual education and problem-solving, it did not significantly postpone the time to unplanned readmission or

decrease mortality. However, educating about symptoms and early care-seeking regularly by mail proved successful for patients who had experienced an AMI before, leading to higher rates of 911 use compared to control groups. (111)

The tricked intervention promoting memory and concern involved participants learning about AMI symptoms with the help of an educator in a community setting. (112) Acronyms such as CURB (AMI symptoms: 'chest sensation or pain', 'unusual fatigue', 'radiating back, jaw, or arm pain', and 'breathing difficulties') and FACTSS (prodromal symptoms: 'fatigue', 'anxiety', 'chest discomfort', 'tummy/ indigestion', 'shortness of breath', and 'sleeping difficulties') were used to aid memory retention of symptoms. Although this intervention increased knowledge scores from 81% to 91%, it should be noted that the sample already had above-average knowledge beforehand, and the long-term effectiveness of the intervention is uncertain.

The innovative method described was the Heart Attack Survival Kit project, where firefighters educated residents about AMI symptoms and distributed kits containing essential information and supplies. (113) The firefighters received prior training for the educational campaign and learned how to assess and respond to barriers to action. These kits increased emergency calls and the frequency of taking aspirin (acetylsalicylic acid) when encountering symptoms of AMI. Similar interventions involving kit distribution via mail or by emergency medical technicians also improved awareness and appropriate actions. (114)

Structured education and counseling interventions, incorporating multiple meetings and advisory materials, successfully increased knowledge, beliefs, and perceived control after three months. (115) In Germany, structured health education is a part of cardiologic rehabilitation programs, but only about half of cardiac patients attend these programs, and German guidelines do not specifically mention education about AMI symptoms and early care seeking. (116, 117)

Despite the success of personalized intervention methods among the elderly, an 18-month intervention targeting mass media, community organizations, and professional, public, and patient education did not result in decreased patient delay in seeking care for AMI symptoms. (118) Likewise, a community-wide educational intervention incorporating media efforts and the help of volunteers did not lead to sustained decreases in reperfusion therapy rates. (119) The meta-analysis by Banharak et al. concluded that only the innovative method involving a kit had a significant effect on care-seeking behavior among older adults. (109)

Conversely, when focusing on the general public rather than solely targeting the elderly, a systematic review by Hoschar et al. found that a mass-media approach was equally effective compared to personalized interventions in reducing pre-hospital delay. (9) Analyzing the interventions, they recommend addressing behavioral consequences and psychological barriers, such as denial, and providing practical action plans in campaign messages to improve outcomes.

Personalized approaches including hands-on physical material, may be more effective for the elderly due to their decreased memory and cognitive ability. (109) Video-based educational programs and interactive learning have been successful, while low-intensity educational campaigns in advertising media were found to be ineffective for the elderly. (120, 121)

Considering their deteriorating visual and acoustic abilities, older adults benefit from stimuli transmitted through multiple senses, leading to better learning outcomes. (109) Given that older adults often have low to moderate health literacy scores and might face similar difficulties as patients with language barriers or from low socio-economic backgrounds, short sessions consisting of explanations and practices are beneficial. (109, 122) These interactions also provide an opportunity to clear up misunderstandings and allow for repetition. For instance, a study from 2016 revealed that a third of German AMI patients held the false belief that an AMI is always accompanied by 'severe chest pain'. (19) To mitigate communication barriers, peer education delivered by a trained patient who has experienced an AMI firsthand can be beneficial. Previous research has shown a positive impact on both learning and coping with the illness. (123–125) Additionally, providing in-hospital instructions and discharge education through brochures is recommended as an easy and cost-effective approach to reach at-risk groups. (126)

In summary, it is advisable to use multimodal approaches such as face-to-face training sessions, peer education, counseling, telephone follow-up, written material, and electronic material. (127) While nationwide educational campaigns utilizing multimedia channels have been shown to reduce pre-hospital delays, innovative approaches such as personal interactions with the use of a kit may be particularly beneficial for the elderly and underprivileged groups. (109, 128) Educational campaigns should aim to psychologically prepare the target group and present real-life scenarios to bridge the gap between theoretical knowledge and practical application. (44)

While educational campaigns to spread awareness and increase knowledge remain crucial, technological advancements may shift their importance. With the increasing adoption of smart speakers in German households, currently exceeding 30%, and the widespread availability of health apps on cell phones, these devices could emerge as invaluable first responders in the future. (129) Leveraging artificial intelligence (AI), personalized AI assistants could utilize the patient's medical history along with data from smartwatches or self-reported symptoms to assess the severity of the situation and promptly summon emergency services when needed.

2.7 Strengths, weaknesses, and limitations

The strength of our systematic review lies in the extensive number of studies sourced from four databases representing the first systematic review assessing the international awareness

of AMI symptoms and cardiac symptom attribution. The weaknesses include the limited representation of studies from regions such as Africa, Russia, and South America, as well as countries with a medium or low Human Development Index. (130) Potential sources of bias stem from the comparison of groups with different compositions, particularly regarding their location and assessment methods. Inconsistencies among studies regarding the inclusion of certain atypical symptoms in the overall knowledge score, such as ‘heartburn’ and ‘fever’, further complicate the analysis.

Our cross-sectional study conducted in Germany has notable strengths, particularly in its evaluation of knowledge and first responder reactions with the description of real-life scenarios. The study's distinction as the first survey comparing awareness and CPR skills in German federal states with varying AMI mortality rates adds significant value to the literature. Regarding limitations, the use of an online assessment excludes elderly individuals who may not be familiar with the Internet. Similarly, conducting the survey only in German may exclude immigrants who lack sufficient proficiency in the language. Moreover, due to the low response rate, selection bias must be considered. Finally, responders in this survey were recruited from those who did not respond to the first invitation to the HeReCa panel. However, it should be noted that an analysis of the HeReCa panel found no sociodemographic differences among first- and second-attempt respondents and observed similar content regarding health-related responses in both groups. (49)

2.8 Conclusion

This thesis highlights the inadequacy of awareness regarding symptoms beyond chest pain, emphasizing the necessity for educating the general population about atypical symptoms. Targeted campaigns can be particularly beneficial for women and the elderly, given their propensity for atypical symptom presentations. Despite possessing broader knowledge among cardiac patients, low cardiac symptom attribution when experiencing symptoms of AMI or ACS underscores the significance of considering psychological factors and symptom congruence in the decision-making process. While the German population demonstrated higher overall knowledge compared to the global level, they exhibited gaps in understanding, notably regarding atypical symptoms like ‘pain in the jaw, neck or back’, or ‘nausea’. Additionally, when presented with real-life scenarios, over a third of German participants did not prioritize seeking immediate help, indicating difficulties in translating theory into practice. Despite prior CPR training, a majority expressed reluctance to perform CPR in emergencies. In essence, this reveals insufficient skills and a lack of confidence in CPR administration, negatively impacting mortality and morbidity in AMI. Although these deficiencies do not explain regional mortality variations in Germany, they emphasize the imperative for improved educational campaigns and recurrent CPR training.

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4. Theses

(1) The knowledge of the symptoms of acute myocardial infarction (AMI) is insufficient in Germany, particularly regarding atypical symptoms.

(2) Insufficient knowledge of atypical symptoms in Germany as well as worldwide is especially detrimental to women and the elderly who are more likely to display those symptoms.

(3) The German participants struggle to adequately transfer their theoretical knowledge of AMI into practical application in a real-life scenario.

(4) In Germany, we found insufficient proficiency and self-efficacy regarding skills in cardiopulmonary resuscitation (CPR).

(5) CPR training might be particularly beneficial in females, older participants, and participants with low educational levels.

(6) Our systematic review suggests that knowledge alone is not sufficient for cardiac symptom attribution.

(7) Cardiac patients have a broader knowledge of the symptoms of AMI which should be considered as beneficial.

(8) Differences in knowledge, reaction to symptoms, and skills in CPR do not appear to contribute to variations in AMI mortality and morbidity rates across four regions in Germany.

Publications

List of included publications and personal contribution

1. **Cardiac symptom attribution and knowledge of the symptoms of acute myocardial infarction: a systematic review**

Birnbach B, Höpner J, Mikolajczyk R. BMC Cardiovascular Disorders 2020; 20(1):445.

Personal contribution relevant to the thesis

Development of the research questionnaire with RM. Extraction of data, analysis, and interpretation. Reviewing the data with JH. Writing the initial manuscript including the tables and figures. Revising the manuscript and submitting it to journals. Addressing inquiries and refining the manuscript in the peer review process.

2. **Knowledge of Symptoms of Acute Myocardial Infarction, Reaction to the Symptoms, and Ability to Perform Cardiopulmonary Resuscitation: Results From a Cross-sectional Survey in Four Regions in Germany**

Kartschmit N*, **Birnbach B***, Hartwig S, Mikolajczyk R. Front Cardiovasc Med 2022; 9:897263.

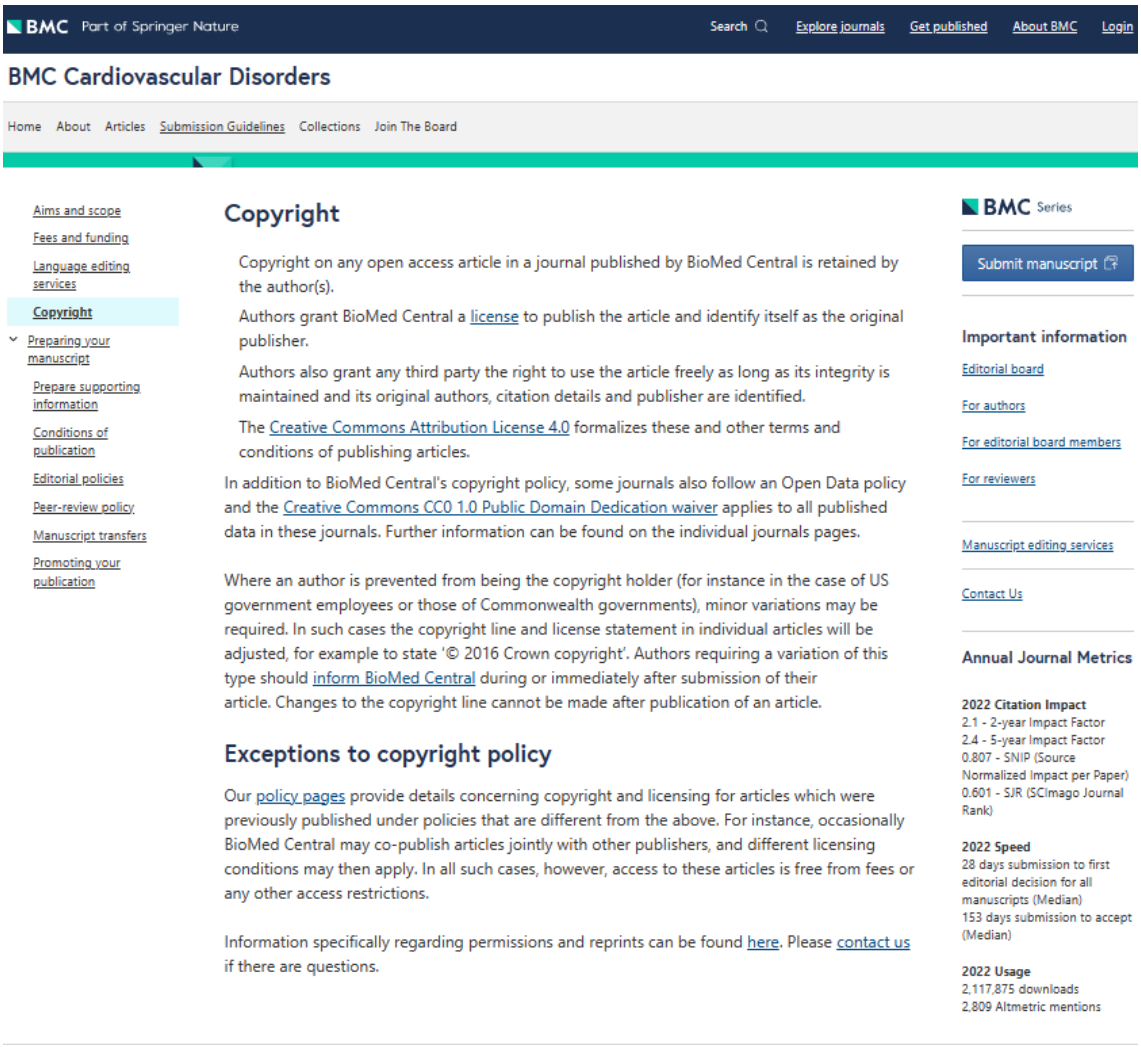
*** These authors have contributed equally to this work and share first authorship.**

Personal contribution relevant to the thesis

Development of the questionnaire with co-authors. Drafting the initial manuscript. Interpretation of the findings with co-authors. Revising the manuscript and submitting it to journals. Addressing inquiries and refining the manuscript in the peer review process.

Publication 1

Birnbach B, Höpner J, Mikolajczyk R. Cardiac symptom attribution and knowledge of the symptoms of acute myocardial infarction: a systematic review. BMC Cardiovascular Disorders 2020; 20(1):445.



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Cardiac symptom attribution and knowledge of the symptoms of acute myocardial infarction: a systematic review

Benedikt Birnbach, Jens Höpner and Rafael Mikolajczyk*

Abstract

Background: Since the knowledge of the symptoms of acute myocardial infarction (AMI) may reduce the decision time for patients to seek help in case of an AMI, we aimed to summarize evidence on the knowledge of the AMI symptoms and the symptom attribution in case of an acute coronary syndrome (ACS).

Methods: Therefore, we systematically searched the databases PubMed, CINAHL, Embase, and Cochrane Library for relevant studies published between January 1, 2008 and 2019 (last search August 1, 2019).

Results: A total of 86 studies were included, with a composite sample size of 354,497 participants. The weighted mean of the knowledge scores for the symptoms of AMI of 14,420 participants from the general population, was 42.1% (when maximum score was considered 100%) and 69.5% for 7642 cardiac patients. There was a substantially better level of knowledge for six symptoms ('chest pain or discomfort', 'shortness of breath', 'pain or discomfort in arms or shoulders', 'feeling weak, lightheaded, or faint', 'pain or discomfort in the jaw, neck, or back', and 'sweating') (49.8–88.5%) compared to the four less obvious/atypical symptoms 'stomach or abdominal discomfort', 'nausea or vomiting', 'headache', and 'feeling of anxiety' (8.7–36.7%). Only 45.1% of 14,843 patients, who experienced ACS, have correctly attributed their symptoms to a cardiac cause.

Conclusion: In conclusion, we found a moderate to good knowledge of "classic" and insufficient knowledge of less obvious symptoms of AMI. This might suggest that increasing knowledge about less obvious symptoms of AMI could be beneficial. It appears also important to address cardiac attribution of symptoms.

Keywords: Acute myocardial infarction, Acute coronary syndrome, Knowledge about symptoms, Symptom attribution, Awareness

Background

About 15.9 million acute myocardial infarctions (AMIs) occurred in 2015 and the aggregated number of AMIs has increased by 6.4% from 2005 to 2015 [1]. With an ageing population, and rising prevalence of obesity and diabetes in many countries, the prevention and therapy of cardiovascular disease will further increase in importance [1].

Since mortality or subsequent morbidity of AMI drastically decreases with a shorter time from symptoms-onset to reperfusion, [2–5] it is important to reduce any delays. One substantial component to ensure a timely treatment is patient delay, the time from symptoms-onset to seeking help. Here, attribution of symptoms to a cardiac cause has been found to be crucial [6–10]. In order to enable the patients to attribute the symptoms to the heart, knowledge of the symptoms of an AMI and the ability to recognize them

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seems to be beneficial [11–13]. However, to our knowledge, no review has attempted to summarize the findings on these factors systematically and give an overview of the world-wide knowledge levels of the AMI symptoms.

In our review, we present the current research status on AMI symptoms knowledge by systematically reviewing the literature and comparing the knowledge levels among the general population and cardiac patients. In addition, we report the cardiac symptom attribution among acute coronary syndrome (ACS) patients.

Methods

Screening process

BB and JH conducted the literature search (Fig. 1) in the databases PubMed, CINAHL, Embase, and Cochrane Library and searched for publications from January 1, 2008 to 2019 (last search August 1, 2019). For PubMed, we used the search algorithm: "myocardial infarction"[mesh] AND ("chest pain" OR symptom* OR "warning signs") AND ("recognition" OR "awareness" OR interpretation* OR perception* OR incongruence* OR congruence* OR expectation* OR "knowledge" OR "understanding" OR "community intervention" OR "educational intervention" OR campaign*) with the restrictions since 01/01/2008, languages: English or German, only human studies.

The search algorithms can be found in the Expanded methods section in the Additional file 1. We identified 1419 records, of which after deduplication 1014 remained for further analysis. After a further screening process by two reviewers (BB and JH), 86 publications

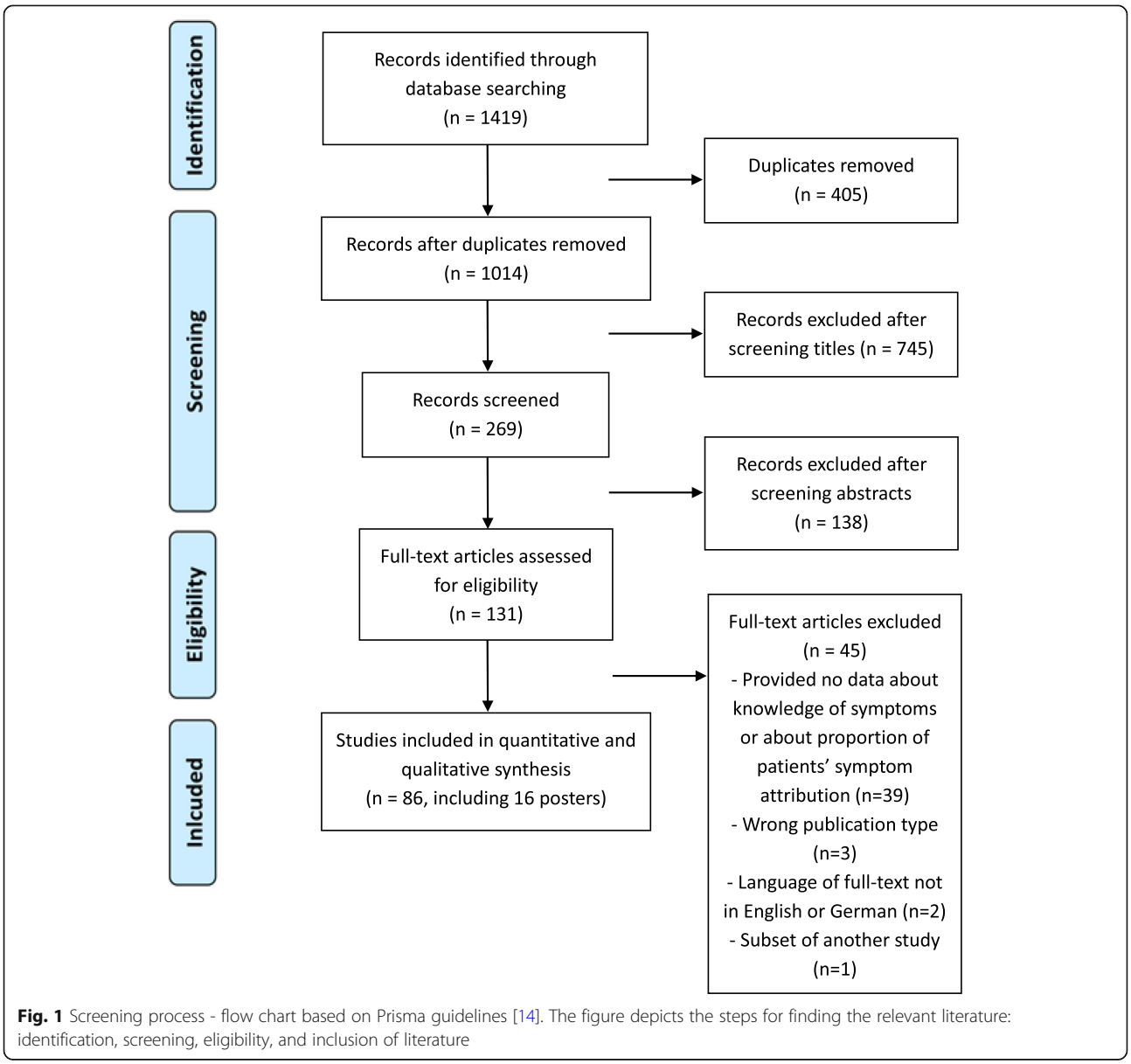

Fig. 1 Screening process - flow chart based on Prisma guidelines [14]. The figure depicts the steps for finding the relevant literature: identification, screening, eligibility, and inclusion of literature

were included in the analysis, of which 16 were conference abstracts or posters. Among them, 10 publications reported data from interventional studies.

Inclusion criteria

The inclusion criteria were a sample size of more than 50 participants, date of publication after January 1, 2008, and English or German publication language. We included studies, if they offered data about the knowledge of the symptoms of AMI or data on the attribution of their ACS (AMI or unstable angina) to a cardiac or non-cardiac cause. Review articles, expert opinions or discussions, case reports, and letters were excluded.

Extracted content

The criteria for the extracted content were set after initial scan of the publications, but before formal extraction started. The primary extraction was conducted by BB, while JH double-checked the extracted content. In case of discrepancies, BB and JH discussed the content and came to a consensus. The table that was used for extraction can be found in Additional file 2.

While there was a variety of methods how knowledge was investigated in these studies, in our review, we examined the knowledge levels (overall knowledge score) given by the studies (sometimes including trap questions and first responder questions), the knowledge level of chest pain as the most common symptom of AMI, [15] and of the 10 most frequently asked symptoms and one trap question. Trap questions were symptoms which usually do not occur in case of an AMI. First responder questions were items that asked about the appropriate response in case of an AMI, for example whether to call the ambulance.

Since previous studies have shown that recognizing symptoms yields higher knowledge scores than recalling them, we looked at open-ended and closed-ended questions separately [16, 17]. In order to compare the knowledge level in the general population and of cardiac patients, we established the following criteria for these groups:

1) General population: we included participants from studies which had as inclusion criteria an age range with a lower bound of 30 years or younger, and an upper bound of 60 years or older. In that way, we excluded studies which only included young or older participants. Additionally, the studies should not focus on a risk group, a certain ethnicity, or clinical staff, and should not include only one gender.
2) Cardiac group: we included samples of patients of any age that had a history of coronary artery disease (CAD) or a cardiac event, did not focus on a different risk group, and similarly did not focus on a certain ethnicity, on clinical staff, or only included one gender.

In this analysis, we only included conference abstracts or posters, when it was evident, whether open- or closed-ended questions were used. The data that we extracted from interventional studies was from the baseline data set or if not available, only extracted from the control group post intervention.

Finally, in order to evaluate the cardiac patients' interpretation of their symptoms in case of an ACS, we assessed the symptom attribution in a ST-elevation myocardial infarction (STEMI) group, an ACS group that excluded the patients from the STEMI group, and a group including all cardiac patients.

Quality assessment

BB and JH conducted a quality assessment based on the adapted version of the Newcastle Ottawa scale that has been used in previous studies to assess the quality of cross-sectional studies [18, 19]. Both authors assessed the studies, discussed the differences in assessment and finally unanimously agreed on a grading. The scale consisted of four questions about Selection (S1-S4), one question about Comparability (C1) and two questions about Outcome (O1, O2). Maximally 10 stars could be allocated. An overview of the allocated number of stars for each study can be found in Additional file 2 and a detailed report of the quality assessment in Additional file 3.

Data analysis and reporting

For the purpose of comparing and summarizing the knowledge levels, we standardized the reported knowledge scores. The standardized score (the overall knowledge score in further text) is the mean knowledge score in the group, divided by the value that could maximally be achieved, multiplied by 100%. When calculating crude arithmetic mean, the overall knowledge score of each sample had the same weight. When calculating the weighted arithmetic mean, the weight of the overall knowledge score of each sample was based on the number of participants in each sample. For all analyses, we used SAS version 9.4.

Results

Study selection and quality assessment

Of the 86 included studies [9–11, 16, 20–101], 10 studies [44, 60, 72, 73, 75–77, 80, 81, 84] were interventional studies and could therefore not be rated with the adapted Newcastle-Ottawa-Scale. The remaining 76 studies were allocated a mean of 4.9 stars. Of those studies, 16 studies were conference abstracts which could

only be assessed partly since some information about the studies was not included in the abstracts [30, 87–101]. Hence, only evaluating the available information the mean number of stars for these studies was 3.2. The 60 full-text articles that we assessed were allocated a mean of 5.4 stars. However, this relatively low number of stars can be explained by questions S4 and C1 which ask about the exposure and confounders. Since in 11 of those 60 studies the scientific question did not contain any exposure, and consequently no need for identifying confounders, those publications could be allocated no more than 6 stars instead of 10 (mean of the 11 studies: 3.0 out of 6 stars).

For our purpose only two criteria appeared relevant: representativeness of the sampling and response proportion. The representativeness was mostly rated high (mean: 0.9 out of 1 star), the response proportion was often high, too, but in only one study the comparability of responders and non-responders with respect to sociodemographic variables and clinical history was established.

Study characteristics

The participants of the identified 86 studies were from 34 different countries. Several studies included samples from various countries, and we considered them as separate units (98 samples in total). A figure depicting the composition of countries can be found in the Additional file 1 (Additional figure 1). There were 26 samples from North America (27.1%), 25 from Europe (26.0%), 21 from East and South Asia (21.9%), 10 from Oceania (10.4%), nine from the Middle East (9.4%), and the remaining five from North/West Asia, South America, and West Africa (5.2%). Two conference abstracts did not specify where the samples were located.

Considering United Nations Human Development Index (HDI), [102] 69 samples (71.9%) were from 24 countries with a very high HDI, 19 samples (19.8%) from 10 countries with a high HDI, seven samples (7.3%) from three countries with a medium HDI, and one sample (1.0%) from a country with a low HDI.

The composite sample size of all studies was 354,497, excluding one study because information of sample size was not given [55]. The sample sizes ranged from 51 participants [81] to 76,864 [21] with a median of 400. Of all the included participants, 51.4% were male.

In the following analyses, the number of included studies varies as some outcomes were not reported by all studies.

Overall knowledge score

Closed-ended questions

19 studies (27 samples) that used closed-ended questions reported a knowledge score. The studies designed their knowledge scores by offering a list to the participants with symptoms, and sometimes additionally with first responder questions or trap questions. The more symptoms the participants correctly identified and the more questions they answered correctly, the higher the score. Since the lists only had minor differences, we used the provided knowledge score of each study, standardized it to an overall knowledge score (dividing by maximum score value in the given study) and afterwards calculated the weighted mean and crude mean of all overall knowledge scores (see Methods, data analysis and reporting). The differences among the studies were that 11 samples were asked only about AMI symptoms, five additionally received one or more trap questions, one a first responder question, and two samples both, a first responder and a trap question. If the studies included participants that were not within the scope of the requirements for the population group or cardiac group that we defined above, we excluded the studies. Furthermore, we excluded studies that asked the patients what symptoms they had expected rather than asking for knowledge of symptoms. The weighted mean in the population group (42.1% of the maximal score) was substantially lower than in the cardiac group (69.5%) (Table 1).

Open-ended questions

In the two studies that used open-ended questions, participants were asked about the symptoms, and the interviewer ticked off the items mentioned on an a priori defined list. The knowledge scores were lower than in most samples that were asked closed-ended questions, with 31.4% for the population group and 33.3% in the cardiac group.

Chest pain knowledge

Closed-ended questions

With regard to the assessment of chest pain knowledge, when closed-ended questions were used, patients were given a list of symptoms that included chest pain and were asked: "Which of the following do you think is a symptom of a heart attack?" The phrasing of the question and description of the symptom differed in some studies. We included eight studies (16 samples) for the analysis of the population group and four studies (four samples) for the analysis of the cardiac group. Here, we also excluded studies that did not meet our requirements for population or cardiac group as defined above, or that asked about expectations rather than knowledge. Among both groups the knowledge of chest pain as symptom of AMI was similar (weighted means 88.2% vs. 86.2%) (Table 2).

Open-ended questions

When open-ended questions were used, the chest pain knowledge depicted the percentage of participants in

Table 1 Overall knowledge score

Composition of sample, form of question	Number of samples	Number of countries	Participants	Crude mean [%] [a]	Weighted mean [%] [b]
Population group, closed-ended	10	10	14,420	36.5	42.1
Cardiac group, closed-ended	5	5	7642	54.7	69.5
Population group, open-ended	1	1	302	31.4	31.4
Cardiac group, open-ended	1	1	137	33.3	33.3

The table depicts the results by comparison of composition of sample and form of question used
[a]mean score in each study was standardized by dividing the mean by the maximum score; thus, the numbers report means in terms of percentage of maximum score
[b]as above; average mean was calculated from means from individual studies weighted by sample size

each sample who reported chest pain, when asked to tell the interviewer about symptoms of a heart attack. For the analysis in the population group, we included four studies (four samples). We found a weighted mean (74.3%) that was smaller than in the group that was asked closed-ended questions. There was only one study including cardiac patients, which also reported a slightly smaller value (82.0%).

Comparison of individual symptoms

When counting the different symptoms that the studies asked about and neglecting different phrasing or minor differences in the description of the symptoms, the studies assessed the knowledge of 26 different symptoms and 14 different trap symptoms.

In the following, we compared the 10 most frequently asked symptoms and the one most frequently asked trap symptom. For the purpose of description, we refer to a symptom as *moderately known,* if it is known by more than a third of all participants, and otherwise as *insufficiently known*.

Population group

In the population group, there were eight studies (16 samples) that applied closed-ended questions. Of those, two were convenience samples (studies 7, 8 in Table 3), and the remaining 14 samples were representative samples.

Closed-ended questions When closed-ended questions were used, the six symptoms 'chest pain or discomfort', 'shortness of breath', 'pain or discomfort in arms or shoulders', 'feeling weak, lightheaded, or faint', 'pain or discomfort in the jaw, neck, or back', and 'sweating' were *moderately known* (weighted mean: 49.8–88.2% of respondents who recognized the given symptom as a symptom of AMI) (Table 3). The mean of the weighted means of the *moderately known* symptoms was 68.7%.

Within the group of *moderately known* symptoms, only the symptoms 'chest pain or discomfort' and 'sweating' were known in all samples by more than half the participants. However, it should be noted that the symptom 'sweating' was only assessed in three samples. Furthermore, the four symptoms 'stomach or abdominal discomfort', 'nausea or vomiting', 'headache', and 'feeling of anxiety' were *insufficiently known* (weighted mean: 8.7–28.0%).

The weighted mean proportion of participants attributing the trap symptom 'sudden trouble seeing in one or both eyes' to AMI was 32.2% (Table 3), which suggests that there is confusion among some participants to differentiate between the symptoms of stroke and AMI. However, this trap symptom was only assessed in three samples.

Open-ended questions When open-ended questions were asked, for every symptom, the weighted mean of the knowledge scores was lower than in the studies that used closed-ended questions. Since the two studies (two samples) which applied open-ended questions were convenience samples, we refrain from more detailed observations.

Table 2 Knowledge of chest pain as symptom of acute myocardial infarction

Composition of sample, form of question	Number of samples	Number of countries	Participants	Crude mean [%] [a]	Weighted mean [%] [b]
Population group, closed-ended	16	14	145,631	83.5	88.2
Cardiac group, closed-ended	4	3	932	79.4	86.2
Population group, open-ended	4	4	7937	76.5	74.3
Cardiac group, open-ended	1	1	251	82.0	82.0

The table depicts the results by comparison of composition of sample and form of question used
[a]mean score in each study depicts the percentage of participants recognizing chest pain as symptom of acute myocardial infarction
[b]as above; average mean was calculated from means from individual studies weighted by sample size

Table 3 10 most frequently asked symptoms and one trap symptom in the population group

				recognizing heart attack symptom [%]										falsely recognizing trap symptom [%]
	n°	country of study	sample size	chest pain or discomfort	shortness of breath	pain or discomfort in the arms or shoulders	feeling weak, lightheaded, or faint	pain or discomfort in the jaw, neck, or back	sweating	stomach or abdominal discomfort	nausea or vomiting	headache	feeling of anxiety	sudden trouble seeing in one or both eyes
Studies that used closed-ended questions	1.1	Russia	2,019	79.1	50.7	14.4	-	-	-	3.9	intense nausea or dizziness: 17.2	19.1	15.9	-
	1.2	Poland	1,019	83	52.1	20.1	-	-	-	3.7	" : 17.5	9.9	17.9	-
	1.3	Germany	2,054	85	62	66.8	-	-	-	9.5	" : 40.7	12	51.2	-
	1.4	France	1,005	84.5	42.2	66.8	-	-	-	5	" : 17.4	11.2	15.1	-
	1.5	United Kingdom	1,042	90.9	68.2	72.4	-	-	-	6.2	" : 26.5	9.3	21.3	-
	1.6	Italy	1,007	66.5	26.8	63.1	-	-	-	21.7	" : 8.4	3.5	6.7	-
	1.7	Austria	501	84.3	60.4	56.7	-	-	-	8.1	" : 37.4	11.9	44.9	-
	1.8	The Netherlands	557	87.5	42.2	69.4	-	-	-	4.1	" : 23.5	4.2	14.8	-
	1.9	Spain	1,024	65.3	33.4	59.6	-	-	-	5.2	" : 11.7	9.8	11.6	-
	2	United States	33,059	89.9	82.1	83.7	68.7	55	-	-	-	-	-	-
	3	United States	76,864	92	83.4	85.6	61.5	49.3	-	-	-	-	-	31.9
	4	Greece	11,000	71.8	34.5	radiating pain: 35.5	fainting: 16.4	-	-	-	-	-	-	-
	5	South Korea	9,600	79.1	70.2	32.9	weakness or dizziness: 49.4	34.8	-	-	-	-	-	vision impairment: 33.7
	6	Singapore	4,192	85.1	72.9	... or from chest area to neck or jaw: 66.6	weak pulse: 65.3, dizziness: 49.8	-	sweating and chills: 61.2	-	39	-	-	-
	7	Lebanon	399	94.7	94.2	86.6	loss of strength: 82.2, dizziness: 44.5	-	79.7	39.9	44.9	35.2	-	-
	8	United States	289	97.1	81.5	91.2	65.8	67.6	91.7	-	-	-	-	58
crude mean				**83.5**	**59.8**	**60.7**	**54.7**	**51.7**	**77.5**	**10.7**	**25.8**	**12.6**	**22.2**	**41.2**
weighted mean				**88.2**	**75.9**	**74.9**	**58.6**	**49.8**	**64.5**	**8.7**	**28**	**12.2**	**23.7**	**32.2**
Studies that used open-ended questions	9	United States, India	434	83	58.3	radiation of pain to arm: 74.5	-	-	59.5	-	-	-	-	-
	10	United Kingdom	302	75	35	arm pain: 40	fainting or dizziness: 21	neck or jaw pain: 6, back pain: 6	21	bloated or painful stomach: 3.4	-	0.9	7.8	-
crude mean				**79**	**46.7**	**57.3**	**21**	**6**	**40.3**	**3.4**	**-**	**0.9**	**7.8**	**-**
weighted mean				**79.7**	**48.7**	**60.3**	**21**	**6**	**43.7**	**3.4**	**-**	**0.9**	**7.8**	**-**

The table depicts crude mean and weighted mean for knowledge of symptoms of acute myocardial infarction in a group that was asked closed-ended questions and a group that was asked open-ended questions. If a study offered more than one knowledge percentage for a composite symptom, e.g. study 6 offered knowledge percentages on 'weak pulse' and 'dizziness' for the symptom 'feeling weak, lightheaded, or faint', we used the arithmetic mean of those percentages for our calculation. Studies included in the table: Study 1, [16] 2, [20], 3, [21] 4, [22] 5, [25] 6, [26] 7, [27] 8, [28] 9, [30] 10 [31].

Cardiac group

In the cardiac group, two studies (two samples, studies 11 and 14 in Table 4) asked the patients what symptoms they had expected, and four studies (four samples, studies 12, 13, 15, 16 in Table 4) asked the patients what symptoms they recognized as AMI symptoms. Two studies (two samples, studies 17, 18 in Table 4) used open-ended questions to assess the patients' knowledge.

Closed-ended questions With regard to closed-ended questions, the same six symptoms that were *moderately known* in the population group were *moderately known* in the cardiac group (weighted mean: 52.8–88.5%). The mean of the weighted means of the *moderately known* symptoms was 70.0%. Regarding the four symptoms that were *insufficiently known* in the population group, there were no studies for the cardiac patient group that asked about 'feeling of anxiety' and only one study that asked about 'headache', in which about 25% of participants recognized it. Similar to the population group, the symptom 'stomach or abdominal discomfort' was also *insufficiently known* in the cardiac group with 23.4%. However, 'nausea or vomiting' was known by 36.7% in the cardiac group as opposed to 28.0% in the population group. Here, it is worth noting that an outlier in study 15 (Table 4) of 61.7% contributed to the higher result.

The trap symptom was only evaluated in two studies and the weighted mean proportion of an incorrect classification of this symptom was 33.0%.

Open-ended questions In the two studies (two samples) that applied open-ended questions, similarly to the population group, the weighted mean for every symptom was smaller than when closed-ended questions were asked.

Cardiac attribution

For calculating the proportion of ACS patients who attributed their symptoms to the heart, we analyzed 25 studies (25 samples) with 14,843 patients from 16 different countries. We looked at three groups, with some participants included in all three groups. Firstly, since a number of studies only included STEMI patients, we reported the cardiac attribution of a composite STEMI group. The STEMI group included patients from 11 studies from nine different countries with 4361 participants.

Secondly, in order to allow for a more representative depiction of the group of ACS patients, we reported the attribution of the remaining studies, excluding studies that only examined STEMI patients. To that group, 15 studies from 12 different countries with 11,442

Table 4 10 most frequently asked symptoms and one trap symptom in the cardiac group

					recognizing heart attack symptom [%]										falsely recognizing trap symptom [%]
	n°	country of study	sample size	sample	chest pain or discomfort	shortness of breath	pain or discomfort in the arms or shoulders	feeling weak, lightheaded, or faint	pain or discomfort in the jaw, neck, or back	sweating	stomach or abdominal discomfort	nausea or vomiting	headache	feeling of anxiety	sudden trouble seeing in one or both eyes
Studies that used closed-ended questions	11	China	799	STEMI patients	71.4	55.5	68.7	52.1	-	40.7	-	28.7	-	-	-
	12	United States	2,580	participants who had a history of AMI or stroke	96.4	90.1	93.6	67	70.5	-	-	-	-	-	35.6
	13	China	116	AMI patients	48	21	16.4	dizziness:2.1, collapse or faint: 16.3	-	21.6	diarrhoea or abdominal pain: 2.0	7.8	-	-	-
	14	Jordan	299	AMI patients	83	-	~44	dizziness: ~30	jaw pain: ~12	54	~10	~36	~25	-	-
	15	Germany	486	STEMI patients	94.8	79	83.2	weakness: 83.0	lower jaw pain: 31.6	80.5	upper abdominal pain: 36.7	61.7	-	-	visual disturbances: 19.2
	16	China	193	AMI patients	chest pain: 83.9, uncomfortable feeling in chest: 55.4	24.4	-	dizziness: 18.1, unconscious-ness: 1.6	-	cold sweat: 50.3	-	25.4	-	-	-
crude mean					**77.2**	**54**	**61.2**	**41.9**	**38**	**49.4**	**16.2**	**31.9**	**25**	**-**	**27.4**
weighted mean					**88.5**	**77.2**	**82.2**	**59.6**	**59.7**	**52.8**	**23.4**	**36.7**	**25**	**-**	**33**
Studies that used open-ended questions	17	Canada	251	in- and outpatients of cardiology clinics	82	39	arm pain: 53	loss of consciousness: 8	-	22	-	nausea: 21	-	-	-
	18	Australia	137	patients with a CHD diagnosis following a cardiac event	91	39	arms: 59, shoulders: 18	dizziness: 14	jaw: 23, neck: 23, back: 10	cold/ sweaty: 24	-	nausea: 20	-	-	-
crude mean					**86.5**	**39**	**45.8**	**11**	**18.7**	**23**	**-**	**nausea: 20.5**	**-**	**-**	**-**
weighted mean					**85.2**	**39**	**47.9**	**10.1**	**18.7**	**22.7**	**-**	**nausea: 20.6**	**-**	**-**	**-**

The table depicts crude mean and weighted mean for knowledge of symptoms of acute myocardial infarction in a group that was asked closed-ended questions and a group that was asked open-ended questions. For our analysis, we proceeded as described in Table 3. STEMI = ST-elevation myocardial infarction. AMI = acute myocardial infarction. CHD = coronary heart disease. Studies included in the table: Study 11, [32] 12, [33] 13, [34] 14, [40] 15, [41] 16, [42] 17, [43] 18 [44].

patients contributed data, including one study with ACS patients, one study with patients about to be investigated for ACS, one study with patients with typical oppressive chest pain indicative for AMI, and the remaining 12 studies with AMI patients, of which two studies only included first-time AMI patients.

Thirdly, we reported the cardiac attribution of all studies.

The studies mostly evaluated the cardiac attribution by asking about the patients' symptom attribution in general or specifically asking whether the patients attributed their symptoms to the heart. Some studies only looked at the symptoms-onset, by asking about the cardiac attribution of the initial symptoms. One study asked whether the reason to turn to a specialized service was that the patients believed the symptoms to be of cardiac origin [35]. The results indicate the percentage of patients who chose a cardiac interpretation.

In the STEMI group, the crude mean for cardiac attribution was 43.3% and the weighted mean 49.8%. In the group of ACS patients excluding the patients from the first group, the crude mean was 39.9% and the weighted mean 43.2%. All participants added up, their crude mean was 41.8% and their weighted mean 45.1%.

Discussion

Main findings

In our world-wide review, we found a moderate to good knowledge of "classic" symptoms of AMI and rather insufficient knowledge of less typical symptoms. Cardiac patients had substantially higher scores in a broader knowledge assessment compared to the general population. However, 'chest pain' as a lead symptom of AMI was equally known in the general population and among cardiac patients. We also found that less than half of patients attributed their symptoms to the heart.

Knowledge of atypical symptoms

Our review showed that there is insufficient knowledge of atypical symptoms, which are especially relevant for women as they have a more atypical symptom presentation than men. While there is also considerable overlap among the symptoms men and women display, men present more often with the best known symptom 'chest pain' as well as 'sweating', which was among the best known symptoms in our comparison [103]. On the other hand, women present more often with *only* non-chest-pain discomfort, showing symptoms as 'neck-, back- and jaw pain' which was considerably less known, or with 'nausea or vomiting' which we found to be insufficiently known [15, 103–105]. Similarly, the observation is relevant for elderly people who also experience more atypical symptoms [5, 106, 107]. This lack of knowledge of atypical symptoms might be one factor for the higher patient delay and mortality among women and the elderly [108–110].

Comparison of the population and cardiac patients

We found a higher knowledge in cardiac patients compared to the general population in a broader knowledge assessment (regarding the overall knowledge scores). When comparing the knowledge of each symptom separately, the knowledge of typical symptoms was similar among the groups, however cardiac patients had a

higher knowledge of atypical symptoms. This suggests that the knowledge of atypical symptom might be the relevant difference.

The broader scope of knowledge in cardiac patients compared to the general population might be a consequence of their higher interest, the success of educational campaigns, or of counseling by their treating physician. It has to be considered as beneficial for delay time since previous studies observed that the time saving impact of knowledge in cardiac patients could mainly be attributed to knowledge of atypical symptoms [41]. One possible explanation for the beneficial effect is *symptom congruence,* [7] defined "as the extent to which one's AMI symptom experience matches those expected of an AMI" [111]. By knowing more symptoms, including atypical symptoms, patients are more likely to choose a cardiac attribution and are not confused by the experience of unknown symptoms. Symptom congruence has been found to be beneficial for cardiac attribution and a higher cardiac attribution has been shown to be significantly associated with a shorter pre-hospital delay [7, 112–114].

Knowledge and its relationship to cardiac attribution

However, in our review, despite a broad knowledge of symptoms, less than half of cardiac patients attributed their ACS (mostly AMI) to the heart when it happened.

This highlights the relevance of psychological factors. Knowledge alone is not sufficient for cardiac attribution, [9] and other components, for example various emotional factors also play a role [12, 115].

In fact, one study found that STEMI patients with a previous history of AMI or stent placement had a significantly lower knowledge score compared to those without it [41]. Albarqouni et al. pointed out that the driving factors might be "denial and psychological-trauma induced by the first attack" [41].

Strömbäck et al. showed that the appearance of atypical symptoms in a second AMI was not a predictor of a longer delay time [116]. One reason for this observation might be that a history of AMI seems to increase symptom congruence [111]. Therefore, the delay time in AMI survivors might not be primarily caused by a lack in knowledge but instead by psychological factors.

In the light of the above, it makes sense that despite our observed broad knowledge of symptoms in cardiac patients, a history of angina, AMI, or heart failure has not been found to have a positive impact on delay time. In fact, a history of angina or heart failure increases the delay time significantly in ACS [117].

All this highlights the significance of not merely educating patients about atypical symptoms in order to increase symptom congruence, but, maybe even more important, to prepare them psychologically. Cognitive and psychological factors that increase delay time have been observed to be denial, fear of troubling others, a lack of perceived seriousness of symptoms, a lack of perceived susceptibility to heart disease and a feeling of being able to cope with or control symptoms [118].

Therefore, we encourage future educational campaigns to not only focus their message on the knowledge of symptoms but also on overcoming psychological obstacles.

Strengths, weaknesses, and sources of bias in the review

The strength of this review is the substantial number of studies from four databases. The weakness is that there are only few studies from Africa, Russia, and South America, as well as from countries with a medium or low HDI. Our review also potentially suffers from three sources of bias. First, the results of the studies might differ by the form of knowledge assessment chosen and the composition of the samples, especially where the participants came from. Secondly, since the compared cardiac groups and population groups did not include the same set of countries, these heterogeneities might have an effect on our analysis. Thirdly, there were inconsistencies among the studies whether the knowledge of some atypical symptoms like 'headache', 'heartburn', and 'fever' contributed positively to the overall knowledge score.

Conclusion

We found a moderate to good knowledge of "classic" and rather insufficient knowledge of atypical symptoms of AMI. However, cardiac patients had a broader knowledge than the general population. As less than half of patients attributed their ACS to the heart when it happened, we see a potential to shorten delay time by educating about the symptoms, especially atypical symptoms, because they are common in the elderly and women, and because a broader knowledge increases symptom congruence. Furthermore, we encourage future campaigns to focus on overcoming psychological barriers that prevent patients from correctly identifying symptoms, attributing them to the heart, and reacting swiftly and appropriately.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12872-020-01714-8.

Additional file 1.
Additional file 2.
Additional file 3.

Abbreviations

AMI: Acute myocardial infarction; ACS: Acute coronary syndrome; CAD: Coronary artery disease; STEMI: ST-elevation myocardial infarction; HDI: Human development index

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None.

Declarations
Not applicable.

Authors' contributions
BB and RM developed the research question. BB and JH conducted the review and extracted data. BB wrote the initial manuscript. JH and RM revised and commented on the manuscript. All authors read and approved the final manuscript.

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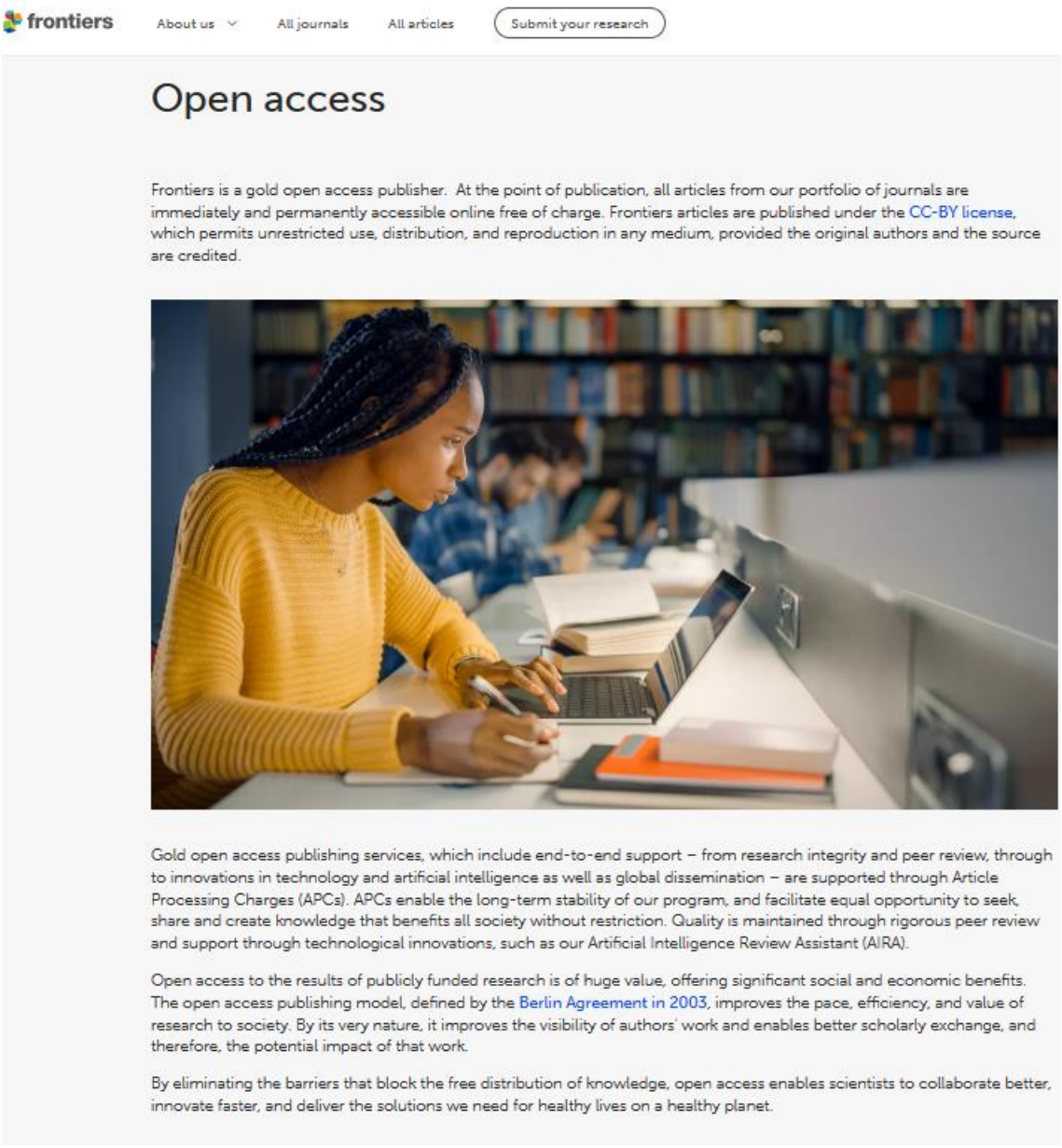

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Knowledge of Symptoms of Acute Myocardial Infarction, Reaction to the Symptoms, and Ability to Perform Cardiopulmonary Resuscitation: Results From a Cross-sectional Survey in Four Regions in Germany

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Background: Ischemic heart disease affects 126 million individuals globally which illustrates the importance of finding ways to decrease mortality and morbidity in case of an acute myocardial infarction (AMI). Since knowledge of symptoms, correct reaction to symptoms, and ability to perform cardiopulmonary resuscitation (CPR) decreases the time from symptoms-onset to reperfusion, which leads to lower AMI mortality, we aimed to examine those factors and identify predicting variables in regions with low and high AMI mortality rates.

Methods: We conducted a cross-sectional online survey including 633 respondents from the general population in four federal states in Germany with low and high AMI mortality and morbidity rates. We used uni- and multivariable regressions to find health-related and sociodemographic factors associated with knowledge, reaction to symptoms, and skills in CPR.

Results: Out of 11 symptoms, the mean of correctly attributed AMI symptoms was 7.3 (standard deviation 1.96). About 93% of respondents chose to call an ambulance when witnessing an AMI. However, when confronted with the description of a real-life situation, only 35 and 65% of the participants would call an ambulance in case of abdominal and chest pain, respectively. The predicting variables for higher knowledge were being female, knowing someone with heart disease, and being an ex-smoker compared to people who never smoked. Higher knowledge was associated with adequate reaction in the description of a real-life situation and ability to perform CPR. Prevalence ratio for being able to perform CPR was lower in females, older participants, and participants with low educational level. About 38% of participants state to know how to perform CPR. Our results indicate rather no difference regarding knowledge, reaction to AMI symptoms, and ability to perform CPR among different regions in Germany.

Conclusions: Knowledge of symptoms and first responder reaction including skills in CPR is inadequate when confronted with the description of a real-life situation. Educational health campaigns should focus on conveying information close to real-life situations. Interventions for enhancing ability to perform CPR should be compulsory in regular intervals. Interestingly, we found no difference regarding the factors in regions with high and low AMI mortality rates in Germany.

Keywords: epidemiology, acute myocardial infarction, knowledge about symptoms, cardiopulmonary resuscitation, help-seeking behavior, first responder reaction, awareness

INTRODUCTION

Ischemic heart disease (IHD) affects around 126 million individuals globally (1,655 per 100,000), the global prevalence is rising, and it is the leading cause of death and disability worldwide, as well as in Germany (1, 2). One main manifestation of IHD is myocardial infarction (AMI). When witnessing an AMI, a swift and appropriate reaction is crucial to decrease the time to reperfusion and therefore improve prognosis (3–5). In Germany, mortality of AMI differs across federal states. The highest mortality rates are observed in Eastern and the lowest in Southern and Western Germany (6). These differences are partly, but not fully explained by differences in the prevalence of cardiovascular risk factors (7). It is hypothesized that differences could also be due to the number of people able to perform cardiopulmonary resuscitation (CPR), knowledge of AMI symptoms, and behavior during AMI (8). However, to date it is unknown whether these factors differ in regions with different mortality rates. Additionally, few studies have examined which health-related and sociodemographic factors are associated with knowledge, reaction to AMI symptoms, and ability to perform CPR.

Awareness of differences in knowledge and reaction to AMI symptoms, as well as ability to perform CPR in regions with different AMI mortality rates, could refine interventions to improve the response when witnessing an AMI (9). Additionally, knowledge of influencing factors of this response is essential. The aim of this study was to investigate associations of knowledge and reaction to AMI symptoms, and ability to perform CPR with health, health behavior, and sociodemographic factors taking into account regions with different AMI mortality rates in Germany.

MATERIALS AND METHODS

Study Population

In December 2020 we re-contacted 35,835 people from a former survey (9,319 in Saxony-Anhalt with one of the highest AMI mortality rate, 9,182 in Baden-Wuerttemberg, 7,104 in North-Rhine Westphalia, and 10,230 in Schleswig-Holstein, among the federal states with the lowest AMI mortality rates) (6). Of these 35,835 invited, 857 persons conducted the cross-sectional online survey (2.4%).

Abbreviations: IHD, ischemic heart disease; AMI, acute myocardial infarction; CPR, cardiopulmonary resuscitation; PR, prevalence ratio; CI, confidence interval.

Outcomes

For evaluating participant's knowledge of AMI symptoms, we included 11 symptoms of which 10 were symptoms of AMI and one was not, and asked the participants whether these symptoms were AMI symptoms. We chose "sudden visual disturbances" as trap question, as it is not usually a symptom of AMI. We calculated a knowledge score for each participant by adding up the participant's correct answers about AMI symptoms, resulting in a score with a theoretical range from 0 to 11. We did not calculate the score in case of missing values. Our used question format was chosen as it has been used regularly in current literature as well as in Germany (10, 11). The included set of symptoms are based on the ten most frequently asked symptoms and trap symptom in the current literature (11).

We evaluated the participant's reaction when witnessing a potential AMI by describing the following everyday scenario and giving different options to choose from:

> You are talking on the phone to a female person you are close with. She is 60 years old and had no severe diseases to date. She says that she
> 1) suddenly has chest pain or
> 2) has abdominal pressure since an hour, but it is getting worse now. She feels weak and wants to lie down and rest. You say goodbye and finish the conversation.

The symptoms (chest or abdominal pain) were randomly assigned to the participants. The following answer options were given:

a) Chest pain/abdominal pain is common. You let her rest and decide to ask her about her health the next time you talk to her.
b) Chest pain/abdominal pain could be related to the heart. Lying down relieves the strain on the heart. You decide to call her back in 2 h and ask about her well-being.
c) Chest pain/abdominal pain could be a sign of a severe disease. You call her back and convince her to call an ambulance.
d) Do not know.
e) Something else (with a free-text field for describing the reaction).

Additionally, the survey included two multiple-choice questions with free-text fields that asked participants what they would do if they saw someone lying on the floor in a department store and what they would do if they thought someone had an AMI. We analyzed these two questions descriptively and did not use them as outcomes in regression.

TABLE 1 | Sociodemographic characteristics and reaction to other people's symptoms of myocardial infarction ($n = 633$).

Gender	
Female, *n* (%)[a]	322 (50.9)
Age	
Age, mean (SD)	49.2 (15.3)
Below 30 years old, *n* (%)	85 (13.4)
30–39 years old, *n* (%)	110 (17.4)
40–49 years old, *n* (%)	102 (16.1)
50–59 years old, *n* (%)	153 (24.1)
60–69 years old, *n* (%)	124 (19.6)
70 years and older, *n* (%)	59 (9.3)
Education	
Master, diploma, doctorate (PhD), *n* (%)	213 (33.6)
Bachelor or equivalent, *n* (%)	139 (22.0)
Vocational training, *n* (%)	245 (38.7)
No degree/still in training or studying, *n* (%)	36 (5.7)
Federal state	
Baden-Wuerttemberg	152 (24.0)
North Rhine-Westphalia	150 (23.7)
Saxony-Anhalt	171 (27.0)
Schleswig-Holstein	160 (25.3)
Disease related factors and risk factors of myocardial infarction	
Disease related to heart, *n* (%)	66 (10.4)
Knowing person with heart disease, *n* (%)	359 (56.7)
High blood pressure (currently/in the past), *n* (%)	220 (34.8)
Current smoker, *n* (%)	99 (15.6)
Former smoker, *n* (%)	204 (32.2)
Never smoked, *n* (%)	330 (52.1)

[a] *One person was diverse. SD, standard deviation.*

For examining the ability to perform CPR we asked the participants whether they know how to perform CPR and gave the following answer options:

a) Yes, I can perform it myself or instruct someone else to perform it.
b) Yes, theoretically, but I do not dare to perform it in a real-life situation.
c) No, I have learned it, but do not remember well how to perform it.
d) No, I never learned or knew how to perform it.

We included the following variables as possible predictors for the above-described outcomes: (1) Gender (self-classified as male, female, diverse), (2) age in years, (3) educational level, (4) federal state, (5) having a heart disease, (6) knowing someone with a heart disease, (7) self-reported high blood pressure, and (8) smoking status. Additionally, we included the knowledge score as predictor for reaction to AMI symptoms and ability to perform CPR. We chose the variables based on thorough literature review (8, 11).

Statistical Analysis

Data of 633 participants were analyzed after excluding observations with missing values for any of the included variables. Since there was only one diverse person, we excluded this observation in all analyses that included gender as variable.

For analyzing the reaction to AMI symptoms, we dichotomized the answer options. We chose convincing the women to call an ambulance as appropriate and all other options as less appropriate. We conducted all analyses separately for the symptoms chest and abdominal pain.

For analyzing the ability to perform CPR, we also dichotomized the answer options. We chose the answer option to be able to perform CPR or instruct someone else to perform it as one category, since this answer option reflects if someone would perform or help to perform it in a real-life situation. The other answer options were included in another category.

For the knowledge score, we performed linear regressions. For the binary outcomes, we estimated Prevalence Ratios (PRs) using binomial distribution with log link function, since the outcomes were common (35.4–64.6% for the certain outcomes) (12).

We conducted uni- and multivariable regressions to identify factors possibly associated with the different outcomes. Since there was no evidence for serious multicollinearity, we included all variables in multivariable regression (variance inflation factor < 5 for all variables) (13–17). Since there is some evidence in previous studies that the effect for age could be non-linear, we tested non-linear associations between age and the outcomes using thin plate splines in generalized additive models. Since non-linear associations did not improve model fit (Akaike Information Criteria < 10 for linear vs. non-linear terms), we included age as linear term in all models (18). We used R-Studio V.3.4.4 and SAS V. 9.4 for the analyses (19, 20).

RESULTS

Females, males, and the four federal states were equally represented in the sample. One person was diverse. The mean age was 49 years. About 56% of the participants held a university degree (Bachelor or higher). About 10% of the participants reported to have a heart disease and more than half of the sample indicated to know a person with heart disease. About 35% of the participants stated to have hypertension (currently or in the past), which is about the percentage of people with hypertension in the general middle-aged German population (21). About half of the sample stated to be current or former smokers (**Table 1**).

Almost all participants correctly identified chest pain/pressure as being a symptom of AMI. The four least known symptoms were abdominal pain, nausea/vomiting, headache, and jaw/neck/back pain (**Figure 1**; **Supplementary Figure 1**). In North Rhine-Westphalia, 63% correctly identified abdominal pain as symptom, while only 44% in Baden-Wuerttemberg did so (**Supplementary Figure 1**). The mean number of correctly attributed symptoms was 7.3 out of 11 symptoms (standard deviation 1.96).

Asking the participants what they would do when witnessing a person lying on the floor in a department store, about 10% would call an ambulance. About 40% stated to check whether the person was breathing before deciding to call an ambulance. Another 40% stated to start CPR, if necessary. About 6% would

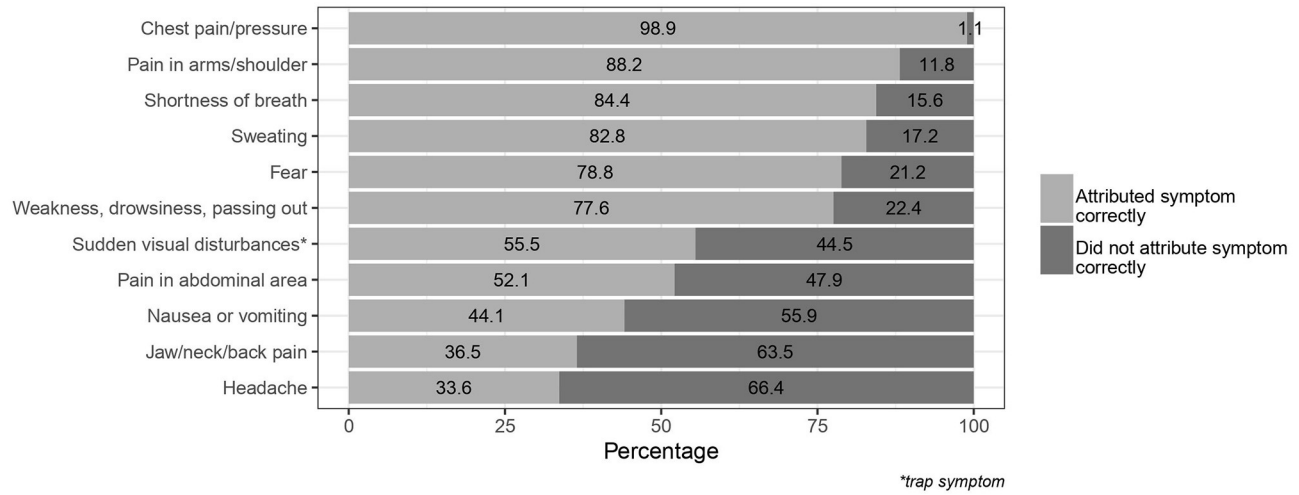

FIGURE 1 | Symptoms of myocardial infarction identified as correct/incorrect by the participants; *trap symptom.

ask somebody else for help, as they did not feel capable of gauging the situation correctly. Almost all participants stated to call an ambulance when they assume that someone has an AMI (**Supplementary Table 1**).

In the phone call scenario, 64% of the participants who received chest pain as symptom would convince the women to call an ambulance, while 35% of the participants who received abdominal pain would do so (**Figure 2**). This tendency was seen in all federal states. The proportion to convince the women to call an ambulance in both scenarios was highest in Saxony-Anhalt when compared to the other federal states (**Supplementary Figure 2**).

About 40% of the participants indicated that they could perform CPR themselves or instruct someone else to perform it. Around 30% indicated theoretically knowing how to perform it or have learned, but do not remember well how to perform it, respectively (**Figure 3**). The highest percentage regarding being able to perform CPR was in Schleswig-Holstein, while the highest percentage of theoretically knowing how to perform it was in Saxony-Anhalt (**Supplementary Figure 3**).

Examining the factors associated with knowledge of AMI symptoms, reaction to symptoms, and ability to perform resuscitation, we found that the mean knowledge score was higher in females when compared to males and lower in people aged 70 years or older when compared to the other age groups. The score was higher for people knowing someone with heart disease when compared to people not knowing someone with heart disease.

In the phone call scenario, the proportion of people choosing the adequate reaction in case of sudden chest pain was highest in the age groups 40–49 and 60–69 years when compared to the other age groups. The proportion was higher for people knowing someone with heart disease and in former smokers.

In case of abdominal pain, the proportion was highest in the age group 60–69 years and higher in people having heart disease.

Regarding the ability to perform CPR, more males than females reported to be able to perform it and the proportion decreased with increasing age. People with higher educational level reported more often to be able to perform CPR when compared to people with lower educational level. Higher proportion of former and current smokers reported to be able to perform CPR (**Table 2**).

Results of Regression Analyses

Estimates for the certain factors were comparable in uni- and multivariable regressions (**Table 3**; **Supplementary Table 2**).

For women, the knowledge score was 0.75 points higher than for men. Age, educational level, having heart disease, and hypertension were not associated with knowledge score. The knowledge score for participants knowing someone with heart disease was about half a point higher when compared to people not knowing anyone with heart disease. The knowledge score of former smokers was almost half a point higher when compared to people who never smoked. There was no consistent difference in the knowledge score among the federal states (**Table 3**). Regarding the symptom chest pain in the phone call scenario, estimates for all variables except knowledge score indicated no association (**Table 3**).

Regarding the symptom abdominal pain there was no association with gender, having heart disease, knowing someone with heart disease, hypertension, and smoking. PR for convincing the women to call an ambulance increased with older age. When compared to people with the highest educational level, PR for convincing the women to call an ambulance was higher in people still studying/having no degree, but CI included the null effect. PR for convincing the women to call an ambulance was lower in Baden-Wuerttemberg compared to Saxony-Anhalt, but again CI included the null effect. Higher knowledge score was associated with higher PR for convincing the women to call an ambulance (**Table 3**). Regarding the ability to perform CPR,

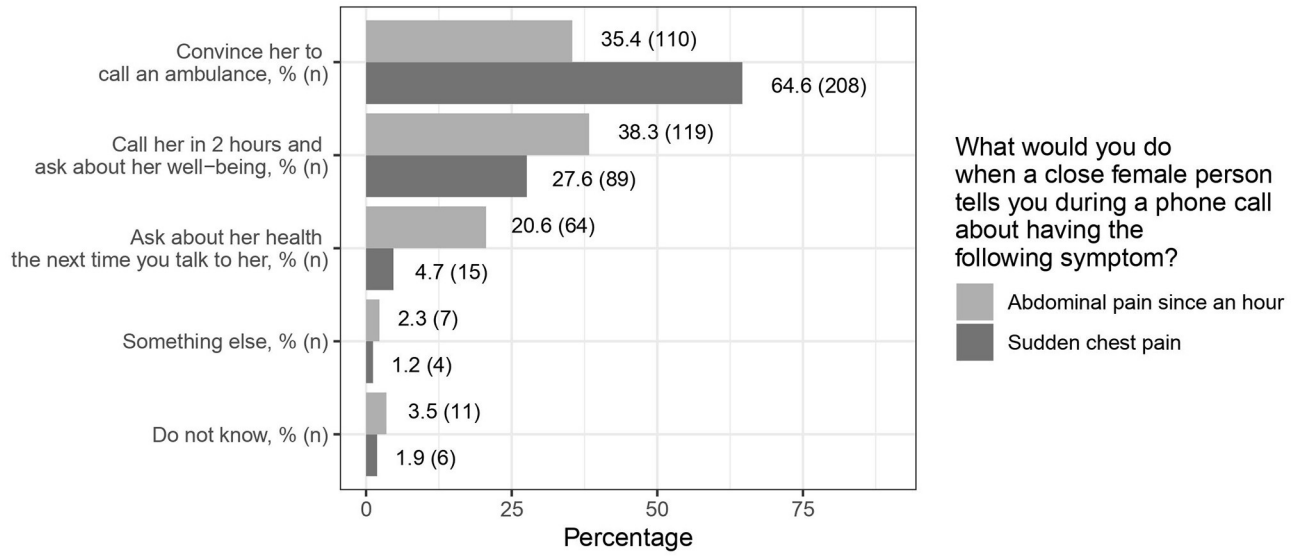

FIGURE 2 | Reaction to two symptoms of myocardial infarction.

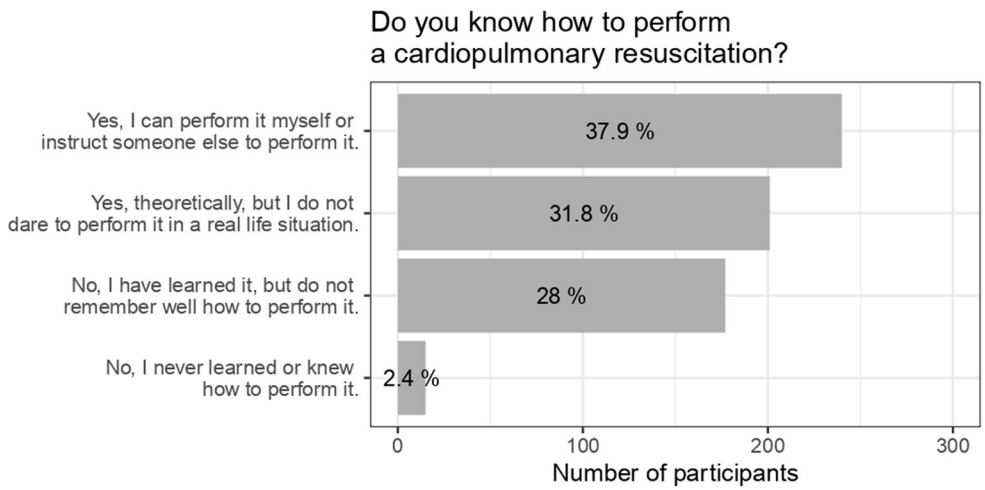

FIGURE 3 | Ability to perform a cardiopulmonary resuscitation.

there was no association with having and knowing someone with heart disease, and hypertension. Women were less likely to perform CPR compared to men. PR for the ability to perform CPR decreased with older age. PR of stating to be able to perform CPR was lower for people with vocational training and still studying/having no degree when compared to people with the highest educational level. When compared to people who never smoked, PR was higher in former and current smokers. However, CI included the null effect. Higher knowledge score was associated with higher PR to be able to perform CPR. There was no consistent difference among the federal states (**Table 3**).

DISCUSSION

In our study, we found that participants had a good understanding of how to react in case of an AMI since the vast majority would call an ambulance. In contrast, when confronted with the description of a phone call in which somebody displayed symptoms of an AMI, the proportion of participants who would convince the women to call an ambulance was considerably lower. Partly, this could be explained by the order of the questions, as the phone-call-scenario was the first question in the survey. Higher knowledge score was associated with higher PR of an adequate reaction in multiple regression. However, knowledge

TABLE 2 | Knowledge score, reaction to other people's symptoms of myocardial infarction, ability to perform CPR and their possible predictors.

	Knowledge score[b]	Would convince her to call ambulance in case of sudden chest pain ($n = 322$)[c]	Would convince her to call ambulance in case of abdominal pain ($n = 311$)[c]	Ability to perform CPR[d]
	Mean (SD)	% (*n*)	% (*n*)	% (*n*)
Female[a]	7.71 (1.84)	64 (103/161)	36 (58/161)	36.0 (116/322)
Male[a]	6.93 (2.00)	65.6 (105/160)	34.7 (52/150)	40.0 (124/310)
Below 30 years old	7.42 (1.87)	57.5 (23/40)	35.6 (16/45)	44.7 (38/85)
30–39 years old	7.29 (2.00)	56.6 (30/53)	26.3 (15/57)	43.6 (48/110)
40–49 years old	7.52 (2.08)	71.7 (38/53)	26.5 (13/49)	39.2 (40/102)
50–59 years old	7.37 (1.89)	64.6 (51/79)	37.8 (28/74)	37.9 (58/153)
60–69 years old	7.33 (1.93)	72.9 (51/70)	48.1 (26/54)	30.6 (38/124)
70 years and older	6.78 (2.03)	55.6 (15/27)	37.5 (12/32)	30.5 (18/59)
Master, diploma, doctorate (PhD)	7.38 (1.92)	63.2 (67/106)	30.8 (33/107)	39.4 (84/213)
Bachelor or equivalent	7.27 (1.95)	61.8 (42/68)	42.3 (30/71)	41.7 (58/139)
Vocational training	7.28 (2.00)	67.7 (88/130)	32.2 (37/115)	35.9 (88/245)
No degree/still in training or studying	7.47 (1.99)	61.1 (11/18)	55.6 (10/18)	27.8 (10/36)
Baden-Wuerttemberg	7.13 (2.08)	58.6 (41/70)	26.8 (22/82)	35.5 (54/152)
North Rhine-Westphalia	7.69 (1.84)	69.1 (56/81)	30.4 (21/69)	38.7 (58/150)
Saxony-Anhalt	7.27 (1.96)	70 (63/90)	46.9 (38/81)	36.3 (62/171)
Schleswig-Holstein	7.22 (1.92)	59.3 (48/81)	36.7 (29/79)	41.3 (66/160)
Heart disease	7.36 (1.97)	67.6 (23/34)	40.6 (13/32)	34.8 (23/66)
Having no heart disease	7.32 (1.87)	64.2 (185/288)	34.8 (97/279)	38.3 (217/567)
Knowing someone with heart disease	7.61 (1.86)	67 (118/176)	35 (64/183)	39.8 (143/359)
Not knowing anyone with heart disease	6.94 (2.02)	61.6 (90/146)	35.9 (46/128)	35.4 (97/274)
High blood pressure	7.24 (1.89)	66.1 (78/118)	37.3 (38/102)	32.3 (71/220)
No high blood pressure	7.37 (2.00)	63.7 (130/204)	34.4 (72/209)	40.9 (169/393)
Never smoked	7.22 (2.00)	62.1 (105/169)	33.5 (54/161)	35.2 (116/330)
Former smoker	7.59 (1.88)	69.3 (70/101)	35.9 (37/103)	39.7 (81/204)
Current smoker	7.12 (2.00)	63.5 (33/52)	40.4 (19/47)	43.4 (43/99)
Knowledge score	–	7.4 (1.8)	8.1 (1.8)	8.0 (1.8)

[a] *Because of only 1 observation, the category "diverse" was not included in the analysis, n = 632.*

[b] *Higher score indicating higher knowledge, possible range: 0–11, minimum in the sample: 2, maximum in the sample: 11.*

[c] *Refers to question: What would you do when a close female person tells you during a phone call about having abdominal pain since an hour/sudden chest pain? The symptom was randomly assigned to the participants.*

[d] *Refers to question: Do you know how to perform a cardiopulmonary resuscitation? The answer option: "Yes, I can perform it myself or instruct someone else to perform it" was considered "ability to perform resuscitation."*

CPR, cardiopulmonary resuscitation; SD, standard deviation.

might not translate directly into reacting appropriately when witnessing an AMI.

In our scenario, it is plausible that more participants chose to convince the women to call an ambulance when confronted with chest pain compared to abdominal pain since chest pain was more frequently recognized as AMI symptom than abdominal pain. This underlines the importance to educate about atypical symptoms of AMI. In fact, especially women present more often with only non-chest pain discomfort and the elderly experience more atypical symptoms (22–24).

Knowledge Score

Exploring the knowledge about symptoms of AMI, we found a mean knowledge score of 7.3/11. Hence, the mean proportion of symptoms that were correctly identified as belonging to AMI was 66.4%. This is considerably higher than in a previous study conducted in Germany in 2006 that found a proportion of 45.7% of symptoms to be correctly identified (10). The reason for the observed difference could be that selection bias in our sample might have influenced the results as well as the limitation to four regions of Germany, while the former study used a representative quota method across Germany. Possibly, in the time span from 2006 to 2020 the German population might have increased their knowledge due to efforts to better inform the public and educational campaigns as organized by the "Deutsche Herzstiftung e. V." (25).

Compared to the weighted mean of a sample of eight European countries, Russia, and Singapore, the proportion that we found in Germany is higher too (66.4 vs. 42.1%) (11).

When looking at the proportion of participants who identified a specific symptom correctly, the least well-known symptom

TABLE 3 | Multivariable regressions for knowledge and reaction to symptoms of myocardial infarction and possible predictors ($n = 632$[a]).

	Knowledge score, ß (95% CI)[b]	Would convince her to call ambulance in case of sudden chest pain ($n = 322$), PR (95% CI)[c]	Would convince her to call ambulance, in case of abdominal pain ($n = 311$), PR (95% CI)[c]	Ability to perform CPR, PR (95% CI)[d]
Male[a]		Reference		
Female[a]	0.75 (0.44, 1.06)	0.93 (0.78, 1.10)	1.00 (0.73, 1.36)	0.77 (0.63, 0.94)
Age (per 10 years)	−0.08 (−0.19, 0.03)	1.03 (0.97, 1.10)	1.11 (1.00, 1.24)	0.91 (0.85, 0.98)
Master, diploma, doctorate (PhD)		Reference		
Bachelor or equivalent	−0.11 (−0.52, 0.30)	0.93 (0.72, 1.19)	1.26 (0.85, 1.85)	1.01 (0.79, 1.29)
Vocational training	−0.23 (−0.59, 0.13)	1.08 (0.89, 1.32)	0.93 (0.64, 1.35)	0.91 (0.70, 1.15)
No degree/still in training or studying	−0.15 (−0.85, 0.56)	0.94 (0.63, 1.40)	1.72 (0.96, 3.06)	0.56 (0.34, 0.93)
Saxony-Anhalt		Reference		
Baden-Wuerttemberg	−0.11 (−0.53, 0.31)	0.89 (0.70, 1.15)	0.66 (0.43, 1.01)	0.93 (0.71, 1.23)
North Rhine-Westphalia	0.29 (−0.13, 0.72)	1.00 (0.80, 1.26)	0.72 (0.48, 1.09)	0.93 (0.71, 1.22)
Schleswig-Holstein	−0.12 (−0.54, 0.29)	0.87 (0.68, 1.13)	0.81 (0.56, 1.19)	1.09 (0.84, 1.41)
Having heart disease	0.18 (−0.33, 0.68)	0.96 (0.74, 1.24)	1.02 (0.67, 1.55)	1.03 (0.73, 1.46)
Knowing someone with heart disease	0.54 (0.24, 0.85)	1.02 (0.87, 1.21)	0.90 (0.67, 1.21)	1.08 (0.90, 1.31)
Having high blood pressure	0.03 (−0.31, 0.37)	1.05 (0.87, 1.26)	0.90 (0.65, 1.25)	0.86 (0.69, 1.08)
Never smoked		Reference		
Former smoker	0.48 (0.14, 0.82)	1.08 (0.91, 1.29)	0.91 (0.65, 1.29)	1.12 (0.90, 1.39)
Current smoker	0.10 (−0.34, 0.54)	1.01 (0.80, 1.28)	1.14 (0.75, 1.74)	1.20 (0.93, 1.54)
Knowledge score (1 unit increase)	–	1.06 (1.01, 1.11)	1.17 (1.07, 1.26)	1.19 (1.13, 1.26)

[a] *Because of only 1 observation, the category "diverse" was not included in the analysis, n = 632.*

[b] *Higher score indicating higher knowledge, possible range: 0-11, minimum: 2, maximum: 11.*

[c] *Refers to question: What would you do when a close female person tells you during a phone call about having abdominal pain since an hour/sudden chest pain?*

[d] *Refers to question: Do you know how to perform a cardiopulmonary resuscitation? The answer option: "Yes, I can perform it myself or instruct someone else to perform it" was considered "ability to perform resuscitation."*

PR, prevalence ratio; CI, confidence interval; CPR, cardiopulmonary resuscitation.

"headache" was still known by 33.8%, which is higher than in the previously mentioned studies (11, 24).

The before mentioned study from Germany observed a lower knowledge of abdominal pain (10). One possible explanation is that our observed higher knowledge of abdominal pain was influenced by our study set up, since half of the participants had already read about the woman on the phone with abdominal pain when we evaluated the knowledge of the AMI symptoms. Indeed, about 61% of the participants who were assigned to the scenario with abdominal pain identified it as symptom, while only 43% of the participants who were assigned to the scenario with chest pain did so.

The trap symptom "sudden visual disturbances" was falsely attributed to AMI by 44.5% of participants. This can be compared to the population in two studies from the United States (31.9%, 58%) and one from South Korea (33,8%), with a weighted mean proportion of 32.2% (11, 15, 17, 26). In a sample of AMI patients in Germany from 2016, the proportion of misattribution was only 19.2% (27). While this might suggest that AMI patients are better informed about this symptom, different forms of recruiting and the different areas in Germany might also influence the results. The false attribution of the symptom to AMI in our sample might point to a confusion about this symptom specifically or be influenced by the confounder that the participants were generally inclined to attribute the listed symptoms to AMI, a phenomenon that has been described by Greenlund et al. (28). However, this phenomenon could also be present in the other studies that were listed before.

Predictors of Knowledge of Symptoms of AMI

When analyzing predicting factors of knowledge of AMI symptoms, we found that factors that are in connection with a general interest in health are also predictors for a better knowledge of AMI symptoms:

(1) Being female was associated with higher knowledge similarly to the findings of previous studies (10, 14–16, 29).
(2) Higher knowledge in people who know someone with heart disease might be influenced by their increased interest and direct talks about the disease. This aligns with a study that found a better knowledge of at least one to four symptoms when relatives, acquaintances, or neighbors had a history of AMI (17).
(3) Being an ex-smoker in comparison to people who never smoked was positively associated with a higher knowledge scale. This might be a result of increased interest in healthy living. When comparing smokers to non-smokers we did not observe an effect.

While past literature observed an association for history of heart disease and a good knowledge of the symptoms, as well as for having coronary heart disease and a recommended heart attack knowledge, we did not observe an effect for having heart disease (15, 30). It is plausible that people with heart disease have a higher interest in AMI so it is not clear to us why this association could not be found in our survey. One possible reason could be that in light of the low response rate to our survey, the interest of the participants was generally higher than in the general population and therefore, the interest among participants with heart disease was similar to the interest of the other participants. However, since we could find an association for other factors related to interest, this might not be a sufficient explanation.

Similarly, we did not find an association between knowledge and hypertension which is a risk factor for AMI. This aligns with a previous study that did not find a significant association between hypertension and excellent knowledge (17).

While we found no association with age, previous studies found young or middle-aged adults to be most knowledgeable (14–17), except for one study that found people aged 14–35 years to be least knowledgeable which might be influenced by the inclusion of teenagers in the sample (10). Regarding the elderly in our study, the results might have been skewed by a selection bias since the observed participants were all mentally fit enough and resourceful enough to use the Internet in order to answer the online survey and additionally, there were only few people aged 70 or older in our sample.

We found that participants with the highest education had the highest knowledge score but the associations were very small including the null effect. Past literature observed a better knowledge of the AMI symptoms in adults with higher education (10, 14–17, 31).

We did not observe differences among the federal states. Our results indicate that differences among Federal States with high and low AMI mortality rates in Germany might not be explained by differences in knowledge of AMI symptoms.

Predictors of Reaction to Symptoms of AMI

When the participants were confronted with the symptom sudden chest pain in the phone call scenario, we observed an association with higher knowledge score and convincing the woman to call an ambulance. All other variables were not associated with the outcome.

When confronted with the symptom abdominal pain, older age and higher knowledge score were associated with convincing the woman to call an ambulance. Older people might be more aware that abdominal pain could be related to a severe disease than younger people and hence be more likely to convince the woman to call an ambulance. People in the federal states with low AMI mortality were less likely to convince the woman to call an ambulance when compared to people in Saxony-Anhalt, the state with the highest AMI mortality. Even though this result included the null effect, which might be partly due to small sample size, it is highly interesting, since it was hypothesized that people in federal states with a higher mortality of AMIs would rather not call an ambulance. This should be explored in further studies.

Since our chosen approach of analyzing the reaction to AMI symptoms by describing a real-life situation has, to our knowledge, not been conducted in the same way in previous literature, it needs more research to better understand the results and the associated factors for our observation.

Predictors of Ability to Perform CPR

Factors associated with performing CPR were a better knowledge of the symptoms, being male, and younger age. People having no degree/still in training or studying were less likely to perform CPR in comparison with people holding Master, diploma, or doctorate degree.

In Germany, training in CPR is mandatory when taking classes for a driving license and in most social and health-related professions. However, in contrast to many other countries, in Germany the population is not regularly trained in CPR (32). Trying to explain our predictors, it might be plausible that for younger people the time span since obtaining their driving license was smaller, so they were able to remember their training in CPR better and therefore showed an increased confidence.

Our results indicate that differences among federal states with high and low AMI mortality rates in Germany might not be explained by differences in the ability to perform CPR.

Limitations and Strength

One limitation of our study is the online assessment, which might exclude mainly the elderly, who are not familiar with the internet. Additionally, because of the low response rate and contacting only non-responders from a former survey, selection bias must be assumed. A strength of the study is that we assessed the knowledge and first responder reaction not only by testing the participants directly about their knowledge/preferred reaction without a practical context but also with real-life scenarios. The description of everyday scenarios could provide a higher external validity since it is closer to the actual experience of a bystander. Furthermore, this study is the first survey to assess knowledge,

reaction to AMI symptoms, and ability to perform CPR in German federal states with different AMI mortality rates.

CONCLUSIONS

This study indicates rather no differences regarding knowledge and reaction to AMI symptoms as well as ability to perform CPR among different regions with high and low AMI mortality rates when taking into account sociodemographic as well as health and health-related factors. Only few of the other examined factors showed an association with the outcomes. Further studies should explore which factors could influence knowledge, reaction to symptoms, and ability to perform CPR. This study highlights that less known AMI symptoms should be included in health campaigns. Educating the public about AMI symptoms and CPR may not be sufficient for enabling bystanders to gauge a real-life situation correctly and act accordingly. Educational health campaigns should focus on conveying the information in a format that is close to a real-life situation in order to have most impact (9). Interventions for enhancing ability to perform CPR should be compulsory in regular intervals.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

This study was approved by the Ethics Committee of the Medical Faculty of the Martin-Luther University Halle-Wittenberg.

AUTHOR CONTRIBUTIONS

RM and SH developed the general idea of the study and prepared the study protocol. SH, RM, and BB developed the questionnaire. BB drafted the initial manuscript. NK conducted the statistical analyses and contributed sections on methods and results. All authors contributed to the interpretation of the findings. All authors revised and commented on the manuscript and read and approved the final version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcvm.2022.897263/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Declaration of previous doctoral attempts

(1) I declare that I have not undergone a doctoral procedure or started a doctoral program at any other university.

(2) I declare that the information I have provided is true and that I have not submitted the scientific work to any other scientific institution for the purpose of obtaining an academic degree.

Halle (Saale),

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(Original signature)

Declaration of independence

I declare in lieu of an oath that I have written this thesis independently and without outside help.

All rules of good scientific practice have been observed; no sources and aids other than those indicated by me have been used and passages taken verbatim or in terms of content from the works used have been identified as such. I affirm that I have not used the paid help of mediation and consulting services (PhD advisors or other persons) for the preparation of the content of this thesis. No one has directly or indirectly received monetary benefits from me for work related to the content of the submitted dissertation.

Halle (Saale),

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(Original signature)

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