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Does a multi-component intervention including pictorial risk communication about subclinical atherosclerosis improve perceptions of cardiovascular disease risk without deteriorating efficacy beliefs?

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ABSTRACT

Background: Pictorial communication about subclinical atherosclerosis can improve cardiovascular disease (CVD) risk, but whether it leads to long-term shifts in self-rated CVD risk (risk perception) and beliefs about possibility to influence personal risk (efficacy beliefs) is unknown.
Purpose: To study the impact of personalized color-coded and age-related risk communication about atherosclerosis and motivational conversation, compared to traditional risk factor-based communication, on risk perception and efficacy beliefs. Also, whether risk perception increases with message severity.
Method: The effect of the pragmatic RCT Visualization of Asymptomatic Atherosclerotic Disease for Optimum Cardiovascular Prevention (VIPVIZA) was analyzed using a linear mixed effects model with risk perception and efficacy believes at 1-year and 3-year follow up as dependent variables. Participants' (n = 3532) CVD risk perception and efficacy beliefs were assessed with visual analog scales (0–10). Fixed effects were group (intervention vs control), time point (1 year or 3 years) and interaction between group and time point. Further, the models were adjusted for corresponding baseline measurement of the dependent variable and a baseline × time point interaction. Effect of pictorial color-coded risk in the intervention group was investigated using a corresponding mixed effects model, but with pictorial risk group (message severity) as exposure instead of intervention group.
Results: After one year, the intervention group rated their CVD risk as higher (m = 0.46, 95% CI 0.32–0.59), with an effect also after 3 years (m = 0.57, 95% CI 0.43–0.70). The effect was consistent in stratified analyses by sex and education. Overall, no effect on efficacy beliefs was observed. In the intervention group, differences in CVD risk perception were found between participants with different color-coded risk messages on atherosclerosis status.
Conclusion: Personalized, color-coded and age-related risk communication about atherosclerosis had an effect on risk perception with an effect also after 3 years, whereas overall, no effect on efficacy beliefs was observed.

1. Introduction

Non-adherence to cardiovascular disease (CVD) prevention guidelines is of great concern (Kones et al., 2019). Over 90 % of the risk of myocardial infarction is due to modifiable risk factors (Yusuf et al., 2004), and promotion of a healthy lifestyle is the most important way to prevent atherosclerotic CVD (Visseren et al., 2021). Mortality from CVD has increased worldwide in the past decade. The previously observed decline in CVD mortality in high-income countries have in many cases slowed down, in some cases even reversed (Lopez and Adair, 2019), linked to increasing prevalence of obesity (Powell-Wiley et al., 2021).

For effective prevention, it is essential that interventions use appropriate behavioral change techniques (BCTs) that target modifiable psychological factors of relevance for behavior change (Michie et al., 2021). However, tests of the mechanisms by which interventions bring about change are not routinely conducted in primary studies and research syntheses of behavior change interventions (Hagger et al., 2020). For example, a meta-review of BCTs used within CVD

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interventions concluded that among the 15 meta-analyses included, remarkably, none of them reported mechanisms of action. Not knowing the links between behavior change techniques, mediating factors (e.g. psychological constructs) and change in behaviors of relevance for CVD limits knowledge about how to improve health behaviors that might prevent or delay onset of disease (Suls et al., 2020).

Theories predicting health behavior change offer important guidance as to why or when behavior change will occur. Two key constructs described in several social cognition theories, theories of motivation and dual-process models are risk perception and efficacy beliefs. The very *combination* of risk perception (including, for example, perceived severity and susceptibility of a disease) and efficacy beliefs (belief in personal capability to perform a specific behavior, self-efficacy, and beliefs that actions will have an effect, response efficacy) is key. In theories of fear appeals, the risk perception component is instead described in terms of threat and fear. For example, the *Extended parallel process model* suggests that threat motivates a response, and that efficacy determines the nature of that response (either danger or fear control) (Witte, 1992). The combination of high threat/high efficacy has been found to be most persuasive (Witte and Allen, 2000). On the other hand, being worried is not always a prerequisite for behavioral change. Studies assessing the predictive power of threat and coping appraisal have in a variety of health- and safety-related contexts found that response efficacy and self-efficacy are the strongest predictors of intentions and behaviors (Milne et al., 2000; Norman et al., 2005). Furthermore, to what extent risk perception, apart from a risk estimate, also includes an affective component varies between studies. In the Attitudes and Beliefs about Cardiovascular Disease Risk Questionnaire, developed to assess patients' awareness of CVD, *knowledge* is central (Woringer et al., 2017).

Rimal defined four attitudinal groups based on the combined role of CVD risk perception and self-efficacy; *responsive* (high perceived risk, high efficacy), *proactive* (low perceived risk, high efficacy), *avoidance* (high perceived risk, low efficacy), and *indifference* (low perceived risk, low efficacy), and suggested that these groups differ regarding motivation to think about CVD, use of health information, and knowledge acquisition. *Responsive* individuals, aware of their risk status and believing they can influence their risk, are expected to actively seek health information. Individuals with an *avoidance* attitude are, due to low efficacy, expected to avoid information that makes their risk status more salient. *Proactive* individuals are inclined to seek information due to motivation to stay healthy and remain CVD free. Finally, individuals with an *indifference* attitude are less motivated since they do not believe they are vulnerable, and do not trust their capability to avert the risk (Rimal, 2001). Taken together, interventions targeting risk perception should also strengthen efficacy beliefs.

Whereas accurate prediction of CVD risk has gained much attention, more focus is needed on how to effectively present patients with risk, to help them decrease individual risk by lifestyle modification and treatment (Waldron et al., 2010). Fortunately, the latest version of European Society of Cardiology Guidelines on cardiovascular disease prevention in clinical practice has addressed the importance of assessing whether patients understand their risk, and the pros and cons of an intervention (Visseren et al., 2021). Health literacy can be defined as "the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions" (Baker, 2006) and "the knowledge, motivation and competences to access, understand, appraise and apply health information" (Kickbusch et al., 2013). This concept is of importance since individuals with low health literacy feel less capable to perform lifestyle changes, exhibit fewer proactive coping behaviors, and are more likely to deny CVD. Low health literacy is associated with low socioeconomic status, and barriers include inadequate provision of information by health providers and lack of awareness of risk factors (Peltzer et al., 2020). A meta-analysis indicates that whereas health literacy contributes uniquely to health behavior participation and health outcomes, social cognition constructs, such as self efficacy, risk perception and attitudes relating to the utility of the behavior, partly explain these effects (McAnally and Hagger, 2023). This is in line with more comprehensive definitions of health literacy, and shows the relevance of assessing the constructs of interest in the present study.

Pictorial health information can improve knowledge and understanding, especially in persons with low health literacy (Schubbe et al., 2020). Health risks need to be communicated in a format that gives meaning to patients, and where emotions are acknowledged for shaping mental representations of risk (Brust-Renck et al., 2013). Concepts such as "heart age", "vascular age" and "risk age" link individual risk factors to life years in a way that may be intuitively and personally engaging (Groenewegen et al., 2016). Age-based CVD risk communication strategies are promising, more vivid risk presentations are thought to promote behavior change, but the available evidence is still sparse (Kulendrarajah et al., 2020). Heart age interventions differ significantly regarding central aspects such as underlying algorithms of the tools, personal or hypothetical risk, presentation modes and formats of risk communication, type and intensity of behavior change intervention, follow-up time, age and CVD risk (Bonner et al., 2021). In parallel, use of medical imaging technologies is increasing, and it has been shown that feedback of medical images to individuals has the potential to motivate risk-reducing behaviours and reduce risk factors (Hollands et al., 2022). A systematic review on cardiovascular risk communication strategies in primary prevention found that strategies that employ personalized and visual evidence of current cardiovascular health status were more likely to promote action to reduce risk (Schulberg et al., 2022). According to Schulberg et al. heart age is relatable and thereby enhances risk perceptions and drives behavior change, while cardiovascular imaging removes uncertainties with the notion of risk by providing direct evidence of CVD.

A barrier for conducting analysis of the mechanisms by which interventions bring about change is that many BCTs are proposed to affect behavior through multiple theory-related mediators, and in addition, many interventions comprise multiple BCTs (Hagger and Hamilton, 2020; Michie et al., 2021). For example, in the VIPVIZA trial, (Visualization of asymptomatic atherosclerosis for optimum cardiovascular prevention), in which the present study was conducted, it can be hypothesized that a certain intervention component primarily might be targeting risk perception, whereas another contributes to a higher extent to strengthening beliefs about capability for behavior and effectiveness of behavior change. Still, in the case of complex interventions, it can be difficult to disentangle how components contribute in isolation to behavior change. However, conducting analyses of modifiable psychological key determinants for behavior change is still important for evaluation of interventions. Development of taxonomies (Kok et al., 2016; Michie et al., 2021), theory integration (Hagger and Hamilton, 2020) and frameworks for development and evaluation of complex interventions (Skivington et al., 2021) represents important ground for testing mechanisms by which interventions bring about change, which can contribute to improving prevention of chronic disease. In addition, to strive for health equality in CVD prevention, we suggest to test the effect of interventions on mediating key determinants of health behavior change in sub group analysis based on sex, level of education and CVD risk, and also to assess how mediating constructs develop over time.

The VIPVIZA trial provides evidence of the contributory role of pictorial presentation of atherosclerosis for reduction of CVD risk factors, even with a sustained effect over three years, and regardless of participants' education level (Bengtsson et al., 2021; Naslund et al., 2019). A secondary analysis, focusing on key constructs of importance for behavior change, is therefore motivated. The present study investigated whether risk perception and efficacy beliefs develop over the first three years among participants in the population-based trial. Risk-messages were personalized, color-coded and related to age, and a motivational conversation was included.

In this longitudinal study, we assessed the impact of the VIPVIZA intervention on risk perception in terms of self-rated CVD risk and a

global, yet health-specific, question on efficacy beliefs.

The following research questions were addressed:

1) Is there an effect of the intervention on risk perception and efficacy beliefs after one year and three years in the entire study population, and when stratifying for sex and level of education, separately?
2) In the intervention group, does change in risk perception differ between participants with different color-coded pictorial risk message about atherosclerosis status?

2. Method

2.1. Study context of the VIPVIZA trial

VIPVIZA is a pragmatic, open-label, randomized controlled trial with masked evaluators conducted in Västerbotten county in northern Sweden (Bengtsson et al., 2021; Naslund et al., 2019). The trial design is outlined in Fig. 1. VIPVIZA participants were recruited from the Västerbotten Intervention Program (VIP), a population-based program for screening and prevention of CVD, offered to all inhabitants of the Västerbotten county the year they turn 40, 50, and 60 years (Norberg et al., 2010). The VIP includes clinical risk factor measurements and an extensive questionnaire covering lifestyle, psychosocial factors and family history of diabetes and CVD. Feedback on results is given to participants in a health dialogue with a nurse within primary care to promote healthy lifestyle habits. When indicated, pharmacological treatment is offered.

During the recruitment period of VIPVIZA, April 2013–June 2016, the participation rate for VIP was 68%, and only small social selection bias has been observed (Norberg et al., 2012). In total, 4177 VIP participants were invited to the VIPVIZA trial, and participation rate was 84.6% (n = 3532). For VIP participants aged 60 years, age constitutes the inclusion criterion irrespectively of any other risk factors (64 % of the VIPVIZA study population), those aged 50 years were included due to at least one conventional CVD risk factor (28%), and those aged 40 years on the bases of history of early CVD among first-grade relatives (8%).

2.2. Active components of the intervention: pictorial risk communication and motivational conversation

Within the VIPVIZA trial, health risk messages regarding atherosclerosis status were personalized, color-coded and related to age, furthermore, a motivational conversation with a nurse was included. In terms of theoretical underpinnings, rather than leaning on a specific theory, theoretical integration was applied in the design of the intervention. A model hypothesizing mediating key constructs between risk communication and behavioral change was developed (Appendix A).

Intima media thickness (IMT) was communicated as vascular age. Here the individual's IMT was compared to that of individuals with the same sex and age in a reference population (Naslund et al., 2019), and depicted as a graphical continuous gauge ranging from green via yellow and orange to red. Green corresponds to the IMT of a person at least ten years younger, and red corresponds to an IMT of a person being at least ten years older than the participant's actual age. Plaque was presented as a traffic light with a red (plaque identified) or green (no plaque) dot. An illustration of graphical elements in the letter is provided in Fig. 2. Written information was also provided in the same letter, describing atherosclerosis as a dynamic process that can be slowed or even reversed by healthier lifestyle and preventive medication (Appendix B).

Two to four weeks after the participants had received the result letter, a nurse called for a motivational conversation, based on motivational interviewing (MI). MI is a method for collaborative communication aiming to enhance readiness for change, in which evoking the client's own perceptions, values and motivations for change is central (Hettema et al., 2005). MI involves "collaboration not confrontation, evocation not education, autonomy rather than authority, and exploration instead of explanation" (Kok et al., 2016).

The active components of the intervention correspond to the following BCTs of the Behavior Change Technique Taxonomy (Michie

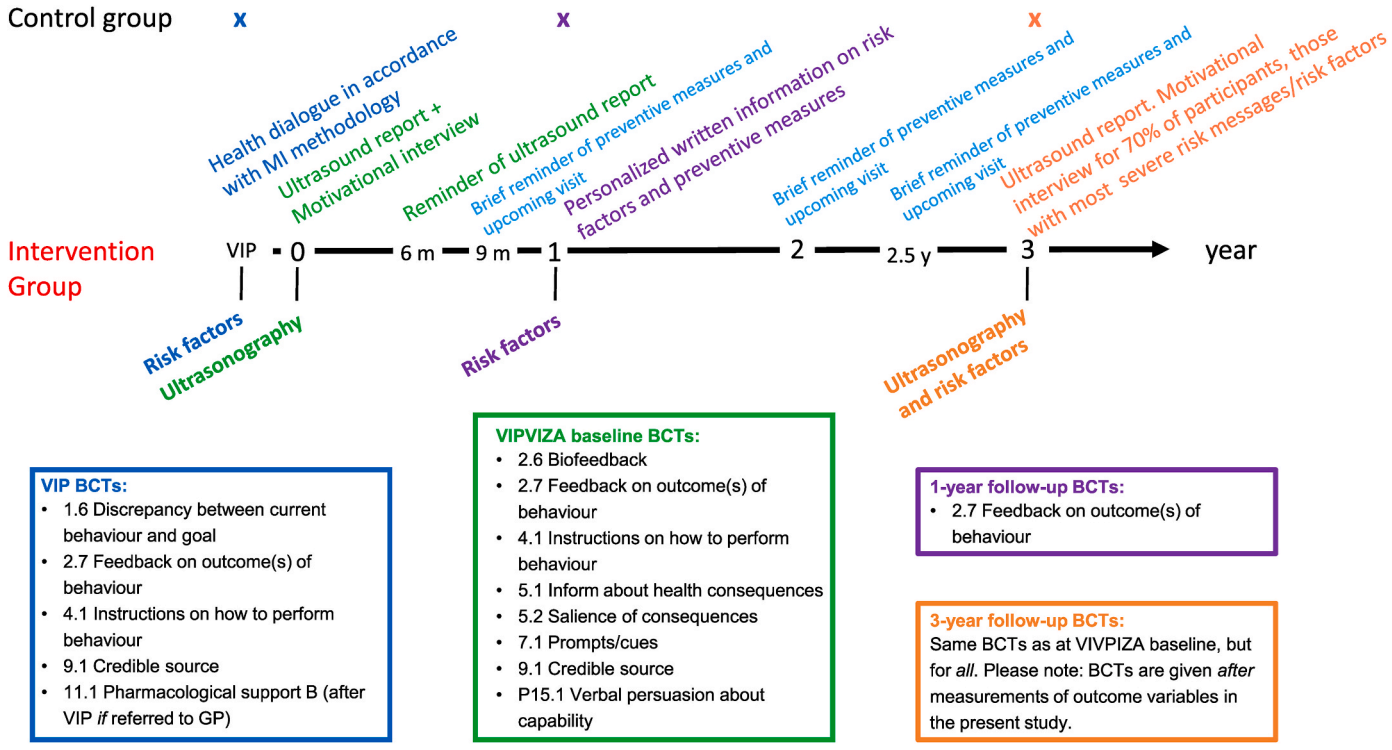

Fig. 1. Outline of the VIPVIZA trial design, including only the first three years of relevance for the present study. Listed behavioral change techniques (BCTs) are adopted from The Behavior Change Techniques Taxonomy version 1 (Michie et al., 2013).

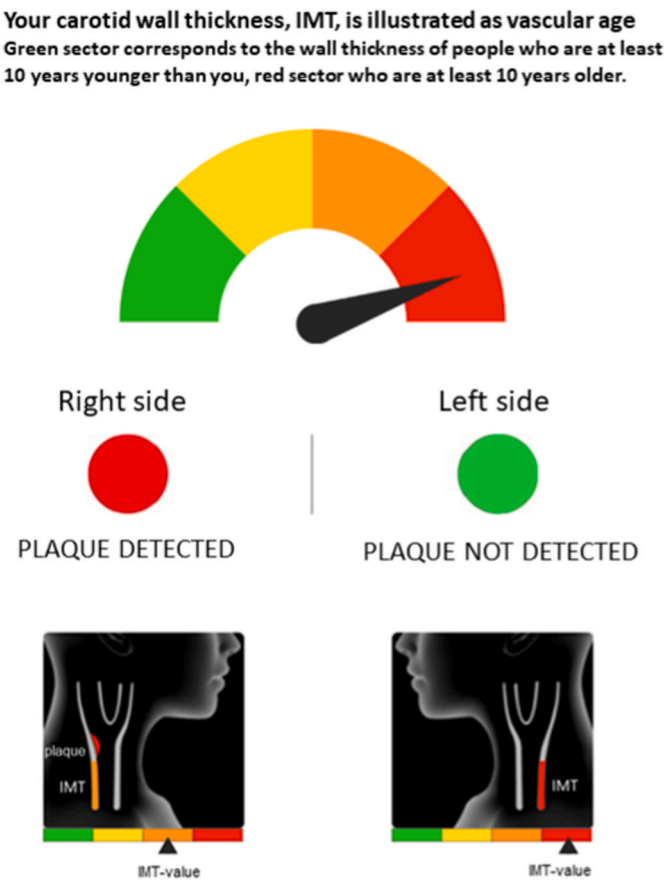

Fig. 2. Illustration of graphical elements in the result letter.

et al., 2013, 2015): *5.1. Information about health consequences:* the CVD risk was conceptualized through the result letter, including pictorial presentation of atherosclerosis status, which might be of importance for understanding the link between lifestyle and the build-up of plaque and narrowing arteries. Communicating risk in relation to age also means that consequences of atherosclerosis are shown. *5.2 Salience of consequences:* The clear-cut message was memorable. According to a qualitative study it was engaging, definite in nature and convincing, the expression "It's stated in black and white" was common (even though colours are used) (Andersson et al., 2023a). *2.6. Biofeedback:* Since the ultrasound examination assessed the underlying process of CVD, the risk communication represents feedback from one's own body. *15.1. Verbal persuasion about capability* and *9.1. Credible source:* The motivational conversation with a nurse is aiming at strengthening self-efficacy and response efficacy to increase motivation for a healthy lifestyle and to empower the study participants. Health care providers (but also the frames of scientific research) contribute to credibility. *7.1. Prompts/cues* and *4.1. Instructions on how to perform a behavior:* The result letters provided information and reminders to follow a healthy lifestyle. Also, the nurse could communicate advise. *2.7. Feedback on outcome(s) of behavior*: All participants (also those in the control group) receive written information about clinical risk factors at 1-year follow up.

2.3. Procedures

The procedures have been described in detail elsewhere (Andersson et al., 2023a), for an overview of the VIPVIZA study, see Fig. 1. Participants were randomly assigned 1:1 to the intervention (n = 1749) or the control group (n = 1783). Presence of carotid atherosclerotic plaque and IMT was assessed with ultrasound with a mobile *CardioHealth Station*, provided by Panasonic Healthcare Corporation of North America, Newark, NJ, USA. In order to evaluate the effect of the intervention, only participants in the intervention group and their primary care physicians received letters with the pictorial presentation of the ultrasound result at baseline.

After the participants in the intervention group had received the letter with pictorial presentation of the ultrasound result, they were contacted by a research nurse by telephone for clarifications if needed, any remaining questions and a motivational conversation (Hettema et al., 2005). After six months, participants in the intervention group, once again, received the letter with the pictorial presentation of the ultrasound result, including a reminder of preventive measures. After nine months, after 2 years and after 2.5 years, participants in the intervention group received a letter reminding them about the next follow-up visit. These letters contained general information about proceedings in the study and the importance of a healthy lifestyle to prevent progression of atherosclerosis. No information letters were sent to the control group.

At 3-year follow-up, all study participants, also those in the control group, received a letter with pictorial presentation of their ultrasound result. At baseline, 1-year follow up and 3-year follow up, participants responded to questions on self-rated CVD risk (*risk perception*) and perceived possibility to impact one's CVD risk (*efficacy beliefs*), which were analyzed in the present study. When, at each occasion, participants responded to these questions, they replied before receiving any results from the present visit. The complete study protocol is available at https://clinicaltrials.gov/ct2/show/NCT01849575.

2.4. Outcomes

Risk perception in terms of self-rated CVD risk was assessed with the question *Right now, how do you assess your personal risk of suffering from cardiovascular disease, for example myocardial infarction or stroke?* (In Swedish: Hur bedömer du just nu att din egen risk är för att drabbas av hjärt-eller kärlsjukdom, t.ex. hjärtinfarkt eller stroke?). The response was given on a scale ranging from 0 = *No risk* to 10 = *Very high risk*.

Efficacy beliefs was assessed with the question *How do you assess your possibilities to influence your risk of cardiovascular disease by lifestyle modifications?* (In Swedish: Hur ser du på dina möjligheter att genom egna beteendeförändringar (=förändra i din livsstil) kunna påverka din risk för hjärt-kärlsjukdom?). The response was given on a scale ranging from 0 = *No possibilities* at all 10 = *Great possibilities*.

2.5. Statistical analysis

The effect of the intervention was analyzed using a linear mixed effects model with risk perception and efficacy believes as dependent variables. The model was fitted using restricted maximum likelihood, avoiding listwise deletion of individuals with single missing outcomes. Fixed effects were group (intervention vs control), time point (1 year or 3 years) and interaction between group and time point. Further, the models were adjusted for corresponding baseline measurement of the dependent variable and a baseline × time point interaction. An unstructured covariance matrix was assumed. Effect of pictorial color-coded risk in the intervention group was investigated using a corresponding mixed effects model, but with pictorial risk group (green/yellow vs orange/red, with and without plaque) as exposure instead of intervention group.

In addition to our primary analysis, the participants were classified into four attitudinal groups based on having high or low risk perception and efficacy beliefs. The distribution of these groups was compared between intervention and control group at baseline (T0) and 3-year follow-up (T3) among participants providing data at all timepoints, resulting in an intervention sample of n = 1332, and a control sample of n = 1139. Low was defined as 0–5, and high as 6–10 for both variables.

2.6. Ethical considerations

All study participants provided written informed consent when included in the VIPVIZA study. The study was performed in line with the principles of the Declaration of Helsinki and was approved by the Umeå Regional Ethics Board (2011-455-31 M and 2012-463-32 M).

3. Results

Baseline characteristics of the VIPVIZA study population is presented in Table 1. In the intervention group, 50.8% of men and 38.0% of women had plaque, and 44.4 % of the men and 41.8% of the women had red on the IMT gauge, illustrating vascular age at least 10 years older than actual age.

Observed values of risk perception and efficacy beliefs are presented in Fig. 3. Risk perception (self-rated CVD risk) was approximately normally distributed in the intervention and control groups at all timepoints, and for both groups the median was 4 at T0 and 5 at T3. Risk perception increased in both groups over time, but more so in the intervention group. The distribution of efficacy beliefs was moderately negatively skewed (range of skewness −1.04 to −0.61), indicating high efficacy beliefs in both groups at all timepoints, the median was 8 at T0 and 7 at T3. However, there was a statistically significant decrease from T0 to T1, and a statistically significant increase from T1 to T3 in both groups. Aggregated data and presence of missing outcome values are presented in Online Supplemental Materials.

Results from the mixed model analysis regarding differences in risk perception and efficacy beliefs between intervention and control groups at T1 and T3 are presented in Table 2. After one year, the intervention group rated their CVD risk as higher (m = 0.46, 95% CI 0.32–0.59; p < .001), with an effect also after 3 years (m = 0.57, 95% CI 0.43–0.70; p < .001). The effect of the intervention on self-rated CVD risk was consistent in stratified analyses by sex and level of education. Even though risk perception increased overall, the intervention did not have an effect on beliefs about the possibility to influence personal risk, except in participants with high education, for whom efficacy beliefs decreased.

Observed values of risk perception in relation to severity of the pictorial risk message are presented in Fig. 4. Table 3 presents results regarding differences in risk perception in the intervention group between participants with different color-coded risk messages at T1 and T3. Differences were found, such that self-rated CVD risk increased with message severity. After one year, participants with orange/red IMT and plaque, compared to participants with green/yellow IMT and no plaque, rated their CVD risk as higher (m = 1.35, 95% CI 0.98–1.73; p < .001) with an effect also after 3 years (m = 0.98 95% CI 0.62–1.35). Data analysis scripts and output are available in the Online Supplemental Materials for this manuscript.

In addition to our primary analysis, we also assessed change in combinations of high or low risk perception (LR/HR) and high or low efficacy beliefs (LE/HE), as described in the literature (Rimal, 2001) and outlined in Table 4. At baseline, distributions were similar between intervention vs. control group: (LRLE: 11.0% vs 11.3%; LRHE: 61.1% vs 59.4%; HRLE: 5.4% vs 5.2%; HRHE: 22.5% vs 24.1%). After three years the HRHE group, by Rimal named *responsive* and hypothesized to be the most favorable group, had increased by 47% (from 22.5% to 33.1%) in the intervention group. Intervention vs. control group at T3: (LRLE: 11.3% vs 13.5%; LRHE: 46.8% vs. 54.8%; HRLE: 8.8% vs. 6.8%; HRHE: 33.1% vs 24.9%).

Table 1
Baseline characteristics of the VIPVIZA study population.

	Men (n = 1662)		Women (n = 1870)		Total (n = 3532)	
	Control (n = 853)	Intervention (n = 809)	Control (n = 930)	Intervention (n = 940)	Control (n = 1783)	Intervention (n = 1749)
Sex, n (%)						
Men	853/1662 (51.3)	809/1662 (48.7)	NA	NA	853/1783 (47.8)	809/1749 (46.3)
Women	NA	NA	930/1870 (49.7)	940/1870 (50.3)	930/178 (52.2)	940/1749 (53.7)
Age, years, n (%)						
40	73/853 (8.6)	63/809 (7.8)	69/930 (7.4)	71/940 (7.6)	142/1783 (8.0)	134/1749 (7.7)
50	250/853 (29.3)	222/809 (27.4)	242/930 (26.0)	264/940 (28.1)	492/1783 (27.6)	486/1749 (27.8)
60	530/853 (62.1)	524/809 (64.8)	619/930 (66.6)	605/940 (64.4)	1149/1783 (64.4)	1129/1749 (64.6)
Education, n (%) *						
Basic or mid-level	608/848 (71.6)	581/803 (72.4)	529/914 (57.9)	562/932 (60.3)	1137/1762 (64.5)	1143/1735 (65.9)
High (Univ.)	240/848 (28.3)	222/803 (27.6)	385/914 (42.1)	370/932 (39.7)	625/1762 (35.5)	592/1735 (34.1)
SCORE2 estimates, n (%)						
Low	226/847 (26.7)	223/806 (27.7)	726/919 (79.0)	767/933 (82.2)	952/1766 (53.9)	990/1739 (56.9)
Moderate	518/847 (61.2)	466/806 (57.8)	179/919 (19.5)	150/933 (16.1)	697/1766 (39.5)	616/1739 (35.4)
High	103/847 (12.2)	117/806 (14.5)	14/919 (1.5)	16/933 (1.7)	117/1766 (6.6)	133/1739 (7.6)
Presence of plaque, n (%)	439/853 (51.5)	411/809 (50.8)	373/930 (40.1)	356/938 (38.0)	812/1783 (45.5)	767/1747 (43.9)
IMT color code/plaque, n (%)						
G/Y, no plaque	NA	127/809 (15.7)	NA	173/938 (18.4)	NA	300/1747 (17.2)
O/R, no plaque	NA	271/809 (33.5)	NA	409/938 (43.6)	NA	680/1747 (38.9)
G/Y, with plaque	NA	110/809 (13.6)	NA	62/938 (6.6)	NA	172/1747 (9.8)
O/R, with plaque	NA	301/809 (37.2)	NA	294/938 (31.3)	NA	595/1747 (34.0)
BMI categories, n (%)						
BMI <25	212/852 (24.9)	186/809 (23.0)	330/930 (35.5)	375/938 (40.0)	542/1782 (30.4)	561/1747 (32.1)
BMI 25 < 30	392/852 (46.0)	397/809 (49.0)	318/930 (34.2)	336/938 (35.8)	710/1782 (39.8)	733/1747 (42.0)
BMI≥30	248/852 (29.1)	226/809 (28.0)	282/930 (30.3)	227/938 (24.2)	530/1782 (29.7)	453/1747 (25.9)
Systolic blood pressure, mmHg, mean (SD)	131.9 (15.3)	132.4 (16.5)	126.8 (16.1)	127.0 (16.4)	129.3 (15.9)	129.5 (16.7)
LDL-cholesterol, mmol/l, mean (SD)	3.56 (1.01)	3.53 (1.00)	3.54 (0.94)	3.58 (0.95)	3.55 (0.98)	3.56 (0.97)
Hyperten-sion medication **, n (%)	257/825 (31.2)	265/779 (34.0)	264/897 (29.4)	270/908 (29.7)	521/1722 (30.3)	535/1687 (31.7)
Lipid lowering medication **, n (%)	117/825 (14.2)	118/779 (15.1)	74/897 (8.2)	81/908 (8.9)	191/1722 (11.1)	199/1687 (11.8)

*Basic to mid-level of education = compulsory 9 years of schooling or senior high school (≤12 years), high level of education = ≤13 years of schooling.
**Self-reported.

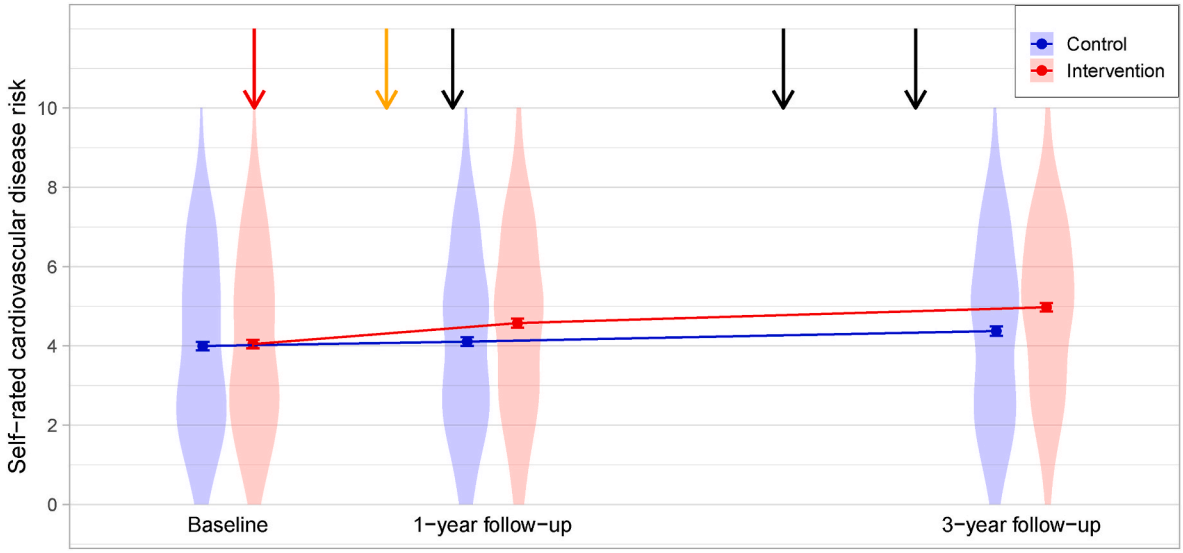

Fig. 3. Observed values of self-rated CVD risk and efficacy beliefs in the intervention and control group. The arrows indicate intervention components for the intervention group. The red arrow indicates a letter with pictorial presentation of atherosclerosis status and a motivational conversation. The orange arrow indicates repeated baseline letter. A black arrow indicates reminder about upcoming visit and general health promoting advice. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 2
Differences in self-rated CVD risk and health-specific self-efficacy between intervention and control groups in total, and stratified for sex and education, analyzed with a mixed model for repeated measures, in which assessment at baseline was used as covariate. A positive value means a higher rating in the intervention group compared to the control group.

	T1 difference (95%CI)	p	T3 difference (95%CI)	p
Self rated CVD risk (total)	**0.46 (0.32; 0.59)**	**<.001**	**0.57 (0.43; 0.70)**	**<.001**
Men	**0.32 (0.13; 0.51)**	**0.001**	**0.41 (0.22; 0.60)**	**<.001**
Women	**0.57 (0.38; 0.76)**	**<.001**	**0.70 (0.51; 0.88)**	**<.001**
High education	**0.50 (0.27; 0.72)**	**<.001**	**0.67 (0.44; 0.90)**	**<.001**
Basic and middle education	**0.40 (0.24; 0.57)**	**<.001**	**0.50 (0.33; 0.67)**	**<.001**
Health specific self efficacy (total)	−0.02 (−0.16; 0.13)	0.844	−0.03 (−0.17; 0.11)	0.635
Men	0.05 (−0.17; 0.26)	0.651	0.17 (−0.03; 0.37)	0.092
Women	−0.08 (−0.29; 0.12)	0.454	**−0.21 (-0.40; -0.02)**	**0.034**
High education	**−0.29 (-0.53; -0.05)**	**0.019**	**−0.34 (-0.58; -0.11)**	**0.004**
Basic and middle education	0.14 (−0.05; 0.32)	0.152	0.13 (−0.04; 0.30)	0.143

4. Discussion

4.1. Perceived CVD risk

To the best of our knowledge, this is the first longitudinal study on perceived CVD risk and efficacy beliefs following atherosclerosis screening, undertaken in a pragmatic population-based RCT. The finding of increased self-rated risk also after three years therefore represents an important result since underestimation of CVD risk is common (Katz et al., 2015; Stol et al., 2020) and can contribute to non-adherence to preventive guidelines (Leick et al., 2022; Thakkar et al., 2016). Furthermore, since ratings of risk increased with message severity, our results indicate that a color-coded and age-related communication strategy can have long-term implications for accurate risk perception. This is encouraging since CVDs have a long asymptomatic period, and self-rated health status, if good, constitutes a barrier for accurate risk perception and participation in prevention (Grauman et al., 2021; Leick et al., 2022). We expect that especially the BCTs *2.6. Biofeedback, 5.1. Information about health consequences* and *5.2. Salience of consequences* contributed to the finding of increased risk perception in the intervention group by clarifying atherosclerosis as the underlying disease process of CVD, in a personalized, memorable and clear-cut message. However, we also recognize the importance of the other BCTs operating in parallel to avoid defensive mechanisms. Since the 1-year follow up and 3-year follow demonstrated reduction of CVD risk factors in the intervention group (Bengtsson et al., 2021; Naslund et al., 2019), our results are in line with a review assessing the effect of visual interventions on illness beliefs and medication adherence in chronic conditions, which found that the most common BCTs identified for interventions with a sustained effect on adherence were *5.1 Information about health consequences, 5.2 Salience of consequences, 9.1 Credible source* and *2.6 Biofeedback* (Brown et al., 2021).

The effect size for self-rated CVD risk (total) at 3-year follow up corresponds to a Cohens d of 0.27, which can be considered a small effect. However, from an epidemiological perspective, a seemingly small effect size in prevention might be clinically important when it is a long-term effect, given that prevention is a long-term challenge. From the perspective of equality, an important finding is that not only individuals with high education, but also those with basic to mid-level of education, who also have more risk factors, had an increase in risk perception. Previous drop-out and sensitivity analyses (Bengtsson et al., 2021; Naslund et al., 2019) give us good reasons to trust findings on change over time in risk- and efficacy beliefs. In the present study, only two secondary outcomes were investigated; no other outcomes were analyzed which could have inflated the familywise error rate. We have chosen not to adjust for multiple outcomes, motivated by that we present secondary analyses from the original trial. However, should e.g. Bonferroni adjustment for two outcomes had been performed, findings

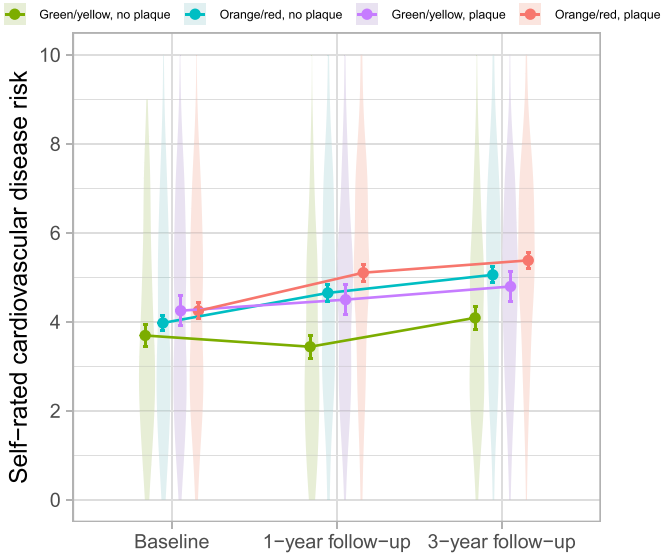

Fig. 4. Self-rated CVD risk in participants in the intervention group with different color-coded risk messages regarding atherosclerosis status. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

would still be significant.

4.2. Efficacy beliefs

When we in a previous study assessed cognitive and emotional reactions in the intervention group, we found that participants reported that the intervention to a large extent had contributed to increased understanding of personal CVD risk, the possibility to influence the risk, and how to influence the risk. Furthermore, these factors in combination were positively associated with sustained lifestyle modification (Andersson et al., 2023b). It is therefore somewhat surprising that whereas the intervention in the present study had an effect on risk perception, overall, no effect on efficacy beliefs was observed, except for in women after three years, and among individuals with high education, for whom efficacy beliefs were lower in the intervention group. One possible explanation is that participants embrace and remember the risk message to a greater extent than the efficacy-enhancing message. Even though the result letter includes written efficacy-strengthening information about the possibility to influence atherosclerosis, participants only have a single session of motivational conversation. Additional measures targeting efficacy beliefs could be beneficial.

The decrease in efficacy beliefs from T0 to T1 in both the intervention and control group might indicate that efficacy beliefs increased in the study population already when included in the VIP, before inclusion in the VIPVIZA trial. Another issue is the possibility that the question was interpreted in terms of whether one has external opportunities to take action, rather than in terms of self-efficacy. However, it is also possible that participants interpreted the question in terms of response efficacy in isolation, i.e. whether they believe that lifestyle changes would effectively have impact on their CVD risk. If so, participants who believe that they already have a healthy lifestyle may think that further lifestyle modification would not be possible, or would not affect their CVD risk. The decrease in efficacy beliefs over time, as seen in women after three years and participants with high education (of which 62% are women), may therefore reflect that lifestyle changes have been implemented. On the other hand, since individual engagement in health behaviors can be used to infer perceptions of risk, increase in health behavior may affect risk perception negatively. However, risk perception increased in the intervention group, and altogether, subgroup analyses showed that gender had an impact on risk perception as well as efficacy beliefs. This evokes the question as to what extent gender has an impact on coping with CVD risk.

Even though the initial level of efficacy beliefs overall was high, which may have affected room for further increase, it is interesting that there was a change in combinations of high and low risk perception and efficacy beliefs, such that the *responsive* group in the intervention group grew from 22.5% at T0 to 33.1% at T3, an increase of 47%. A higher proportion of responsive individuals in the intervention group at T3 corresponds well with the primary study at 3-year follow up showing a beneficial effect on cardiovascular risk; Framingham Risk Score was

Table 4
Rimal's four attitudinal groups based on the combined role of perceived CVD risk and efficacy beliefs. Distribution, in percentage, of participants in the intervention group (I) and control group (C) at the 3-year follow-up.

		Perceived risk	
		Low	High
Efficacy beliefs	Low	*Indifference* I: 11.3 C: 13.5	*Avoidance* I: 8.8 C: 6.8
	High	*Proactive* I: 46.8 C: 54.8	*Responsive* I: 33.1 C: 24.9

Table 3
Differences in self-rated CVD risk between groups in the intervention groups with different color-coded risk messages regarding IMT-value and plaque status analyzed with a mixed model for repeated measures, in which assessment at baseline was used as covariate. A positive value means a higher rating in the reference group.

	T1		T3	
	Difference between groups (95%CI)	p	Difference between groups (95%CI)	p
Self rated CVD risk (within IV-group)				
Orange/red plaque				
Green/yellow plaque	**0.54 (0.13; 1.05)**	**0.004**	**0.56 (0.11; 1.01)**	**0.007**
Orange/red no plaque	**0.32 (0.03; 0.62)**	**0.025**	0.17 (−0.12; 0.46)	0.533
Green/yellow no plaque	**1.35 (0.98; 1.73)**	**<.001**	**0.98 (0.62; 1.35)**	**<.001**
Green/yellow plaque				
Orange/red no plaque	−0.27 (−0.72; 0.19)	0.537	−0.39 (−0.83; 0.06)	0.123
Green/yellow no plaque	**0.76 (0.27; 1.29)**	**<.001**	0.42 (−0.07; 0.92)	0.136
Orange/red no plaque				
Green/yellow no plaque	**1.03 (0.67; 1.39)**	**<.001**	**0.81 (0.46; 1.17)**	**<.001**

13.38 for the intervention group and 14.08 for the control group (p = .047) and SCORE was 1.69 vs. 1.82 (p = .022) (Bengtsson et al., 2021). It is also worth noticing that we in the present study show that, at the 3 year follow up, the control group, on a group level, rated their risk lower, compared to the ratings of the intervention group, when in fact, the control group at this point had higher CVD risk.

4.3. Color-coded and age-related risk communication about atherosclerosis

In the intervention group, differences in perceived CVD risk were found between participants with different color-coded risk messages on atherosclerosis status, for which self-rated CVD risk increased with message severity. However, there was no statistically observed difference in self-rated CVD risk between, on the one hand, participants with orange or red IMT without plaque, and, on the other hand, participants with a green or yellow IMT who have plaque. Participants with orange/red IMT and no plaque rated their risk as *higher* compared to those with green/yellow IMT with plaque. This implicates that, not only communication of occurrence of plaque, which would comprise a more serious health threat, but also the color-coded and age-related communication of a thicker IMT affects self-rated CVD risk. This finding reflects that the concept of vascular age can work through the BCT *5.2 Salience of consequences* by linking individual risk factors to life years in a way that may be intuitively and personally engaging. This is also in line with previous research on age-based CVD risk communication strategies (Bonner et al., 2021) and a qualitative study among participants who managed to significantly decrease their CVD risk, which indicated that an interpretation of the IMT-result in terms of "older than I actually am" can sting (Andersson et al., 2023a). However, as shown by a quantitative study, overall, affective reactions to the result letter of negative valence, feeling worried/afraid or shocked to a high extent, were uncommon (Andersson et al., 2023b). Still, visual images are commonly perceived as effective means of communication, reflected in the idioms of "Seeing is believing" and "A picture is worth a thousand words" (Hollands et al., 2022). It is possible that communication of vascular age conceptualizes atherosclerosis as underlying process of CVD, and thereby raises awareness of the link between lifestyle and CVD. To avoid defensive reactions, and not least for ethical reasons, strengthening health-specific self-efficacy and response efficacy should be central when communicating CVD risk. Previous studies undertaken in the present study population have indicated that visualization of underlying subclinical atherosclerosis, rather than indirect information about risk factors for CVD, has the potential to evoke not only a *disease prevention focus*, characterized by avoiding losses and taking precautionary actions, but also a *health promotion focus,* concerned with aspirations to preserve good health (Andersson et al., 2023a).

4.4. Strengths and limitations

The strengths of the study include the longitudinal perspective, the population-based sample with asymptomatic atherosclerosis, the pragmatic RCT design, performed in real-world health care, and the sample size. A limitation is the unvalidated single-item question on subjective CVD risk formulated specifically for this intervention, although similar assessments are described in the literature (Maffei et al., 2022). Regardless of formats of such questions, there is a tendency to underestimate CVD risk (Grauman et al., 2021).

4.5. Clinical implications and future research

Specific and context-bound scales (e.g. self-efficacy regarding physical activity) can be utmost relevant for interventions aiming at strengthening efficacy beliefs to accomplish behavioral change. But for CVD, several *different* health behaviors are of relevance, and distributing several specific scales targeting different behaviors may not be feasible in a clinical setting. However, simple questions such as those we present here can be given to patients recurrently, and have the potential to give important information to clinicians, not least, if related to objective measures of CVD risk. Future research may assess self-rated risk and efficacy beliefs in relation to accuracy of perceived risk, optimistic bias and lifestyle modification.

4.6. Conclusions

Communicating asymptomatic atherosclerosis with a personalized, pictorial, color-coded and age-based strategy, that also includes a motivational conversation, had an effect on self-rated CVD risk, whereas, overall, no effect on efficacy beliefs was observed, except for women after three years and among participants with high education. Regarding combinations of high and low risk- and efficacy beliefs, there was a shift towards more participants being defined as *responsive,* meaning that they are aware of their risk status, believe that they can influence the risk of CVD, and are expected to actively seek health information. For effective prevention, it is essential that interventions use appropriate behavioral change techniques that target modifiable psychological factors of relevance for behavior change such as risk perception and efficacy beliefs.

CRediT authorship contribution statement

Elin M. Andersson: Formal analysis, Writing - original draft. **Per Liv:** Formal analysis, Writing - review & editing. **Steven Nordin:** Supervision, Writing - review & editing. **Ulf Näslund:** Conceptualization, Writing - review & editing. **Kristina Lindvall:** Supervision, Writing - review & editing.

Declaration of competing interest

The authors declare no conflicts of interest or competing interests. The funders of the study had no role in the study design, data collection, data interpretation or writing the report.

Informed consent regarding participation and publication has been obtained from participants. The study was performed in line with the principles of the Declaration of Helsinki and approved by the Umeå Regional Ethics Board (2011-455-31 M and 2012-463-32 M).

Trial registration: ClinicalTrials.gov identifier: NCT01849575, registration May 8, 2013.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2023.116530.

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