Original Article

Participation in the German Mammography Screening Program

An Analysis of Data From the NAKO Health Study

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Summary

Background: European guidelines recommend a minimum participation rate of 70% for mammography screening programs (MSP), but the rate in Germany has so far been only 50% per round. In this study, we identify factors associated with non-participation in MSP.

Methods: Cross-sectional data on women aged 50 to 69 from the population-based NAKO Health Study (2014–2019) were used to identify factors associated with MSP participation, and dimensions of participatory behavior were derived by principal component analysis (PCA).

Results: Of 48 057 women aged 50 to 69, 14.6% had never participated in MSP, 35.3% had participated once, and 50.2% had participated multiple times. Age-adjusted regression analyses of individual factors revealed that the use of other primary and secondary prevention measures was the strongest predictor of MSP participation. Smoking was associated with lower probability of participation (odds ratio [OR]: 0.70; 95% confidence interval: [0.67; 0.75]), and overweight with higher ones (OR: 1.26 [1.19; 1.34]). PCA enabled the aggregation of factors into three dimensions: "use of preventive measures," "socioeconomic status," and "lifestyle factors."

Conclusion: In this study, marked differences were found between MSP non-participants and participants, especially with respect to their use of other preventive measures and their socioeconomic status. One limitation of this study was the self-reporting of MSP participation. Its findings nevertheless provide a basis for interventions directed at specific target groups, for example, education about preventive services (and MSP in particular) in the primary care setting.

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Since 2009, women in Germany aged between 50 and 69 have been invited every 2 years, through an organized invitation procedure, to participate in a population-based, quality-assured mammography screening program (MSP) and have been supported in their decision-making by information leaflets (1, 2). The aim of this screening program is to reduce breast cancer mortality by bringing forward the time of diagnosis to more prognostically favorable tumor stages (3). European guidelines recommend that the minimum participation rate among invited women should be 70% for the screening program to be cost-effective (4, 5). Despite 13 years of full MSP implementation, this target has still not been met, with participation rates of around 50% per screening round in Germany (1).

National and international observational studies have shown associations between MSP participation and demographic, socioeconomic, educational, and behavioral factors (6–22). For the German MSP, Pokora et al. (20) found that socioeconomic inequalities in equivalence income and educational status are associated with MSP participation. Schnoor et al. (21) found that medical reasons and personal attitudes may lead to MSP non-participation, while Heinig et al. (22) demonstrated an association between MSP participation and the use of other screening examinations.

In July 2024, the upper age limit for the German MSP was raised to 75 years, resulting in an increase in the number of eligible women from 12 to 14.5 million (23). As in other European countries, Germany is also evaluating whether the screening could be extended to younger age groups. In this context, a better understanding of MSP participation

Table 1

Sociodemographic characteristics and specific factors (use of medical [preventive] measures, cancer [family] history, lifestyle factors) of the study cohort, stratified by MSP participation status

Characteristics (row %)	No MSP participation n = 6999 (astd)	One-time MSP participation n = 16 939	Multiple MSP participation n = 24 119	Total n = 48 057
Study centers	**6999 (14.6)**	**16 939 (35.2)**	**24 119 (50.2)**	**48 057**
North (Hannover, Hamburg, Bremen, Kiel)	1438 (15.1)	2972 (31.1)	5144 (53.8)	9554
East (north, central, and south Berlin, as well as Halle, Leipzig, Neubrandenburg, Neustrelitz, Waren [Müritz], Demmin)	1993 (11.6)	6573 (38.3)	8617 (50.1)	17 183
West (Essen, Münster, Düsseldorf)	987 (14.5)	2220 (32.6)	3612 (53.0)	6819
South (Augsburg, Regensburg, Mannheim, Freiburg, Saarbrücken)	2581 (17.8)	5174 (35.7)	6746 (46.5)	14 501
Partnership	**6982 (14.6)**	**16 914 (35.3)**	**24 086 (50.2)**	**47 982**
Yes	4824 (13.0)	13 159 (35.6)	19 024 (51.4)	37 007
No	2158 (19.7)	3755 (34.2)	5062 (46.1)	10 975
Level of education*[1]	**6397 (14.4)**	**15 579 (35.1)**	**22 395 (50.5)**	**44 371**
Low	242 (16.3)	642 (43.1)	606 (40.7)	1490
Medium	2818 (13.0)	7861 (36.3)	10 999 (50.7)	21 678
High	3336 (15.7)	7076 (33.4)	10 790 (50.9)	21 202
Employment status	**6923 (14.5)**	**16 840 (35.3)**	**23 946 (50.2)**	**47 709**
Employed	4568 (14.6)	11 216 (35.8)	15 560 (49.6)	31 344
Unemployed	219 (19.4)	435 (38.5)	475 (42.1)	1129
Non-working person	2136 (14.0)	5189 (34.1)	7911 (51.9)	15 236
Relative income position	**6384 (14.4)**	**15 634 (35.3)**	**22 311 (50.3)**	**44 329**
< 60 % (at risk of poverty)	989 (17.7)	2183 (39.1)	2415 (43.2)	5587
60 % to < 100 %	1939 (14.0)	5137 (37.1)	6773 (48.9)	13 849
≥ 100 %	3455 (13.9)	8314 (33.4)	13 123 (52.7)	24 892
Health insurance status	**6120 (14.4)**	**15 010 (35.2)**	**21 497 (50.4)**	**42 627**
Statutory health insurance	5179 (13.7)	13 578 (35.9)	19 102 (50.5)	37 859
Private health insurance	941 (19.7)	1432 (30.0)	2395 (50.2)	4768
Use of outpatient medical services	**5942 (14.8)**	**13 860 (34.4)**	**20 450 (50.8)**	**40 252**
In the last year	5102 (13.7)	12 776 (34.4)	19 269 (51.9)	37 147
More than 1 year ago	840 (27.1)	1084 (34.9)	1181 (38.0)	3105
Clinical breast examination	**6981 (14.6)**	**16 911 (35.3)**	**24 084 (50.2)**	**47 976**
No use	2283 (53.0)	1105 (25.6)	921 (21.4)	4309
One-time use	2429 (16.6)	10 219 (69.9)	1972 (13.5)	14 620
Multiple use	2269 (7.8)	5587 (19.2)	21 191 (73.0)	29 047
Flu vaccination	**6996 (14.6)**	**16 921 (35.2)**	**24 101 (50.2)**	**48 018**
Never	4819 (19.7)	8751 (35.8)	10 878 (44.5)	24 448
Once so far	929 (13.1)	1332 (28.3)	2445 (52.0)	4706
Occasionally	695 (10.2)	2278 (33.5)	3831 (56.3)	6804
Regularly	552 (4.6)	4560 (37.8)	6947 (57.6)	12 059
Family history (mother) of breast cancer	**6013 (14.7)**	**14 115 (34.5)**	**20 820 (50.8)**	**40 948**
No, no family history	5608 (15.0)	13 102 (35.1)	18 578 (49.8)	37 288
Yes, positive family history	405 (11.1)	1013 (27.7)	2242 (61.3)	3660
Contraceptive pill	**6978 (14.6)**	**16 905 (35.3)**	**24 057 (50.2)**	**47 940**
Never	1012 (19.0)	1900 (35.6)	2425 (45.4)	5337
Ever	5966 (14.0)	15 005 (35.2)	21 632 (50.8)	42 603

Hormone replacement therapy	**6009 (13.6)**	**15 299 (34.6)**	**22 896 (51.8)**	**44 204**
Never	4880 (14.9)	11 490 (35.0)	16 465 (50.1)	32 835
Ever	1129 (9.9)	3809 (33.5)	6431 (56.6)	11 369
Smoking status	**6991 (14.6)**	**16 917 (35.2)**	**24 102 (50.2)**	**48 010**
Never	3041 (13.3)	7969 (34.8)	11 922 (52.0)	22 932
Former	2369 (14.1)	5759 (34.2)	8731 (51.8)	16 859
Current	1581 (19.2)	3189 (38.8)	3449 (42.0)	8219
Risky alcohol consumption*2	**6991 (14.6)**	**16 930 (35.3)**	**24 112 (50.2)**	**48 033**
No	4866 (14.6)	11 849 (35.6)	16 600 (49.8)	33 315
Yes	2125 (14.4)	5081 (34.5)	7512 (51.0)	14 718
Body mass index	**6993 (14.6)**	**16 932 (35.3)**	**24 097 (50.2)**	**48 022**
< 18.5 (Underweight)	124 (26.8)	162 (35.1)	176 (38.1)	462
18.5 bis < 25 (Normal weight)	3218 (16.4)	6650 (33.9)	9732 (49.7)	19 600
≥ 25 (Overweight/obesity)	3651 (13.1)	10 120 (36.2)	14 189 (50.7)	27 960
Physical activity (≥ 150 min/week)*3	**6999 (14.6)**	**16 939 (35.3)**	**24 119 (50.2)**	**48 057**
No	732 (15.8)	1668 (35.9)	2244 (48.3)	4644
Yes	6267 (14.4)	15 271 (35.2)	21 875 (50.4)	43 413
Social network index	**5941 (14.7)**	**13 880 (34.5)**	**20 460 (50.8)**	**40 280**
Level I (isolated)	1169 (21.8)	1886 (35.1)	2318 (43.1)	5373
Level II–IV	4772 (13.7)	11 994 (34.4)	18 142 (52.0)	34 908

Note I: Due to age standardization among non-participants, there are minimal deviations in the total numbers as a result of rounding.
Note II: In individual categories, response options were grouped together. All response options, as well as additional factors, are presented in *Table S2* in *Chapter 2* of the *eSupplement*..
Note III: This table (= *eSupplement – Chapter 2: Table S2*) is presented without age standardization in *Chapter 3* of the *eSupplement*. There, column percentages (*eSupplement – Chapter 3*: *Table S2*) are reported in addition to row percentages (*eSupplement – Chapter 3*: *Table S1*).
Age standardization (astd) was applied to the data on women who had never participated in the mammography screening program (MSP) by transferring the age structure of the participants (at least one-time MSP participation) per year of age to non-participants and adjusting the frequencies accordingly (for more information, see *eSupplement – Chapter 1* , *Section S1*).
*1 According to ISCED-97 level: International Standard Classification of Education 97
*2 Alcohol Use Disorders Identification Test (Audit-C score): women > 3
*3 According to the World Health Organization recommendation

behavior in Germany is crucial to identify reasons associated with non-use of MSP. To date, no comprehensive investigation of the individual factors described here has been conducted using a broad primary dataset for the German MSP. Based on data from the NAKO Health Study (NAKO *Gesundheitsstudie*), factors described in the international context were investigated for their effects on MSP participation in Germany—in addition to those factors proposed by other German studies—and potentially modifiable components were identified.

Methods

Study population

Between March 2014 and September 2019, 204 733 individuals aged 20–69 years were recruited using random draws from compulsory residents' registries, with an average response rate of 18.0% (24–27). The baseline examination conducted at 18 study centers included an interview and assessments using standardized questionnaires, as well as medical examinations and the collection of biomaterials. A total of 48 057 women of eligible age were included in the main analyses *(eSupplement – Chapter 2: Figure S1)*.

Characteristics assessed

MSP participation was assessed based on information regarding X-ray examination of the breast ("mammography", "breast cancer screening") and the response options "never", "once", and "multiple times". More details on all variables used are presented in *Table S1* in *Chapter 2* of the *eSupplement*.

Statistical analysis

Relative and absolute frequencies (age-standardized for MSP non-participants [*eSupplement – Chapter 1 : Section S1*]) were calculated for discrete variables, while means were calculated for continuous variables. Logistic regression, adjusted for age (per year), was used to evaluate the association between MSP participation at least once and demographic, socioeconomic, educational, and behavioral variables. For the 16 identified variables whose confidence intervals did not include 1, a polychoric principal component analysis (PCA) was conducted to identify meaningful dimensions of MSP participation behavior. To determine the number of principal components, testing procedures for the extraction of different PCA models were applied, from which a three-component solution

Table 2

Odds ratios for individual factors influencing participation in the Mammography Screening Program (ever versus never) after age adjustment

Variable (reference)	Response categories	OR [95% CI]
Level of education (low)	Medium	1.29 [1.10; 1.49]
	High	1.04 [0.89; 1.20]
Relative income position[*1] (< 60 %)	60 ≤ x < 80	1.29 [1.17; 1.43]
	80 ≤ x <100	1.25 [1.13; 1.38]
	100 ≤ x < 150	1.41 [1.30; 1.54]
	≥ 150	1.28 [1.17; 1.39]
Insurance status (SHI)	PHI	0.65 [0.60; 0.71]
Partnership (no partner)	Separated	1.13 [1.03; 1.24]
	Living together	1.68 [1.58; 1.78]
SNI[*2] (level I, isolated)	Level II	1.42 [1.31; 1.53]
	Level III	1.95 [1.80; 2.12]
	Level IV	2.27 [1.88; 2.75]
Smoking status (never)	Former	0.97 [0.92; 1.03]
	Current	0.70 [0.66; 0.75]
Alcohol consumption[*3] (no risky consumption)	Risky consumption	1.02 [0.97; 1.08]
BMI (normal weight, 18.5–24.9)	Underweight (< 18.5)	0.53 [0.43; 0.66]
	Overweight and obesity (≥ 25)	1.28 [1.22; 1.35]
Physical activity[*4] (< 150 min)	≥ 150 Min	1.06 [0.97; 1.15]
Screening examinations (never)	FOBT	2.44 [2.32; 2.57]
	Colonoscopy	2.78 [2.59; 2.97]
	Skin cancer screening	2.05 [1.95; 2.16]
	Clinical breast examination	9.56 [8.89; 10.27]
	Cervical smear	3.70 [3.49; 3.93])
Flu vaccination (never)	Once so far	1.58 [1.44; 1.74]
	Occasionally	2.02 [1.86; 2.20]
	Regularly	2.77 [2.57; 3.00]
Use of (never)	Contraceptive pill	1.40 [1.30; 1.51]
	Hormone replacement therapy	1.54 [1.43; 1.65]
Family history of breast cancer (negative)	Positive	1.52 [1.37; 1.70]

[*1] Income is defined as a relative income position (based on the net equivalized income of the European Union Statistics on Living Conditions [EU-SILC]), with individuals below 60% at risk of poverty.
[*2] The Social Network Index (SNI) is differentiated into four levels, with level-I indicating social isolation.
[*3] Risky alcohol consumption among women was defined as reporting an Audit-C score > 3.
[*4] In line with World Health Organization recommendations, adequate physical activity was defined as at least 150 min/week.
CI, confidence interval; OR, odds ratio; BMI, body mass index; FOBT, fecal occult blood test; SHI, statutory health insurance; PHI, private health insurance; SNI, Social Network Index

was selected based on content. Standardized values of the principal components were then included as independent variables in the multivariable regression model. In addition to principal components, age and family history of breast cancer were included, depending on the model, as factors that were not included in the PCA or could not be assigned to a component.

Detailed information on the statistical methods can be found in *Section S2* of *Chapter 1* in the *eSupplement*.

All analyses were conducted in R 4.4.0 using the following packages: readr (version 2.1.5), tidyverse (version 2.0.0), dplyr (version 1.1.4), flextable (version 0.9.6), nFactors (version 2.4.1.1), EFAtools (version 0.4.4), gt (version 0.10.1), scales (version 1.3.0), gtsummary (version 2.0.2), psych (version 2.4.3), ggplot2 (version 3.5.1), and ggforestplot (version 0.1.0).

Sensitivity analyses

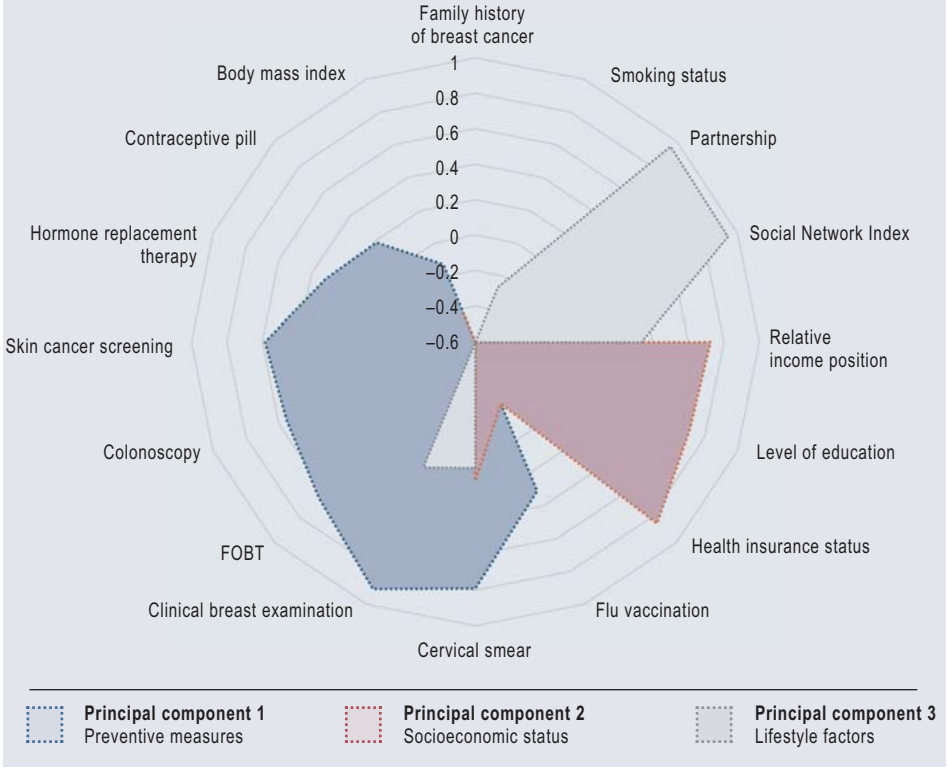
The PCA and multivariable regression analyses were repeated without the factor "clinical breast examination," since this screening measure is performed at a different medical center but serves the same purpose as the MSP.

Furthermore, sensitivity analyses were conducted with varying study populations. More information on this can be found in *Section S1* of *Chapter 4* in the *eSupplement*.

Results

Of a total of 48 057 women included in the study, 14.6% had never participated in the MSP, 35.2% had participated once, and 50.2% had participated multiple times *(Table 1, eSupplement – Chapter 2: Figure S2)*. In the age-standardized frequency analyses, women living in southern Germany were most likely to report non-participation in the MSP (17.8%). Women without a partner (19.7%) more often reported never having participated in the MSP compared with women in a partnership (13.0%). Women with a medium level of education were less likely than other women to report non-use of the MSP (13.0%). Among women with a relative income position of less than 60% of the median income and who are at risk of poverty, the proportion of non-participants in the MSP is highest (17.7%) compared with women in higher income groups. Women with private health insurance more frequently reported never having participated in the MSP (19.7%) than did women with statutory health insurance (13.7%). Of the women who reported breast cancer in their mother, 11.1% stated that they had never participated in the MSP, 27.7% once, and 61.3% multiple times. Overall, women who also used other preventive services, such as flu vaccinations and other screening examinations, were more likely to report having participated in the MSP at least once. The same applied to women who had taken the contraceptive pill and/or hormone replacement therapy at least once. Current smokers were more likely never to have participated in the MSP (19.2%) compared with non- and ex-smokers. Among women with overweight or obesity, multiple participation was more common (50.7%) than among women with underweight and normal weight (38.1% and 49.7%, respectively). Furthermore, it was observed that women who had participated multiple times in the MSP also had larger social networks *(Table 1)*.

Figure 1



Radar chart of the principal component analysis loadings
The factor loadings, which vary between −1 and 1 and can be assigned to multiple principal components, are shown.
Principal component 1 is most strongly influenced by the clinical breast examination (0.91), followed by the cervical smear (0.79), and the FOBT (0.65), and least influenced by the contraceptive pill (0.19). Body mass index is the only factor negatively correlated (−0.14) with principal component 1.
Principal component 2 is most strongly correlated with health insurance status (0.91), income (0.73), and level of education (0.70). In comparison, flu vaccination (−0.22) and clinical breast examination (0.19) correlate only slightly with principal component 2.
The factors social network (0.96) and income (0.94) are most strongly correlated with principal component 3. Other factors that correlate with principal component 3 include partnership (−0.27), level of education (0.33), cervical smear (0.11), and clinical breast examination (0.16).
Family history of breast cancer was the only factor that could not be assigned to any of the three principal components.
FOBT, fecal occult blood test

The factors identified in the age-adjusted regression analyses (confidence intervals not including 1) *(Table 2)* were combined in the PCA into three principal components—"use of preventive measures" (RC1), "socioeconomic status" (RC2), and "lifestyle factors" (RC3)—which together explained 43.0% of the variance *(eSupplement – Chapter 2: Table S3)*. The variable "family history of breast cancer" was the only one of altogether 16 variables that could not be assigned to any of the three extracted principal components *(Figure 1)*.

In the multivariable regression analyses, an odds ratio (OR) of 1.42 (95% confidence interval [1.39; 1.44]) was calculated for RC1, an OR of 0.81 [0.79; 0.83] for RC2, and an OR of 1.14 [1.11; 1.17] per standard deviation of the standardized principal component *(Figure 2, Model 1)*. After adjusting for age and family history of breast cancer, these three principal components showed virtually unchanged estimates and confidence intervals, with family history of breast cancer (OR: 1.35 [1.13; 1.62]) and higher age at the time of the survey (OR: 1.02 [per life year] [1.01; 1.03]) each being positively associated with MSP participation *(Figure 2, Model 4)*.

Sensitivity analyses

Analyses without "clinical breast examination" yielded results comparable to those of the main analyses. All dimensions showed overall comparable loadings and variances *(eSupplement – Chapter 2: Figure S3* and *Table S4)*.

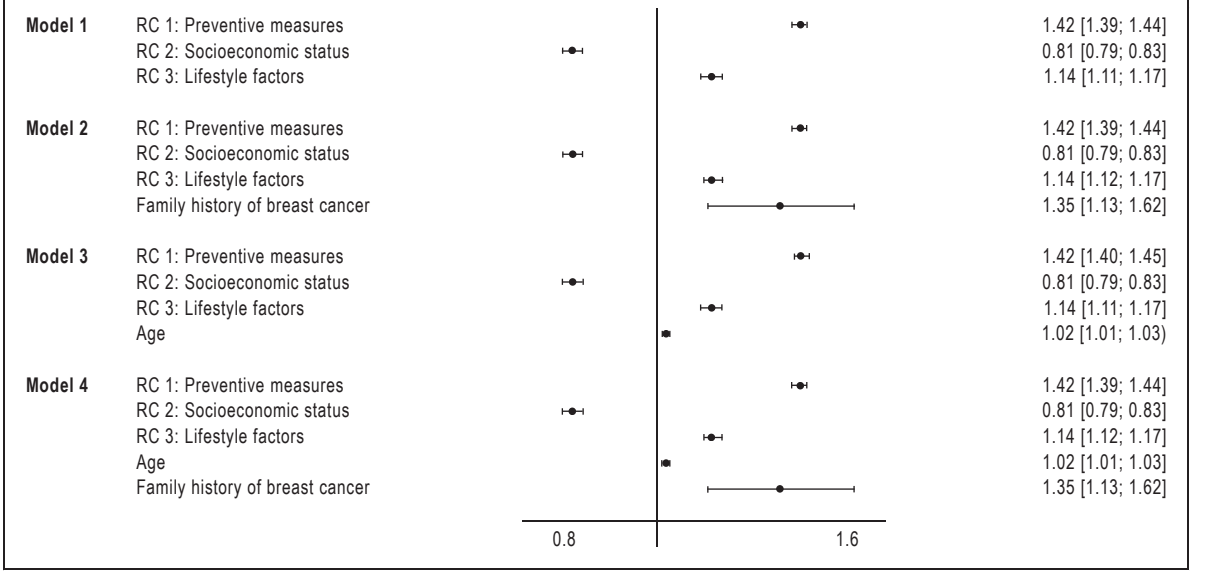
Analyses based on varying study populations also yielded virtually identical results *(eSupplement – Chapter 4: Figures S1.1* and *S2.1,* and *Tables S1.1–S1.3, S2.1–S2.3)*.

Discussion

Using primary data from the NAKO Health Study, factors influencing MSP participation behavior in Germany were investigated. In the study population, 85.5% of women reported having participated in the MSP at least once. This cumulative use, recorded by self-reporting and relating retrospectively to several years (that is, over multiple screening rounds), is by nature higher than the likelihood of participating in a single screening round. Assuming that all women aged 50 and older had had the opportunity to participate in the MSP up to their age at the baseline examination—which was the case according to the NAKO baseline examination conducted 5 years after full implementation of the MSP—and that the probability of participation per screening round was 50% (1), this cumulative MSP participation rate is plausible *(eSupplement – Chapter 1 : Section S3)* and, taking into account the age structure of the respective cohorts, comparable with previous studies (9, 20). Our study confirmed the findings published by the German Mammography Cooperation Group (*Kooperationsgemeinschaft Mammografie*) (1) regarding regional differences in the use of the German MSP (28).

Using PCA, the individual factors could be aggregated into "use of preventive measures" (RC1), "socioeconomic status" (RC2), and "lifestyle factors" (RC3), thereby demonstrating their association with MSP participation. As comparative studies are lacking, the individual factors aggregated in the principal components are considered below and compared with the existing evidence.

Figure 2



Models of the multivariable regression analyses
Across the models, it can be seen that principal components 1 and 3 are positively and principal component 2 negatively associated with participation in the Mammography Screening Program (MSP), with the respective odds ratios and their corresponding confidence intervals remaining virtually unchanged, even after including age and family history of breast cancer. While increasing age is associated with only a minimally higher likelihood of MSP participation, the likelihood is higher in the case of a family history of breast cancer. RC, rotated components (principal components)

In our study, analyses of the use of other preventive measures offered by the health care system showed consistent results, as participation in other screening programs or uptake of flu vaccines was always associated with higher MSP participation. This confirms the findings of Heinig et al. (22), suggesting, overall, more health-conscious behavior among MSP participants.

Analyses of the individual lifestyle factors yielded heterogeneous results. For example, smoking was associated with lower MSP participation, as also shown in international studies by Loewen et al. (14) and Aro et al. (15). In contrast, overweight and obesity were associated with a higher participation rate. Lower MSP uptake was observed among underweight women, possibly indicating serious illnesses that, in turn, prevent MSP participation.

Unlike our study, previous studies have shown that adequate physical activity and the absence of alcohol abuse were associated with having participated in the MSP at least once (16, 11); however, in these studies, the response categories for these factors were defined somewhat differently and therefore had different research objectives (e.g., risky alcohol consumption versus dependence) *(Tables 1–2, eSupplement – Chapter 2: Tables S1–2; eSupplement – Chapter 3: Tables S1–S2)*.

When considering the sociodemographic and socioeconomic factors individually, the data from the NAKO Health Study—as in international studies (11, 15, 17, 18, 20) and the first German study (20)—showed that women with a lower educational level and lower income participated less frequently in the MSP than women in higher educational and income categories. In agreement with the results of Aro et al. (15), we demonstrated a slightly U-shaped association, whereby women of medium educational level and medium income were most likely to participate in the MSP. The modest decline among women of high educational level may be attributable to a higher proportion of privately insured women, since our study—as well as a cross-sectional study in Schleswig-Holstein (21)—showed that women with private health insurance were less likely to participate in the MSP. This could be due to the fact that, although privately insured women are legally entitled to participate in the mammography screening program (2), they often receive mammograms outside the MSP or use alternative examination methods such as magnetic resonance imaging (MRI) and ultrasound as part of their gynecological care—methods that, according to the S3 guideline (29, 30), are recommended only for women at high risk or as possible supplementary, but not sole, methods of breast cancer screening (29, 30). By the same token, non-participation in the MSP may be due to the effect of costs on the patient's deductible or premium refund, depending on the insurance plan (31). Furthermore, it was observed that women who were married, did not live alone, and had a social network were more likely to participate in the MSP—a finding compatible with international study results (10–13). The remaining results of this study, such as those regarding the use of hormone replacement therapy, are also in agreement with international studies (9).

Although numerous factors were analyzed as part of our broad study concept, the three principal components explain only 43.0% of the total variance. Thus, the larger proportion of 57.0% remains unexplained, for which there could be various explanations. On the one hand, women

are advised to inform themselves using the information material provided and to decide for or against MSP participation. It is conceivable that unassessed or difficult-to-assess factors also play a role in informed decision-making against uptake of the MSP. Furthermore, other individual factors that were not investigated in this study may also be possible explanations, such as refusal to undergo X-ray examinations. On the other hand, there are factors such as a positive family history of breast cancer that were considered but could not be included in the principal components. However, for this individual factor, the multivariable regression analysis also showed an OR of 1.35 ([1.13; 1.62]) *(Figure 2)*. International studies conducted by Tracy et al. (32) and Murabito et al. (33), which investigated, among other factors, the impact of a positive first-degree family history compared with a negative family history of breast cancer, showed stronger associations (OR: 3.2 [1.4; 7.7]; OR: 2.13 [1.35; 3.37]). It should be noted that the NAKO Health Study recorded only breast cancer diagnoses in mothers, meaning that the true prevalence of a family history of breast cancer is likely to be underestimated in the present data. Another factor contributing to the observed results is that, in Germany, women with a positive family history of breast cancer are more likely to undergo opportunistic screening (16, 22); in cases of a positive family history with a confirmed genetic predisposition, other screening measures outside the MSP are also used (30), and women may be under the care of centers for familial breast and ovarian cancer.

Based on the results obtained here, initial approaches for possible interventions and target groups can be identified. Although the MSP has an organized invitation procedure, it was found that women who use other screening programs are also more likely to participate in the MSP. This means that medical personnel, such as general practitioners whom women consult for other reasons, could be more actively involved in providing information about the various screening options available, thereby helping to ensure that women can make an informed decision for or against screening examinations—and thus also for or against participation in the MSP. Women with private health insurance could also represent a target group for which specific approaches can be derived, since here too, the MSP participation rate was low.

One of the limitations of this study is the representativeness of the study population. Although the underlying primary data from the largest population-based cohort study in Germany were collected at 18 locations in urban and rural areas (27), they tend to more closely reflect an urban population. Moreover, given that health-conscious individuals are more likely to participate in the NAKO Health Study, the uptake of screening examinations is higher here than the national average (34, 35).

In addition to the limitations in collecting family history of breast cancer, there are also constraints in defining MSP participation status, since not only was no supplementary explanatory information provided, but the date of the respective examination was also not requested to verify age-based eligibility. Thus, it is possible that diagnostic mammograms were also included, although only MSP participation was intended to be collected. One indication of the presence of this type of misclassification is the reporting of multiple instances of participation among women aged 50 or 51 *(eSupplement – Chapter 4: Figure S2.1* and *Tables S2.1–S2.3)*; however, excluding these women in the sensitivity analysis did not alter the results. Misclassifications in the remaining information cannot be ruled out if, for example, older women additionally reported mammograms performed prior to MSP participation.

Summary

Using primary data from the NAKO Health Study, relevant factors for MSP participation were identified and aggregated into principal components. These principal components offer initial starting points for the development of targeted interventions to support the decision-making process among eligible women.

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Declarations
All participants were fully informed and provided their written informed consent to participate in the study. The study was conducted in compliance with national law and the 1975 Declaration of Helsinki (in its current revised form) and was approved by the ethics committees responsible for the study centers.

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Conflict of interest statement
AS served as a member of the advisory board of the Mammography Screening Cooperation Group (*Beirat der Kooperationsgemeinschaft Mammografiescreening*) until March 2025.

The remaining authors declare that no conflict of interest exists.

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Supplementary material
Complete list of full references, eSupplement
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Supplementary material to accompany the article

Participation in the German Mammography Screening Program

An Analysis of Data From the NAKO Health Study

by Laura Buschmann, Nadine Bonberg, [...]* and André Karch

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Supplement (consisting of four individual chapters) to the publication:

Participation in the mammography screening programme – an analysis based on data from the German National Cohort

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Overview of the supplement

The present supplement is comprised of a compilation of four individual chapters. Each of these chapters contains various presentations in the form of supplementary information texts, illustrations and/or tables, which are briefly listed below for overview purposes. A more thorough exposition of the respective contents can be found in the preliminary sections of the individual chapters:

Chapter 1: Additional information on the methodological approach

Section S1 of this chapter provides detailed information on age standardisation. In addition to a brief explanation of why this is necessary, the implementation is explained in detail.
Section S2 contains more detailed information on the analyses presented in the main text.
Section S3 provides a more detailed discussion on the cumulative MSP participation rate. Despite the probability of MSP participation per screening round among the women invited being only approximately 50%, women have the capacity to participate a total of ten times over a period of 20 years, or 13 times over a period of 25 years. Consequently, the cumulative rate of at least one MSP participation over the longitudinal course is considerably higher. Although MSP participation in this case was only documented at a specific point in time, the information provided is based on self-reporting and therefore covers a longer period of time, extending from eligibility for MSP participation to the collection of self-reported data in the German National Cohort. The manuscript presents a comparison of the calculated cumulative MSP participation with the expected cumulative MSP participation for the study cohort. This is undertaken in order to underline the plausibility of the calculated results.

Section S1: Detailed information on age standardisation

As part of the frequency analyses, age standardisation was carried out in order to avoid distortions resulting from differences in age structure and to enable better comparison of the results of the individual subgroups of the study population.

To this end, the age structure of the MSP participants was transferred to the non-participants, so that the frequencies of the individual characteristics among the non-participants in the manuscript are fully age-standardised in accordance with the age structure of the MSP participants. The frequencies that have not undergone age standardisation can be located in Chapter 3, Table S1 and Table S2.

Given the variability in the total number and, consequently, the number of MSP participants and non-participants across the individual factors examined in the frequency tables, the total number was determined for each factor. The age distribution of the MSP participants was then calculated and transferred to the non-participants. The following procedure was employed in each instance:

1. Creation of a subset containing only women who selected one of the response options for the factor under investigation shown in Tables 1 and 2.
2. Creation of a cross-tabulation table with age (in years) and MSP participation behaviour (never/ever) for the women included in the subset in order to calculate the relative frequency of MSP participation (ever) for each age group.
3. Determination of the expected frequency of non-participation in MSP for the individual age groups by multiplying the total number of non-participants in MSP by the respective relative frequency for the age group
4. Creation of a further subset containing only women who are non-participants in MSP. Based on this data, a cross-tabulation table was then created with age (in years) and the factor to be examined. Using this table, the number of responses for each age group was divided by the total number of women in that age group and then multiplied by the expected frequency for the corresponding age group.

Section S2: Detailed information on statistical analysis

The subsequent section provides a more detailed exposition of the statistical analyses employed in the manuscript, namely principal component analysis and subsequent multivariate regression analyses.

Principal component analysis (PCA) with Varimax rotation was performed on the basis of a previously created polychoric correlation matrix.

The Kaiser-Gutmann criterion was utilised to ascertain the number of principal components, whilst the MAP/BIC test and parallel analysis were also conducted. A content-based 3-dimensional solution was selected following a review of all resulting PCA models.

The polychoric PCA loadings were then extracted to calculate standardised values. The variables utilised in this study were first scaled and then centred, with the objective of facilitating the utilisation of the standardised values of the principal components as independent variables in the multivariate regression analyses.

Section S3: Detailed information on the cumulative participation quoata

A woman can participate in the MSP a maximum of ten times between the eligible ages of 50 and 69, with an average probability of participating in the MSP per round of 50%:

Round	Number of paths	Probability stratified by frequency of participation
1	2	N-P: 1×0.5 = 0.5 P_1: 1×0.5 = 0.5 P_m: NA
2	4	N-P: $1 \times 0.5^2 = 0.25$ P_1: $2 \times 0.5^2 = 0.5$ P_m: $1 \times 0.5^2 = 0.25$
3	8	N-P: $1 \times 0.5^3 = 0.125$ P_1: $3 \times 0.5^3 = 0.375$ P_m: $4 \times 0.5^3 = 0.5$
4	16	N-P: $1 \times 0.5^4 = 0.0625$ P_1: $4 \times 0.5^4 = 0.25$ P_m: $11 \times 0.5^4 = 0.6875$
5	32	N-P: $1 \times 0.5^5 = 0.03125$ P_1: $5 \times 0.5^5 = 0.15625$ P_m: $26 \times 0.5^5 = 0.8125$
6	64	N-P: $1 \times 0.5^6 = 0.015625$ P_1: $6 \times 0.5^6 = 0.09375$ P_m: $57 \times 0.5^6 = 0.890625$
7	128	N-P: $1 \times 0.5^7 = 0.0078125$ P_1: $7 \times 0.5^7 = 0.0546875$ P_m: $120 \times 0.5^7 = 0.9375$
8	256	N-P: $1 \times 0.5^8 = 0.00390625$ P_1: $8 \times 0.5^8 = 0.03125$ P_m: $247 \times 0.5^8 = 0.9648375$
9	512	N-P: $1 \times 0.5^9 = 0.001953125$ P_1: $9 \times 0.5^9 = 0.017578125$ P_m: $502 \times 0.5^9 = 0.98046875$
10	1024	N-P: $1 \times 0.5^{10} = 0.0009765625$ P_1: $10 \times 0.5^{10} = 0.009765625$ P_m: $1013 \times 0.5^{10} = 0.9892578125$

MSP: Mammography screening programme
N-P: Non-Participants (no participation in MSP)
P_1: Participants with one-time participation in the MSP
P_m: Participants with multiple participation in the MSP

A calculation can be made of the number of women expected in each MSP round according to their participation status. In order to undertake this analysis, the number of women in the study population is first determined in 2-year age groups. This is then multiplied by the probabilities calculated above:

Age range	Number of women	Probability of participation status in the respective MSP round	Expected distribution of women by participation status
50-51 (1. round)	5,977	N-P: 1×0.5 = 0.5 P_1: 1×0.5 = 0.5 P_m: NA	N-P=2,988.5 P_1=2,988.5 P_m= -
52-53 (2. round)	5,573	N-P: $1 \times 0.5^2 = 0.25$ P_1: $2 \times 0.5^2 = 0.5$ P_m: $1 \times 0.5^2 = 0.25$	N-P=1,393.25 P_1=2,786.5 P_m= 1,393.25

54-55 (3. round)	5,206	N-P: $1 \times 0.5^3 = 0.125$ P_1: $3 \times 0.5^3 = 0.375$ P_m: $4 \times 0.5^3 = 0.5$	N-P=650.75 P_1=1,952.25 P_m=2,603
56-57 (4. round)	4,729	N-P: $1 \times 0.5^4 = 0.0625$ P_1: $4 \times 0.5^4 = 0.25$ P_m: $11 \times 0.5^4 = 0.6875$	N-P=295.5625 P_1=1,182.25 P_m=3,251.1875
58-59 (5. round)	4,357	N-P: $1 \times 0.5^5 = 0.03125$ P_1: $5 \times 0.5^5 = 0.15625$ P_m: $26 \times 0.5^5 = 0.8125$	N-P=136.15625 P_1=680.78125 P_m=3,540.0625
60-61 (6. round)	4,453	N-P: $1 \times 0.5^6 = 0.015625$ P_1: $6 \times 0.5^6 = 0.09375$ P_m: $57 \times 0.5^6 = 0.890625$	N-P=69.578125 P_1=417.46875 P_m=3,965.953125
62-63 (7. round)	4,987	N-P: $1 \times 0.5^7 = 0.0078125$ P_1: $7 \times 0.5^7 = 0.0546875$ P_m: $120 \times 0.5^7 = 0.9375$	N-P=38.9609375 P_1=272.7265625 P_m=4,675.3125
64-65 (8. round)	4,949	N-P: $1 \times 0.5^8 = 0.00390625$ P_1: $8 \times 0.5^8 = 0.03125$ P_m: $247 \times 0.5^8 = 0.9648375$	N-P=19.33203125 P_1=154.65625 P_m=4,774.9807875
66-67 (9. round)	4,475	N-P: $1 \times 0.5^9 = 0.001953125$ P_1: $9 \times 0.5^9 = 0.017578125$ P_m: $502 \times 0.5^9 = 0.98046875$	N-P=8.740234375 P_1=78.662109375 P_m=4,387.59765625
68-69 (10. round)	3,351	N-P: $1 \times 0.5^{10} = 0.0009765625$ P_1: $10 \times 0.5^{10} = 0.009765625$ P_m: $1{,}013 \times 0.5^{10} = 0.9892578125$	N-P=3.2724609375 P_1=32.724609375 P_m=3,315.0029296875

MSP: Mammography screening programme
N-P: Non-Participants (no participation in MSP)
P_1: Participants with one-time participation in the MSP
P_m: Participants with multiple participation in the MSP

By adding the expected numbers for each participation status in the individual rounds, the following distribution would be expected in the study population:

- MSP-Non-Participants: 5,604.1025390625= 5,604
- MSP-Participants with one-time participation: 10,546.51953125=10,547
- MSP-Participants with multiple participation: 31,906.346998437=31,906

A comparison of the expected and actual distribution of participation status in the study population yields the following results:

MSP participation status	**Expected frequency N (%)**	**Observed frequency* N (%)**
No MSP participation	5,604 (11.7)	6,999 (14.6)
One-time participation in MSP	10,547 (21.9)	16,939 (35.2)
Multiple participation in MSP	31,906 (66.4)	24,119 (50.2)

MSP: Mammography screening programme

* Without age standardisation.

Chapter 2: Supplementary information and results based on the study population defined in the manuscript, taking into account age standardisation

Figure S1 presents a flow chart illustrating the creation of the study population (n=48,057) for the main analyses.

Table S1 provides an overview of the variables with response categories stratified according to the respective analyses.

Figure S2 shows the MSP participation frequency – differentiated into no participation, one-time participation and multiple participation – of women (n=48,057) stratified by age.

Table 1 in the main text shows the frequencies for specific factors, some of which have been grouped together into response categories. Table S2 shows all response categories and all factors examined, taking into account age standardisation with rank percentages, in order to supplement the results presented in the main text.

Table S3 shows the information on the loadings and variance of the principal component analysis.

Finally, the sensitivity analysis based on this study cohort is presented, in which, however, the factor ‘breast examination’ was not taken into account in the repetition of the main analyses (PCA and multivariable regression analyses). The results are presented in Figure S3 and Table S4.

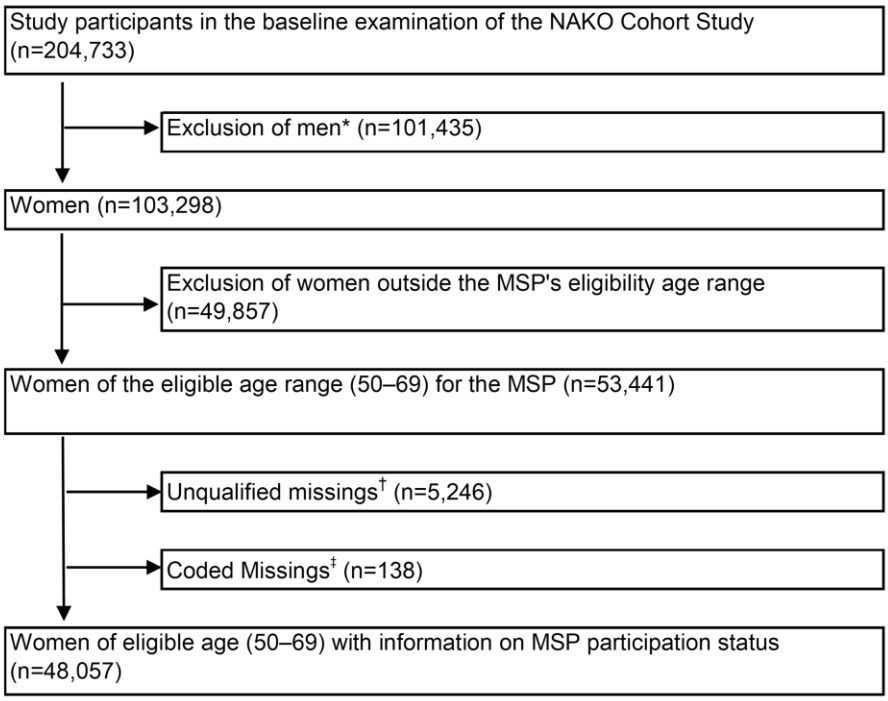

Figure S1: Flow chart showing the women included in the main analyses

MSP: Mammography screening programme

* In addition to the gender recorded at the registration office, the survey only distinguishes between ‘male’ and “female”, with the interviewer usually providing the answer without directly asking the participant. The option to select ‘diverse’ is only available from the third survey onwards, the data from which was not used here.
† An unqualified missing entry is when no answer has been given and therefore information is missing.
‡ Coded missing responses are defined response options (e.g. don't know, no answer) that were selected by the respondent as their answer.

Note: In sensitivity analyses, the study population was varied (see Chapter 4).

Table S1: Overview of variables with response categories stratified according to the respective analyses

Variable (response options – coded values* and coded missing values†)	**Frequency analyses**	**Stratified analyses**	**Logistic regression analyses with age adjustment**	**Principal component analysis**	**Multivariable regression analyses**
Study centres (Name of the 18 study centres)	Locations of the 18 study centres by federal state or grouped together in North, South, West and East	-	-	-	
Age (in years, 50-69)	Mean (standard deviation)	Age (in years)	Age (in years)	-	Age (in years)
Marital status (Single; married living together; married living apart; divorced; widowed; missing value)	Single Married (living together und living apart, sum up) Divorced Widowed	Single Married (living together und living apart, sum up) Divorced Widowed	-	-	
Partnership (Living with partner; living apart from partner; without partner; missing value)	Without partner Living together with a partner Living apart from partner	Without partner Living together with a partner Living apart from partner	Without partner Living together with a partner Living apart from partner	Without partner Living together with a partner Living apart from partner	In RC 3
Household size (Single-person household; household with 2 persons; household with 3 persons; household with 4 persons; household with at least 5 persons; missing or implausible value)	Single-person household Household with 2 persons Household with 3 persons Household with 4 persons Household with at least 5 persons	Single-person household Household with 2 persons Household with 3 persons Household with 4 persons Household with at least 5 persons	-	-	
Level of education (ISCED-97-Level) (Low; average; high; study participants who are still in vocational training; study participants who are currently still pupils at a full-time general education school and do not have a vocational qualification, missing value)	Low Average High	Low Average High	Low Average High	Low Average High	In RC2
Employment status (Unemployed; employed; non-working person; missing value)	Employed Unemployed Non-working person	Employed Unemployed Non-working person	-	-	
Relative income position	<60% (at risk of poverty)	<60% (at risk of poverty)	<60% (at risk of poverty)	<60% (at risk of poverty)	In RC2

Variable (response options – coded values* and coded missing values†)	Frequency analyses	Stratified analyses	Logistic regression analyses with age adjustment	Principal component analysis	Multivariable regression analyses
(<60% (at risk of poverty); 60% to less than 80%; 80% to less than 100%; 100% to less than 150%; 150% and above; missing value)	60% to less than 80% 80% to less than 100% 100% to less than 150% 150% and above	60% to less than 80% 80% to less than 100% 100% to less than 150% 150% and above	60% to less than 80% 80% to less than 100% 100% to less than 150% 150% and above	60% to less than 80% 80% to less than 100% 100% to less than 150% 150% and above	
Health insurance status (Yes, I am a member of a statutory health insurance; yes, I am a member of a private health insurance, yes, I have other insurance (e.g. free medical care); no, I am not insured; I don't know; no information) Note: Combination of self-reported information and prediction model	Statutory health insurance Private health insurance	Statutory health insurance Private health insurance	Statutory health insurance Private health insurance	Statutory health insurance Private health insurance	In RC2
Use of medical services (within the last 4 weeks, within the last 2 to 3 months, within the last 4 to 12 months, more than a year ago; no information; don't know)	Last year More than a year	Last year More than a year			
Use of stationary services in the last year (Within the last 12 months; more than a year ago; no information; don't know)	Last year More than a year	Last year More than a year			
MSP (X-ray examination of the breast ('mammography' (early detection of breast cancer)) (No participation; single participation; multiple participation; no information; don't know)	No participation Single participation Multiple participation	No participation At least one participation	No participation At least one participation	No participation At least one participation	No participation At least one participation
Colonoscopy (Colonoscopy (early detection of colon cancer)) (No participation; single participation; multiple participation; no information; don't know)	No participation Single participation Multiple participation	No participation At least one participation	No participation At least one participation	No participation At least one participation	In RC1
FOBT (Testing stool for blood (early detection of colon cancer))	No participation Single participation Multiple participation	No participation At least one participation	No participation At least one participation	No participation At least one participation	In RC1

Variable (response options – coded values* and coded missing values†)	Frequency analyses	Stratified analyses	Logistic regression analyses with age adjustment	Principal component analysis	Multivariable regression analyses
(No participation; single participation; multiple participation; no information; don't know)					
Skin cancer screening (examination of the skin for moles (early detection of skin cancer)) (No participation; single participation; multiple participation; no information; don't know)	No participation Single participation Multiple participation	No participation At least one participation	No participation At least one participation	No participation At least one participation	In RC1
Breast examination by medical personnel (early detection of breast cancer) (No participation; single participation; multiple participation; no information; don't know)	No participation Single participation Multiple participation	No participation At least one participation	No participation At least one participation	No participation At least one participation	In RC1
Cervical smear (No participation; single participation; multiple participation; no information; don't know)	No participation Single participation Multiple participation	No participation At least one participation	No participation At least one participation	No participation At least one participation	In RC1
Flu vaccination (Not at all; once so far; occasionally (in some years); regularly; don't know; no answer)	Not at all once so far Occasionally Regularly	Not at all once so far Occasionally Regularly	Not at all once so far Occasionally Regularly	Not at all once so far Occasionally Regularly	In RC1
Family history of cancer (biological mother) (No, yes, but age unknown, yes, younger than 40 years old, yes, between 40 and 59 years old, yes, 60 years old and older, don't know, no information, unplausible information)	No family history Positive family history	Positive family history No family history			
Family history of breast cancer (among women with a positive family history of cancer) (No; yes, but age unknown; yes, younger than 40 years old; yes, between 40 and 59 years old; yes, between 60 and 74 years old; yes,	No family history Positive family history	No family history Positive family history			

Variable (response options – coded values* and coded missing values†)	Frequency analyses	Stratified analyses	Logistic regression analyses with age adjustment	Principal component analysis	Multivariable regression analyses
75 years old and older; yes, 60 years old and older; don't know; no answer)					
Familienanamnese Brustkrebs (unter allen Frauen) (Newly calculated: no family history; positive family history)	No family history Positive family history	No family history Positive family history	No family history Positive family history	No family history Positive family history (was the only factor not assigned to a main component)	No family history Positive family history (As a single factor in addition to the main components (alone and together with the single factor age))
1. Cancer diagnosis (List of various types of cancer; skipped as permitted; calculation not possible due to missing data; no information; don't know)	No breast cancer At least one diagnosis of breast cancer	No breast cancer At least one diagnosis of breast cancer	(Sensitivity analysis: separate consideration of the sub-cohort without these women)	(Sensitivity analysis: separate consideration of the sub-cohort without these women)	(Sensitivity analysis: separate consideration of the sub-cohort without these women)
2. Cancer diagnosis (List of various types of cancer; skipped as permitted; calculation not possible due to missing data; no information; don't know)					
3. Cancer diagnosis (List of various types of cancer; skipped as permitted; calculation not possible due to missing data; no information; don't know)					
Last cancer diagnosis (List of various types of cancer; skipped as permitted; calculation not possible due to missing data; no information; don't know)					
Taking the contraceptive pill (Never; ever; don't know; no information)	Never Ever	Never Ever	Never Ever	Never Ever	In RC1
Taking hormone replacement therapy (Never; ever; don't know; no information)	Never Ever	Never Ever	Never Ever	Never Ever	In RC1
Smoking status (No smoker, not even formerly; former smoker; smoker;	Never Former At present	Never Former At present	Never Former At present	Never Former At present	In RC3

Variable (response options – coded values* and coded missing values†)	Frequency analyses	Stratified analyses	Logistic regression analyses with age adjustment	Principal component analysis	Multivariable regression analyses
smoking status unknown; unqualified missings; coded missings)					
Risky alcohol consumption according to Audit-C score (women >3) (No; yes; cannot be determined (allowed to be skipped or missing or implausible values))	No Yes	No Yes	No Yes		
Body mass index (entered values)	< 18,5 (underweight) 18,5 bis < 25 (normal weight) 25 and above (overweight/obesity) bzw. 25 bis < 30 (overweight) >= 30 (obesity)	< 18,5 (underweight) 18,5 bis < 25 (normal weight) 25 and above (overweight/obesity) bzw. 25 bis < 30 (overweight) >= 30 (obesity)	< 18,5 (Untergewicht) 18,5 bis < 25 (Normalgewicht) 25 and above (overweight/obesity)	< 18,5 (underweight) 18,5 bis < 25 (normal weight) 25 and above (overweight/obesity)	In RC3
Physical activity: At least 150 minutes per week, in accordance with World Health Organisation recommendations (No; yes)	No Yes	No Yes	No Yes		
Social Network Index (Level I (isolated); Level II; Level III; Level IV; calculation not possible due to missing data)	Level I (isolated) Level II Level III Level IV	Level I (isolated) Level II Level III Level IV	Level I (isolated) Level II Level III Level IV	Level I (isolated) Level II Level III Level IV	In RC3
RC of the principal component analysis					RC1: Preventive measures RC2: Socioeconomic status) RC3: Lifestyle factors

AUDIT-C Score: Alcohol Use Disorders Identification Test: women > 3
FOBT: Fecal Occult Blood Test
ISCED-97-Level: International Standard Classification of Education 97

MSP: Mammography screening programme
RC: Rotated Components (principal components)

* An unqualified missing entry is when no answer has been given and therefore information is missing.
† Coded missing responses are defined response options (e.g. don't know, no answer) that were selected by the participant as their answer.

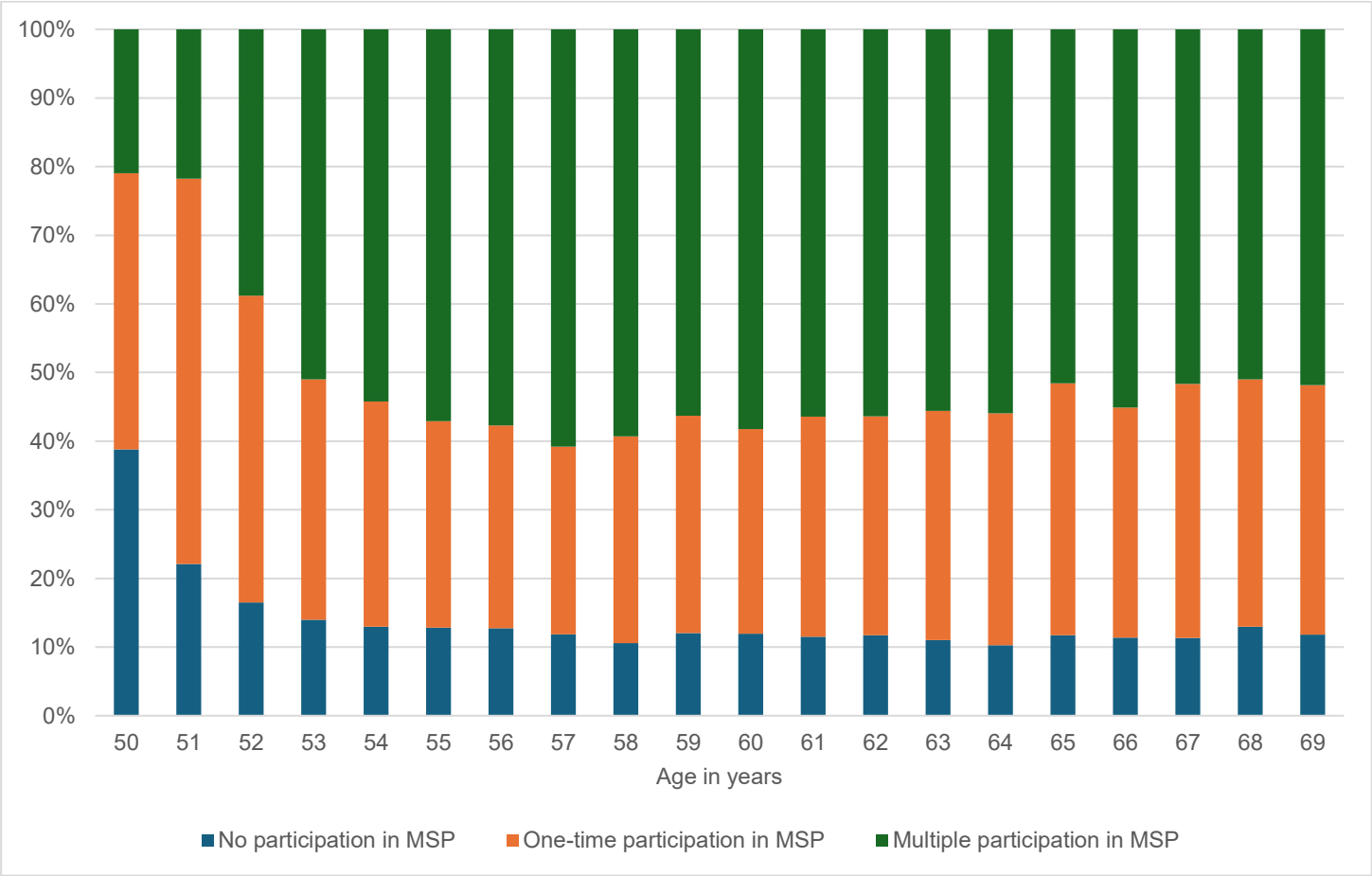

Figure S2: Participation status of women (n=48,057) by age

Additional information: The respective mean value (standard deviation) (in years) for the individual participant groups and overall are as follows:

- No participation in MSP: 57.2 (6.1)
- One-time participation in MSP: 58.5 (6.0)
- Multiple participation in MSP: 59.6 (5.3)
- In total: 58,8 (5,8)

MSP: Mammography screening programme

Table S2: Characteristics and specific factors (use of medical (preventive) measures, cancer (family) history, lifestyle factors) of the study cohort stratified according to participation status in the MSP

Properties n (row-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Study centres	**7,000 (14.6)**	**16,939 (35.2)**	**24,119 (50.2)**	**48,058**
Bavaria (Augsburg, Regensburg)	1,280 (17.8)	2,562 (35.7)	3,342 (46.5)	7,184
Baden-Württemberg (Mannheim, Freiburg)	871 (18.5)	1,647 (34.9)	2,197 (46.6)	4,715
Saarland (Saarbrücken)	430 (16.5)	965 (37.1)	1,207 (46.4)	2,602
North Rhine-Westphalia (Essen, Münster, Düsseldorf)	987 (14.5)	2,220 (32.6)	3,612 (53.0)	6,819
Lower Saxony (Hannover)	330 (14.1)	780 (33.3)	1,229 (52.5)	2,339
Hamburg (Hamburg)	322 (13.0)	776 (31.4)	1,376 (55.6)	2,474
Bremen (Bremen)	475 (19.6)	737 (30.4)	1,209 (49.9)	2,421
Schleswig-Holstein (Kiel)	312 (13.4)	679 (29.3)	1,330 (57.3)	2,321
Saxony-Anhalt (Halle)	299 (12.2)	944 (38.5)	1,207 (49.3)	2,450
Saxony (Leipzig)	230 (8.6)	996 (37.2)	1,448 (54.2)	2,674
Berlin (Berlin North, Central, South)	1,095 (15.1)	2,650 (36.4)	3,529 (48.5)	7,274
Mecklenburg-Vorpommern (Neubrandenburg, Neustrelitz, Waren (Müritz), Demmin)	369 (7.7)	1,983 (41.4)	2,433 (50.8)	4,785
Marital status	**6,995 (14.6)**	**16,931 (35.2)**	**24,111 (50.2)**	**48,040**
Single	1,086 (21.3)	1,701 (33.4)	2,303 (45.2)	5,090
Married (living together and separately)	3,948 (12.5)	11,190 (35.4)	16,457 (52.1)	31,595
Divorced	1,484 (18.7)	2,840 (35.7)	3,630 (45.6)	7,954
Widowed	478 (14.1)	1,203 (35.4)	1,721 (50.6)	3,402
Partnership	**6,982 (14.6)**	**16,914 (35.3)**	**24,086 (50.2)**	**47,982**
Living together	4,139 (12.5)	11,790 (35.5)	17,259 (52.0)	33,188
Living apart	685 (17.9)	1,369 (35.8)	1,765 (46.2)	3,819
Without partner	2,158 (19.7)	3,755 (34.2)	5,062 (46.1)	10,975
Household size	**6,993 (14.6)**	**16,935 (35.3)**	**24,106 (50.2)**	**48,034**
Single-person household	2,192 (19.1)	3,873 (33.7)	5,424 (47.2)	11,489
Household with 2 people	3,564 (12.6)	9,734 (34.5)	14,941 (52.9)	28,239
Household with 3 people	785 (14.6)	2,067 (38.4)	2,533 (47.0)	5,385
Household with 4 people	331 (14.9)	958 (43.0)	939 (42.1)	2,228
Household with at least 5 persons	120 (17.4)	303 (43.8)	269 (38.9)	692
Level of education*	**6,397 (14.4)**	**15,579 (35.1)**	**22,395 (50.5)**	**44,371**
Low	242 (16.3)	642 (43.1)	606 (40.7)	1,490
Average	2,818 (13.0)	7,861 (36.3)	10,999 (50.7)	21,678
High	3,336 (15.7)	7,076 (33.4)	10,790 (50.9)	21,202
Employment status	**6,923 (14.5)**	**16,840 (35.3)**	**23,946 (50.2)**	**47,709**

Properties n (row-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Employed	4,568 (14.6)	11,216 (35.8)	15,560 (49.6)	31,344
Unemployed	219 (19.4)	435 (38.5)	475 (42.1)	1,129
Non-working person	2,136 (14.0)	5,189 (34.1)	7,911 (51.9)	15,236
Relative income position	**6,384 (14.4)**	**15,634 (35.3)**	**22,311 (50.3)**	**44,329**
Under 60% (at risk of poverty)	989 (17.7)	2,183 (39.1)	2,415 (43.2)	5,587
60% to less than 80%	1,011 (13.7)	2,802 (38.1)	3,548 (48.2)	7,361
80% to less than 100%	928 (14.3)	2,335 (36.0)	3,225 (49.7)	6,488
100% to less than 150%	1,821 (13.2)	4,738 (34.3)	7,251 (52.5)	13,810
150% and above	1,634 (14.7)	3,576 (32.3)	5,872 (53.0)	11,082
Health insurance status	**6,120 (14.4)**	**15,010 (35.2)**	**21,497 (50.4)**	**42,627**
Statutory health insurance	5,179 (13.7)	13,578 (35.9)	19,102 (50.5)	37,859
Private health insurance	941 (19.7)	1,432 (30.0)	2,395 (50.2)	4,768
Use of medical services				
Outpatient	**5,942 (14.8)**	**13,860 (34.4)**	**20,450 (50.8)**	**40,252**
Last year	5,102 (13.7)	12,776 (34.4)	19,269 (51.9)	37,147
More than a year ago	840 (27.1)	1,084 (34.9)	1,181 (38.0)	3,105
Stationary last year	**5,905 (17.8)**	**13,749 (34.4)**	**20,309 (50.8)**	**39,963**
Yes	694 (13.5)	1,803 (35.0)	2,659 (51.6)	5,156
No	5,211 (15.0)	11,946 (34.3)	17,650 (50.7)	34,807
Use of preventive measures				
Colonoscopy	**4,406 (12.2)**	**11,980 (33.1)**	**19,794 (54.7)**	**36,180**
No use	3,021 (17.6)	5,365 (31.3)	8,753 (51.1)	17,139
Single use	1,240 (7.5)	6,153 (37.4)	9,077 (55.1)	16,470
Multiple use	145 (5.6)	462 (18.0)	1,964 (76.4)	2,571
FOBT	**6,858 (14.6)**	**16,558 (35.2)**	**23,564 (50.2)**	**46,980**
No use	4,028 (20.9)	7,292 (37.9)	7,919 (41.2)	19,239
Single use	1,975 (11.6)	7,536 (44.2)	7,529 (44.2)	17,040
Multiple use	855 (8.0)	1,730 (16.2)	8,116 (75.8)	10,701
Skin cancer screening	**6,967 (14.6)**	**16,830 (35.2)**	**23,968 (50.2)**	**47,765**
No use	3,629 (21.2)	6,516 (38.1)	6,944 (40.6)	17,089
Single use	2,384 (12.5)	8,195 (43.1)	8,445 (44.4)	19,024
Multiple use	954 (8.2)	2,119 (18.2)	8,579 (73.6)	11,652
Breast examination by medical personnel	**6,981 (14.6)**	**16,911 (35.3)**	**24,084 (50.2)**	**47,976**
No use	2,283 (53.0)	1,105 (25.6)	921 (21.4)	4,309
Single use	2,429 (16.6)	10,.219 (69.9)	1,972 (13.5)	14,620
Multiple use	2,269 (7.8)	5,587 (19.2)	21,191 (73.0)	29,047
Cervical smear	**6,897 (14.7)**	**16,485 (352)**	**23,417 (50.0)**	**46,799**
No use	2,861 (30.8)	3,338 (35.9)	3,092 (33.3)	9,291
Single use	2,018 (15.3)	8,624 (65.3)	2,570 (19.5)	13,212

Properties n (row-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Multiple use	2,018 (8.3)	4,523 (18.6)	17,755 (73.1)	24,296
Flu vaccination	**6,996 (14.6)**	**16,921 (35.2)**	**24,101 (50.2)**	**48,018**
Not at all	4,819 (19.7)	8,751 (35.8)	10,878 (44.5)	24,448
Once so far	929 (13.1)	1,332 (28.3)	2,445 (52.0)	4,706
Occasionally	695 (10.7)	2,278 (33.5)	3,831 (56.3)	6,804
Regularly	552 (7.2)	4,560 (37.8)	6,947 (57.6)	12,059
Family history of cancer	**6,022 (14.7)**	**14.154 (34,5)**	**20.842 (50,8)**	**41,018**
No, no family history	4,489 (15.3)	10.378 (35,4)	14.424 (49,2)	29,291
Yes, positive family history	1,533 (13.1)	3.776 (32,2)	6.418 (54,7)	11,727
Family history (mother) of breast cancer (among all women)	**6,013 (14.7)**	**14.115 (34,5)**	**20.820 (50,8)**	**40,948**
No, no family history	5,608 (15.0)	13,102 (35.1)	18,578 (49.8)	37,288
Yes, positive family history	405 (11.1)	1,013 (27.7)	2,242 (61.3)	3,660
Personal history of breast cancer	**6,970 (14.6)**	**16,873 (35.2)**	**24,045 (50.2)**	**47,888**
No	6,843 (15.0)	16,330 (35.8)	22,412 (49.2)	45,585
Yes	127 (5.5)	543 (23.6)	1,633 (70.9)	2,303
Contraceptive pill	**6,978 (14.6)**	**16,905 (35.3)**	**24,057 (50.2)**	**47,940**
Never	1,012 (19.0)	1,900 (35.6)	2,425 (45.4)	5,337
Ever	5,966 (14.0)	15,005 (35.2)	21,632 (50.8)	42,603
Hormone replacement therapy	**6,009 (13.6)**	**15,299 (34.6)**	**22,896 (51.8)**	**44,204**
Never	4,880 (14.9)	11,490 (35.0)	16,465 (50.1)	32,835
Ever	1,129 (9.9)	3,809 (33.5)	6,431 (56.6)	11,369
Smoking status	**6,991 (14.6)**	**16,917 (35.2)**	**24,102 (50.2)**	**48,010**
Never	3,041 (13.3)	7,969 (34.8)	11,922 (52.0)	22,932
Former	2,369 (14.1)	5,759 (34.2)	8,731 (51.8)	16,859
At present	1,581 (19.2)	3,189 (38.8)	3,449 (42.0)	8,219
Risky alcohol consumption†	**6,991 (14.6)**	**16,930 (35.3)**	**24,112 (50.2)**	**48,033**
No	4,866 (14.6)	11,849 (35.6)	16,600 (49.8)	33,315
Yes	2,125 (14.4)	5,081 (34.5)	7,512 (51.0)	14,718
Body mass index	**6,993 (14.6)**	**16,932 (35.3)**	**24,097 (50.2)**	**48,022**
Under 18,5 (Underweight)	124 (26.8)	162 (35,1)	176 (38.1)	462
18,5 to under 25 (Normal weight)	3,218 (16.4)	6,650 (33.9)	9,732 (49.7)	19,600
25 to under 30 (Overweight)	2,029 (13.3)	5,421 (35.5)	7,819 (51.2)	15,269
Over 30 (Obesity)	1,622 (12.8)	4,699 (37.0)	6,370 (50.2)	12,691
Physical activity (at least 150 min./week)‡	**6,999 (14.6)**	**16,939 (35.3)**	**24,119 (50.2)**	**48,057**
No	732 (15.8)	1,668 (35.9)	2,244 (48.3)	4,644
Yes	6,267 (14.4)	15,271 (35.2)	21,875 (50.4)	43,413
Social Network Index	**5,941 (14.7)**	**13,880 (34.5)**	**20,460 (50.8)**	**40,280**

Properties n (row-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Level I (isolated)	1,196 (21.8)	1,886 (35.1)	2,318 (43.1)	5,373
Level II	2,679 (16.0)	5,803 (34.6)	8,278 (49.4)	16,760
Level III	1,954 (11.6)	5,769 (34.3)	9,101 (54.1)	16,824
Level IV	139 (10.5)	422 (31.9)	763 (57.6)	1,324

Note I: Due to age standardisation among non-participants, there are minimal deviations in the total numbers as a result of rounding.
Note II: This table is presented without age standardisation, both analogously with row percentages and additionally with column percentages in Chapter 3.

Astd: Age standardisation – Age standardisation was applied to the data for women who had never participated in the MSP (to date) by transferring the age structure of participants (who had ever participated in the MSP) per age group to non-participants and adjusting the frequencies accordingly. Further information can be found in Chapter 1: Section S1.
FOBT: Fecal Occult Blood Test

* ISCED-97-Level: International Standard Classification of Education 97
† Alcohol Use Disorders Identification Test (Audit-C Score): Women > 3
‡ In accordance with the recommendation of the World Health Organisation

Table S3: Information on the loadings and variance of the PCA according to main components in the main analysis

	RC1	**RC3**	**RC2**
Loadings	2,777	2,063	2,033
Proportion Variance	0,174	0,129	0,127
Cumulative Variance	0,174	0,303	0,430

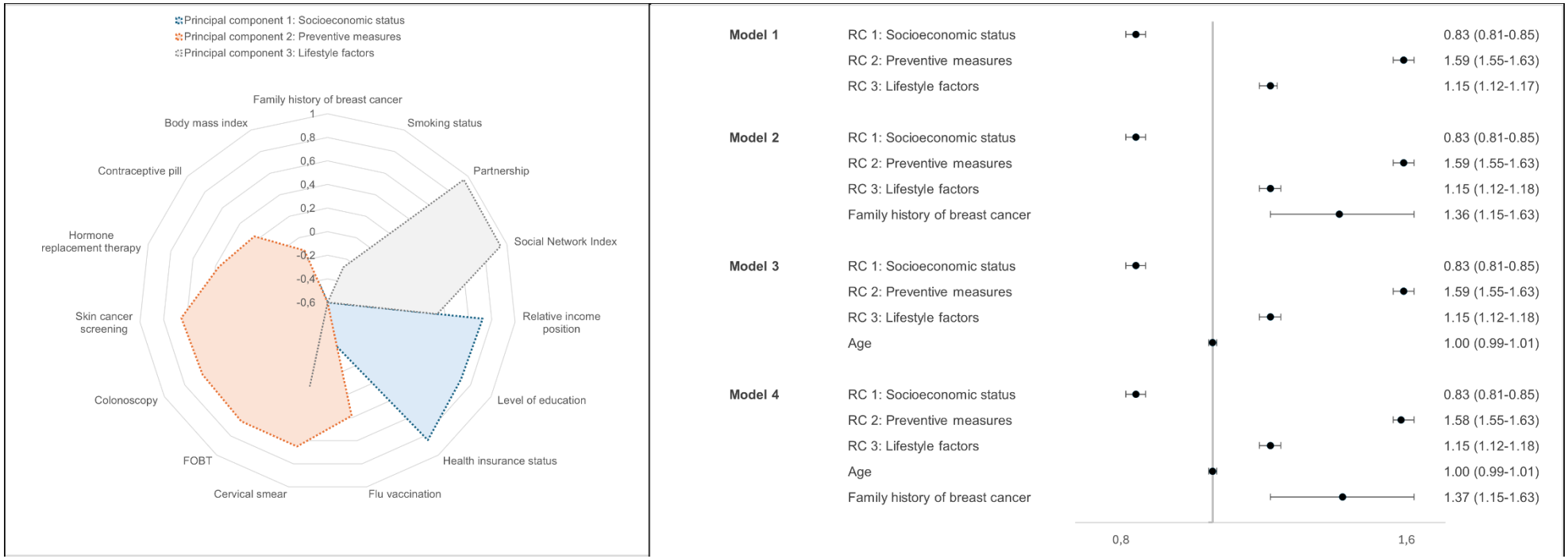

Figure S3: (A) Net diagram of the loads of the principal component analysis by factors and (B) models of the multivariate regression analyses in the sensitivity analysis without the factor 'breast examination by medical personnel' based on the study population of the main analysis

FOBT: Fecal Occult Blood Test
RC: Rotated Component

Table S4: Sensitivity analysis without the factor ‘Breast examination by medical personnel’ – Table with information on the loadings and variance of the PCA according to main components

	RC3: Lifestyle factors	**RC1: Socioeconomic status**	**RC2: Preventive measures**
Loadings	2.042	2.038	2.020
Proportion Variance	0.136	0.136	0.135
Cumulative Variance	0.136	0.272	0.407

Chapter 3: Descriptive results of Chapter 2 without consideration of age standardisation

This chapter presents the descriptive results of all factors without summarising response categories (as shown in Table S2 in Chapter 2) and without age standardisation. In addition to the row percentages (Table S1), the table also shows column percentages (Table S2).

Table S1: Socio-demographic characteristics and specific factors (use of medical (preventive) measures, cancer (family) history, lifestyle factors) of the study cohort stratified according to participation status in the MSP (without age standardisation, row percentages)

Properties n (row-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Study centres	**6,999 (14.6)**	**16,939 (35.3)**	**24,119 (50.2)**	**48,057**
Bavaria (Augsburg, Regensburg)	1,230 (17.2)	2,562 (35.9)	3,342 (46.9)	7,134
Baden-Württemberg (Mannheim, Freiburg)	837 (17.9)	1,647 (35.2)	2,197 (46.9)	4,681
Saarland (Saarbrücken)	420 (16.2)	965 (37.2)	1,207 (46.6)	2,592
North Rhine-Westphalia (Essen, Münster, Düsseldorf)	978 (14.4)	2,220 (32.6)	3,612 (53.0)	6,810
Lower Saxony (Hannover)	352 (14.9)	780 (33.0)	1,229 (52.0)	2,361
Hamburg (Hamburg)	328 (13.2)	776 (31.3)	1,376 (55.5)	2,480
Bremen (Bremen)	464 (19.3)	737 (30.6)	1,209 (50.2)	2,410
Schleswig-Holstein (Kiel)	297 (12.9)	679 (29.4)	1,330 (57.7)	2,306
Saxony-Anhalt (Halle)	331 (13.3)	944 (38.0)	1,207 (48.6)	2,482
Saxony (Leipzig)	232 (8.7)	996 (37.2)	1,448 (54.1)	2,676
Berlin (Berlin North, Central, South)	1,139 (15.6)	2,650 (36.2)	3,529 (48.2)	7,318
Mecklenburg-Vorpommern (Neubrandenburg, Neustrelitz, Waren (Müritz), Demmin)	391 (8.3)	1,983 (41.3)	2,433 (50.6)	4,807
Marital status	**6,995 (14.6)**	**16,931 (35.2)**	**24,111 (50.2)**	**48,040**
Single	1,185 (22.8)	1,701 (32.8)	2,303 (44.4)	5,189
Married (living together and separately)	3,989 (12.6)	11,190 (35.4)	16,457 (52.0)	31,636
Divorced	1,417 (18.0)	2,840 (36.0)	3,630 (46.0)	7,887
Widowed	404 (12.1)	1,203 (36.2)	1,721 (51.7)	3,328
Partnership	**6,982 (14.6)**	**16,914 (35.3)**	**24,086 (50.2)**	**47,982**
Living together	4,234 (12.7)	11,790 (35.4)	17,259 (51.9)	33,283
Living apart	731 (18.9)	1,369 (35.4)	1,765 (45.7)	3,865
Without partner	2,017 (18.6)	3,755 (34.7)	5,062 (46.7)	10,834
Household size	**6,993 (14.6)**	**16,935 (35.3)**	**24,106 (50.2)**	**48,034**
Single-person household	1,994 (17.7)	3,873 (34.3)	5,424 (48.0)	11,291
Household with 2 people	3,378 (12.0)	9,734 (34.7)	14,941 (53.3)	28,053
Household with 3 people	975 (17.5)	2,067 (37.1)	2,533 (45.4)	5,575
Household with 4 people	483 (20.3)	958 (40.3)	939 (39.5)	2,380
Household with at least 5 persons	163 (22.2)	303 (41.2)	269 (36.6)	735
Level of education*	**6,397 (14.4)**	**15,579 (35.1)**	**22,395 (50.5)**	**44,371**
Low	222 (15.1)	642 (43.7)	606 (41.2)	1,470
Average	2,812 (13.0)	7,861 (36.3)	10,999 (50.8)	21,672
High	3,363 (15.8)	7,076 (33.3)	10,790 (50.8)	21,229

Properties n (row-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Employment status	**6,923 (14.5)**	**16,840 (35.3)**	**23,946 (50.2)**	**47,709**
Employed	4,976 (15.7)	11,216 (35.3)	15,560 (49.0)	31,752
Unemployed	213 (19.0)	435 (38.7)	475 (42.3)	1,123
Non-working person	1,734 (11.7)	5,189 (35.0)	7,911 (53.3)	14,834
Relative income position	**6,384 (14.4)**	**15,634 (35.3)**	**22,311 (50.3)**	**44,329**
Under 60% (at risk of poverty)	949 (17.1)	2,183 (39.4)	2,415 (43.5)	5,547
60% to less than 80%	974 (13.3)	2,802 (38.3)	3,548 (48.4)	7,324
80% to less than 100%	939 (14.5)	2,335 (35.9)	3,225 (49.6)	6,499
100% to less than 150%	1,859 (13.4)	4,738 (34.2)	7,251 (52.4)	13,848
150% and above	1,663 (15.0)	3,576 (32.2)	5,872 (52.9)	11,111
Health insurance status	**6,120 (14.4)**	**15,010 (35.2)**	**21,497 (50.4)**	**42,627**
Statutory health insurance	5,240 (13.8)	13,578 (35.8)	19,102 (50.4)	37,920
Private health insurance	880 (18.7)	1,432 (30.4)	2,395 (50.9)	4,707
Use of medical services				
Outpatient	**5,942 (14.8)**	**13,860 (34.4)**	**20,450 (50.8)**	**40,252**
Last year	5,124 (13.8)	12,776 (34.4)	19,269 (51.8)	37,169
More than a year ago	818 (26.5)	1,084 (35.2)	1,181 (38.3)	3,083
Stationary last year	**5,905 (17.8)**	**13,749 (34.4)**	**20,309 (50.8)**	**39,963**
Yes	651 (12.7)	1,803 (35.3)	2,659 (52.0)	5,113
No	5,254 (15.1)	11,946 (34.3)	17,650 (50.7)	34,850
Use of preventive measures				
Colonoscopy	**4,405 (12.2)**	**11,980 (33.1)**	**19,794 (54.7)**	**36,179**
No use	3,047 (17.8)	5,365 (31.3)	8,753 (51.0)	17,165
Single use	1,219 (7.4)	6,153 (37.4)	9,077 (55.2)	16,449
Multiple use	139 (5.4)	462 (18.0)	1,964 (76.6)	2,565
FOBT	**6,858 (14.6)**	**16,558 (35.2)**	**23,564 (50.2)**	**46,980**
No use	4,166 (21.5)	7,292 (37.6)	7,919 (40.9)	19,377
Single use	1,913 (11.3)	7,536 (44.4)	7,529 (44.4)	16,978
Multiple use	779 (7.3)	1,730 (16.3)	8,116 (76.4)	10,625
Skin cancer screening	**6,967 (14.6)**	**16,830 (35.2)**	**23,968 (50.2)**	**47,765**
No use	3,499 (20.6)	6,516 (38.4)	6,944 (41.0)	16,959
Single use	2,400 (12.6)	8,195 (43.0)	8,445 (44.4)	19,040
Multiple use	1,068 (9.1)	2,119 (18.0)	8,579 (72.9)	11,766
Breast examination by medical personnel	**6,981 (14.6)**	**16,911 (35.3)**	**24,084 (50.2)**	**47,976**
No use	2,006 (49.8)	1,105 (27.4)	921 (22.8)	4,032
Single use	2,396 (16.4)	10,219 (70.1)	1,972 (13.5)	14,587
Multiple use	2,579 (8.8)	5,587 (19.0)	21,191 (72.2)	29,357
Cervical smear	**6,897 (14.7)**	**16,485 (35.2)**	**23,417 (50.0)**	**46,799**
No use	2,531 (28.2)	3,338 (37.3)	3,092 (34.5)	8,961
Single use	2,032 (15.4)	8,624 (65.2)	2,570 (19.4)	13,226

Properties n (row-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Multiple use	2,334 (9.5)	4,523 (18.4)	17,755 (72.1)	24,612
Flu vaccination	**6,996 (14.6)**	**16,921 (35.2)**	**24,101 (50.2)**	**48,018**
Not at all	4,802 (19.7)	8,751 (35.8)	10,878 (44.5)	24,431
Once so far	570 (13.1)	1,332 (30.6)	2,445 (56.3)	4,347
Occasionally	728 (10.7)	2,278 (33.3)	3,831 (56.0)	6,837
Regulary	896 (7.2)	4,560 (36.8)	6,947 (56.0)	12,403
Family history of cancer	**6,024 (14.7)**	**14,154 (34.5)**	**20,845 (50.8)**	**41,018**
No, no family history	4,527 (15.4)	10,378 (35.4)	14,424 (49.2)	29,329
Yes, positive family history	1,495 (12.8)	3,776 (32.3)	6,418 (54.9)	11,689
Family history (mother) of breast cancer (among all women)	**6,013 (14.7)**	**14,115 (34.5)**	**20,820 (50.8)**	**40,948**
No, no family history	5,623 (15.1)	13,102 (35.1)	18,578 (49.8)	37,303
Yes, positive family history	390 (10.7)	1,013 (27.8)	2,242 (61.5)	3,645
Personal history of breast cancer	**6,970 (14.6)**	**16,873 (35.2)**	**24,045 (50.2)**	**47,888**
No	6,866 (15.1)	16,330 (35.8)	22,412 (49.1)	45,608
Yes	104 (4.6)	543 (23.8)	1,633 (71.6)	2,280
Contraceptive pill	**6,978 (14.6)**	**16,905 (35.3)**	**24,057 (50.2)**	**47,940**
Never	977 (18.4)	1,900 (35.8)	2,425 (45.7)	5,302
Ever	6,001 (14.1)	15,005 (35.2)	21,632 (50.7)	42,638
Hormone replacement therapy	**6,009 (13.6)**	**15,299 (34.6)**	**22,896 (51.8)**	**44,204**
Never	4,933 (15.0)	11,490 (35.0)	16,465 (50.1)	32,888
Ever	1,076 (9.5)	3,809 (33.7)	6,431 (56.8)	11,316
Smoking status	**6,991 (14.6)**	**16,917 (35.2)**	**24,102 (50.2)**	**48,010**
Never	3,074 (13.4)	7,969 (34.7)	11,922 (51.9)	22,965
Former	2,308 (13.7)	5,759 (34.3)	8,731 (52.0)	16,798
At present	1,609 (19.5)	3,189 (38.7)	3,449 (41.8)	8,247
Risky alcohol consumption†	**6,991 (14.6)**	**16,930 (35.3)**	**24,112 (50.2)**	**48,033**
No	4,846 (14.6)	11,849 (35.6)	16,600 (49.9)	33,295
Yes	2,145 (14.6)	5,081 (34.5)	7,512 (51.0)	14,738
Body mass index	**6,993 (14.6)**	**16,932 (35.3)**	**24,097 (50.2)**	**48,022**
Under 18,5 (Underweight)	127 (27.3)	162 (34.8)	176 (37.9)	465
18,5 to under 25 (Normal weight)	3,304 (16.8)	6,650 (33.8)	9,732 (49.5)	19,686
25 to under 30 (Overweight)	1,995 (13.1)	5,421 (35.6)	7,819 (51.3)	15,235
Over 30 (Obesity)	1,567 (12.4)	4,699 (37.2)	6,370 (50.4)	12,636
Physical activity (at least 150 min./week)‡	**6,999 (14.6)**	**16,939 (35.3)**	**24,119 (50.2)**	**48,057**
No	743 (16.0)	1,668 (35.8)	2,244 (48.2)	4,655
Yes	6,256 (14.4)	15,271 (35.2)	21,875 (50.4)	43,402

Properties n (row-%)	No participation in MSP n=6,999	One-time participation in MSP n=16,939	Multiple participation in MSP n=24,119	In total n=48,057
Social Network Index	**5,940 (14.8)**	**13,880 (34.5)**	**20,460 (50.8)**	**40,280**
Level I (isolated)	1,126 (21.1)	1,886 (35.4)	2,318 (43.5)	5,330
Level II	2,634 (15.8)	5,803 (34.7)	8,278 (49.5)	16,715
Level III	2,040 (12.1)	5,769 (34.1)	9,101 (53.8)	16,910
Level IV	140 (10.6)	422 (31.9)	763 (57.6)	1,325

FOBT: Fecal Occult Blood Test

* ISCED-97-Level: International Standard Classification of Education 97

† Alcohol Use Disorders Identification Test (Audit-C Score): Women > 3

‡ In accordance with the recommendation of the World Health Organisation

Table S2: Socio-demographic characteristics and specific factors (use of medical (preventive) measures, cancer (family) history, lifestyle factors) of the study cohort stratified by participation status (without age standardisation, column percentages)

Properties n (Columns-%)	No participation in MSP n=6,999	One-time participation in MSP n=16,939	Multiple participation in MSP n=24,119	In total n=48,057
Study centres	**6,999**	**16,939**	**24,119**	**48,057**
Bavaria (Augsburg, Regensburg)	1,230 (17.6)	2,562 (15.1)	3,342 (13.9)	7,134 (14.8)
Baden-Württemberg (Mannheim, Freiburg)	837 (12.0)	1,647 (9.7)	2,197 (9.1)	4,681 (9.7)
Saarland (Saarbrücken)	420 (6.0)	965 (5.7)	1,207 (5.0)	2,592 (5.4)
North Rhine-Westphalia (Essen, Münster, Düsseldorf)	978 (14.0)	2,220 (13.1)	3,612 (15.0)	6,810 (14.2)
Lower Saxony (Hannover)	352 (5.0)	780 (4.6)	1,229 (5.1)	2,361 (5.0)
Hamburg (Hamburg)	328 (4.7)	776 (4.6)	1,376 (5.7)	2,480 (5.2)
Bremen (Bremen)	464 (6.6)	737 (4.4)	1,209 (5.0)	2,410 (5.0)
Schleswig-Holstein (Kiel)	297 (4.2)	679 (4.0)	1,330 (5.5)	2,306 (4.8)
Saxony-Anhalt (Halle)	331 (4.7)	944 (5.6)	1,207 (5.0)	2,482 (5.2)
Saxony (Leipzig)	232 (3.3)	996 (5.9)	1,448 (6.0)	2,676 (5.6)
Berlin (Berlin North, Central, South)	1,139 (16.3)	2,650 (15.6)	3,529 (14.6)	7,318 (15.2)
Mecklenburg-Vorpommern (Neubrandenburg, Neustrelitz, Waren (Müritz), Demmin)	391 (5.6)	1,983 (11.7)	2,433 (10.1)	4,807 (10.0)
Marital status	**6,995**	**16,931**	**24,111**	**48,040**
Single	1,185 (16.9)	1,701 (10.1)	2,303 (9.6)	5,189 (10.8)
Married (living together and separately)	3,989 (57.0)	11,190 (66.1)	16,457 (68.3)	31,636 (65.9)
Divorced	1,417 (20.3)	2,840 (16.8)	3,630 (15.1)	7,887 (16.4)
Widowed	404 (5.8)	1,203 (7.1)	1,721 (7.1)	3,328 (6.9)
Partnership	**6,982**	**16,914**	**24,086**	**47,982**

Properties n (Columns-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Living together	4,234 (60.6)	11,790 (69.7)	17,259 (71.7)	33,283 (69.4)
Living apart	731 (10.5)	1,369 (8.1)	1,765 (7.3)	3,865 (8.1)
Without partner	2,017 (28.9)	3,755 (22.2)	5,062 (21.0)	10,834 (22.6)
Household size	**6,993**	**16,935**	**24,106**	**48,034**
Single-person household	1,994 (28.5)	3,873 (22.9)	5,424 (22.5)	11,291 (23.5)
Household with 2 people	3,378 (48.3)	9,734 (57.5)	14,941 (62.0)	28,053 (58.4)
Household with 3 people	975 (13.9)	2,067 (12.2)	2,533 (10.5)	5,575 (11.6)
Household with 4 people	483 (6.9)	958 (5.7)	939 (3.9)	2,380 (5.0)
Household with at least 5 persons	163 (2.3)	303 (1.8)	269 (1.1)	735 (1.5)
Level of education*	**6,397**	**15,579**	**22,395**	**44,371**
Low	222 (3.5)	642 (4.1)	606 (2.7)	1,470 (3.3)
Average	2,812 (44.0)	7,861 (50.5)	10,999 (49.1)	21,672 (48.8)
High	3,363 (52.6)	7,076 (45.4)	10,790 (48.2)	21,229 (47.8)
Employment status	**6,923**	**16,840**	**23,946**	**47,709**
Employed	4,976 (71.9)	11,216 (66.6)	15,560 (65.0)	31,752 (66.6)
Unemployed	213 (3.1)	435 (2.6)	475 (2.0)	1,123 (2.4)
Non-working person	1,734 (25.1)	5,189 (30.8)	7,911 (33.0)	14,834 (31.1)
Relative income position	**6,384**	**15,634**	**22,311**	**44,329**
Under 60% (at risk of poverty)	949 (14.9)	2,183 (14.0)	2,415 (10.8)	5,547 (12.5)
60% to less than 80%	974 (15.3)	2,802 (17.9)	3,548 (15.9)	7,324 (16.5)
80% to less than 100%	939 (14.7)	2,335 (14.9)	3,225 (14.5)	6,499 (14.7)
100% to less than 150%	1,859 (29.1)	4,738 (30.3)	7,251 (32.5)	13,848 (31.2)
150% and above	1,663 (26.1)	3,576 (22.9)	5,872 (26.3)	11,111 (25.1)
Health insurance status	**6,120**	**15,010**	**21,497**	**42,627**
Statutory health insurance	5,240 (85.6)	13,578 (90.5)	19,102 (88.9)	37,920 (89.0)
Private health insurance	880 (14.4)	1,432 (9.5)	2,395 (11.1)	4,707 (11.0)
Use of medical services				
Outpatient	**5,942**	**13,860**	**20,450**	**40,252**
Last year	5,124 (86.2)	12,776 (92.2)	19,269 (94.2)	37,169 (92.3)
More than a year ago	818 (13.8)	1,084 (7.8)	1,181 (5.8)	3,083 (7.7)
Stationary last year	**5,905**	**13,749**	**20,309**	**39,963**
Yes	651 (11.0)	1,803 (13.1)	2,659 (13.1)	5,113 (12.8)
No	5,254 (89.0)	11,946 (86.9)	17,650 (86.9)	34,850 (87.2)
Use of preventive measures				
Colonoscopy	**4,405**	**11,980**	**19,794**	**36,179**
No use	3,047 (69.2)	5,365 (44.8)	8,753 (44.2)	17,165 (47.4)
Single use	1,219 (27.7)	6,153 (51.4)	9,077 (45.9)	16,449 (45.5)
Multiple use	139 (3.2)	462 (3.9)	1,964 (9.9)	2,565 (7.1)
FOBT	**6,858**	**16,558**	**23,564**	**46,980**
No use	4,166 (60.8)	7,292 (44.0)	7,919 (33.6)	19,377 (41.3)
Single use	1,913 (27.9)	7,536 (45.5)	7,529 (32.0)	16,978 (36.1)

Properties n (Columns-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Multiple use	779 (11.4)	1,730 (10.5)	8,116 (34.4)	10,625 (22.6)
Skin cancer screening	**6,967**	**16,830**	**23,968**	**47,765**
No use	3,499 (50.2)	6,516 (38.7)	6,944 (29.0)	16,959 (35.5)
Single use	2,400 (34.5)	8,195 (48.7)	8,445 (35.2)	19,040 (39.9)
Multiple use	1,068 (15.3)	2,119 (12.6)	8,579 (35.8)	11,766 (24.6)
Breast examination by medical personnel	**6,981**	**16,911**	**24,084**	**47,976**
No use	2,006 (27.7)	1,105 (6.5)	921 (3.8)	4,032 (8.4)
Single use	2,396 (34.3)	10,219 (60.4)	1,972 (8.2)	14,587 (30.4)
Multiple use	2,579 (36.9)	5,587 (33.0)	21,191 (88.0)	29,357 (61.2)
Cervical smear	**6,897**	**16,485**	**23,417**	**46,799**
No use	2,531 (367)	3,338 (20.3)	3,092 (13.2)	8,961 (19.2)
Single use	2,032 (29.5)	8,624 (52.3)	2,570 (11.0)	13,226 (28.3)
Multiple use	2,334 (33.8)	4,523 (27.4)	17,755 (75.8)	24,612 (52.6)
Flu vaccination	**6,996**	**16,921**	**24,101**	**48,018**
Not at all	4,802 (68.6)	8,751 (51.7)	10,878 (45.1)	24,431 (50.9)
Once so far	570 (8.2)	1,332 (7.9)	2,445 (10.1)	4,347 (9.1)
Occasionally	728 (10.4)	2,278 (13.5)	3,831 (15.9)	6,837 (14.2)
Regularly	896 (12.8)	4,560 (27.0)	6,947 (28.8)	12,403 (25.8)
Family history of cancer	**6,024**	**14,154**	**20,845**	**41,018**
No, no family history	4,527 (75.1)	10,378 (73.3)	14,424 (69.2)	29,329
Yes, positive family history	1,495 (24.8)	3,776 (26.7)	6,418 (30.8)	11,689
Family history (mother) of breast cancer (among all women)	**6,013**	**14,115**	**20,820**	**40,948**
No, no family history	5,623 (93.5)	13,102 (92.8)	18,578 (89.2)	37,303 (91.1)
Yes, positive family history	390 (6.5)	1,013 (7.2)	2,242 (10.8)	3,645 (8.9)
Personal history of breast cancer	**6,970**	**16,873**	**24,045**	**47,888**
No	6,866 (98.5)	16,330 (96.8)	22,412 (93.2)	45,608
Yes	104 (1.5)	543 (3.2)	1,633 (6.8)	2,280
Contraceptive pill	**6,978**	**16,905**	**24,057**	**47,940**
Never	977 (14.0)	1,900 (11.2)	2,425 (10.1)	5,302 (11.1)
Ever	6,001 (86.0)	15,005 (88.8)	21,632 (89.9)	42,638 (88.9)
Hormone replacement therapy	**6,009**	**15,299**	**22,896**	**44,204**
Never	4,933 (82.1)	11,490 (75.1)	16,465 (71.9)	32,888 (74.4)
Ever	1,076 (17.9)	3,809 (24.9)	6,431 (28.1)	11,316 (25.6)
Smoking status	**6,991**	**16,917**	**24,102**	**48,010**
Never	3,074 (44.0)	7,969 (47.1)	11,922 (49.5)	22,965 (47.8)
Former	2,308 (33.0)	5,759 (34.0)	8,731 (36.2)	16,798 (35.0)
At present	1,609 (23.0)	3,189 (18.9)	3,449 (14.3)	8,247 (17.2)

Properties n (Columns-%)	**No participation in MSP n=6,999**	**One-time participation in MSP n=16,939**	**Multiple participation in MSP n=24,119**	**In total n=48,057**
Risky alcohol consumption†	**6,991**	**16,930**	**24,112**	**48,033**
No	4,846 (69.3)	11,849 (70.0)	16,600 (68.9)	33,295 (69.3)
Yes	2,145 (30.7)	5,081 (30.0)	7,512 (31.2)	14,738 (30.7)
Body mass index	**6,993**	**16,932**	**24,097**	**48,022**
Under 18,5 (Underweight)	127 (1.8)	162 (1.0)	176 (0.7)	465 (1.0)
18,5 to under 25 (Normal weight)	3,304 (47.3)	6,650 (39.3)	9,732 (40.4)	19,686 (41.0)
25 to under 30 (Overweight)	1,995 (28.5)	5,421 (32.0)	7,819 (32.5)	15,235 (31.7)
Over 30 (Obesity)	1,567 (22.4)	4,699 (27.8)	6,370 (26.4)	12,636 (26.3)
Physical activity (at least 150 min./week)‡	**6,999**	**16,939**	**24,119**	**48,057**
No	743 (10.6)	1,668 (9.9)	2,244 (9.3)	4,655 (9.7)
Yes	6,256 (89.4)	15,271 (90.2)	21,875 (90.7)	43,402 (90.3)
Social Network Index	**5,940**	**13,880**	**20,460**	**40,280**
Level I (isolated)	1,126 (19.0)	1,886 (13.6)	2,318 (16.7)	5,330 (13.2)
Level II	2,634 (44.3)	5,803 (41.8)	8,278 (59.6)	16,715 (41.5)
Level III	2,040 (34.3)	5,769 (41.6)	9,101 (65.6)	16,910 (42.0)
Level IV	140 (2.4)	422 (3.0)	763 (5.5)	1,325 (3.3)

FOBT: Fecal Occult Blood Test

* ISCED-97-Level: International Standard Classification of Education 97

† Alcohol Use Disorders Identification Test (Audit-C Score): Women > 3

‡ In accordance with the recommendation of the World Health Organisation

Chapter 4: Information and results of sensitivity analyses based on varying study populations

This chapter presents further sensitivity analyses in which the study population was restricted by additional exclusion criteria. The resulting study populations therefore differ from the study population (n=48,057) of the main analyses.

Section S1 provides further information on the two additional sensitivity analyses.

Tables S1.1-1.3 and Figure S1.1 show the results of the sensitivity analyses in which women with a personal history of breast cancer were excluded.

Tables S2.1-S2.3 and Figure S2.1 show the results of the sensitivity analyses in which women with multiple MSP participation at the age of 50 and 51 were excluded.

Since the tables and figures are designed in the same way as the presentations in the main text and can therefore be interpreted in the same way as the explanations given in the legends there, no additional explanations have been provided here.

Section S1: Further information on sensitivity analyses

In the baseline survey, women were asked to self-report whether they had ever been diagnosed with breast cancer. Since neither the reason for detection (diagnosis within or outside the MSP) of breast cancer was asked nor information on the time of participation in the MSP was available, all analyses were repeated after excluding women who reported a breast cancer diagnosis (2,280) and qualified missing data (n=169) were repeated, as women were not eligible to participate in the MSP for five years from the date of diagnosis in the first decade after its nationwide introduction.

In further sensitivity analyses, all women who reported multiple participation in the first MSP round, i.e. at the ages of 50 and 51 (n=1,276), were excluded in order to better estimate possible misclassification and the associated effects of grey or opportunistic screening.

The sensitivity analyses therefore included a total of 45,608 and 46,781 women, respectively.

Table S1.1: Sensitivity analysis (women without a family history of breast cancer) – odds ratios for individual factors of participation in MSP (never/ever) after age adjustment

Variable (Reference group)	Response categories	OR (95 % CI)
Level of education (low)	Average	1.27 (1.09-1.49)
	High	1.03 (0.88-1.20)
Relative income position* (< 60%)	60≤X<80	1.29 (1.16-1.42)
	80≤X<100	1.26 (1.14-1.40)
	100≤X<150	1.40 (1.29-1.53)
	≥ 150	1.28 (1.17-1.40)
Health insurance status (GKV)	PKV	0.65 (0.60-0.71)
Partnership (without partner)	Living apart	1.13 (1.02-1.24)
	Living together	1.67 (1.57-1.77)
SNI† (Level I, isolated)	Level II	1.43 (1.32-1.55)
	Level III	1.95 (1.79-2.11)
	Level IV	2.23 (1.85-2.70)
Smoking status (never)	Former	0.97 (0.92-1.03)
	At present	0.70 (0.66-0.75)
Alcohol consumption‡ (no risky consumption)	Risky consumption	1.03 (0.97-1.09)
BMI (normal weight, 18-24,9)	Underweight (<18,5)	0.54 (0.44-0.67)
	Overweight and obesity (≥25)	1.29 (1.22-1.35)
Physical activity§ (<150 minutes)	≥150 minutes	1.04 (0.96-1.13)
Early detection examinations (never)	FOBT	2.44 (2.31-2.57)
	Colonoscopy	2.78 (2.59-2.97)
	Skin cancer screening	2.06 (1.95-2.17)
	Clinical breast examination	9.13 (8.48-9.82)
	Cervical smear	3.65 (3.45-3.88)
Flu vaccination (Not at all)	Once so far	1.58 (1.44-1.74)
	Occasionally	2.03 (1.87-2.21)
	Regularly	2.77 (2.56-2.90)
Use of (never)	Contraceptive pill	1.40 (1.29-1.51)
	Hormone replacement therapy	1.57 (1.46-1.68)
Family history of breast cancer (negative)	Positive	1.49 (1.34-1.67)

CI: Confidence interval
OR: Odds Ratio
BMI: Body- mass index
FOBT: Fecal Occult Blood Test
GKV: Statutory health insurance
PKV: Private health insurance
SNI: Social Network Index

* Income is defined as a relative income position, with individuals earning less than 60% considered at risk of poverty.
† The Social Network Index is divided into four different levels, with people at Level I living in isolation.
‡ Risky alcohol consumption in women was defined as an Audit-C score greater than three.
§ In accordance with the recommendations of the World Health Organisation, sufficient physical activity has been defined as at least 150 minutes per week.

Table S1.2: Sensitivity analysis (women without a family history of breast cancer) – Table of PCA loadings by principal components

	RC1	RC2	RC3
Level of education		0.706	
Relative income position		0.727	0.333
Partnership			0.955
Social Network Index			0.943
Health insurance status		0.849	
Family history of breast cancer			
FOBT	0.653		
Colonoscopy	0.557		
Skin cancer screening	0.589		
Clinical breast examination	0.908		0.161
Cervical smear	0.789	0.189	0.113
Hormone replacement therapy	0.322		
Contraceptive pill	0.181		
Flu vaccination	0.313	-0.212	
Smoking status			-0.268
Body mass index	-0.120	-0.422	

FOBT: Fecal Occult Blood Test

RC: Rotated Components (principal components)

Table S1.3: Sensitivity analysis (women without a family history of breast cancer) – Table with information on the loadings and variance of the PCA according to principal components

	RC1	RC3	RC2
Loadings	2.797	2.059	2.037
Proportion Variance	0.175	0.129	0.127
Cumulative Variance	0.175	0.304	0.431

RC: Rotated Components (principal components)

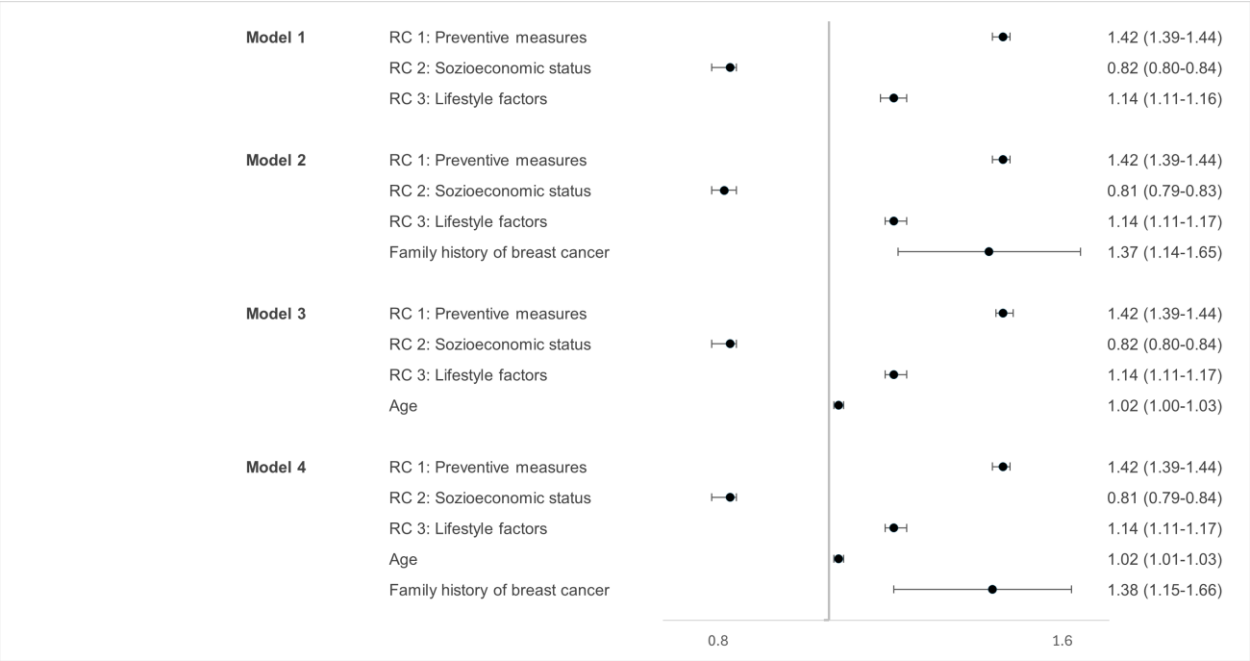

Figure S1.1: Sensitivity analysis (women without a family history of breast cancer) – Forest plot of multivariate regression analyses of specific factors and main components and the dependent variable participation in MSP (never/ever)

FOBT: Fecal Occult Blood Test

Table S2.1: Sensitivity analysis (women without multiple participation aged 50 and 51) – odds ratios for individual factors of participation in MSP (never/ever) after age adjustment

Variable (Reference group)	Response categories	OR (95 % CI)
Level of education (low)	Average	1.28 (1.10-1.49)
	High	1.03 (0.89-1.20)
Relative income position* (< 60%)	60≤X<80	1.27 (1.15-1.41)
	80≤X<100	1.23 (1.12-1.36)
	100≤X<150	1.40 (1.28-1.52)
	≥ 150	1.25 (1.15-1.37)
Health insurance status (GKV)	PKV	0.64 (0.59-0.71)
Partnership (without partner)	Living apart	1.13 (1.02-1.24)
	Living together	1.67 (1.58-1.78)
SNI† (Level I, isolated)	Level II	1.41 (1.30-1.53)
	Level III	1.93 (1.78-2.10)
	Level IV	2.21 (1.84-2.68)
Smoking status (never)	Former	0.97 (0.92-1.03)
	At present	0.71 (0.66-0.76)
Alcohol consumption‡ (no risky consumption)	Risky consumption	1.02 (0.97-1.08)
BMI (normal weight, 18-24,9)	Underweight (<18,5)	0.54 (0.44-0.66)
	Overweight and obesity (≥25)	1.29 (1.22-1.35)
Physical activity§ (<150 minutes)	≥150 minutes	1.05 (0.97-1.14)
Early detection examinations (never)	FOBT	2.45 (2.32-2.59)
	Colonoscopy	2.78 (2.59-2.97)
	Skin cancer screening	2.00 (1.90-2.11)
	Clinical breast examination	9.40 (8.74-10.11)
	Cervical smear	3.64 (3.43-3.86)
Flu vaccination (Not at all)	Once so far	1.58 (1.44-1.73)
	Occasionally	2.01 (1.85-2.19)
	Regularly	2.75 (2.55-2.97)
Use of (never)	Contraceptive pill	1.39 (1.29-1.50)
	Hormone replacement therapy	1.53 (1.40-1.64)
Family history of breast cancer (negative)	Positive	1.44 (1.29-1.60)

CI: Confidence interval
OR: Odds Ratio
BMI: Body mass index
FOBT: Fecal Occult Blood Test
GKV: Statutory health insurance
PKV: Private health insurance
SNI: Social Network Index

* Income is defined as a relative income position, with individuals earning less than 60% considered at risk of poverty.
† The Social Network Index is divided into four different levels, with people at Level I living in isolation.
‡ Risky alcohol consumption in women was defined as an Audit-C score greater than three.
§ In accordance with the recommendations of the World Health Organisation, sufficient physical activity has been defined as at least 150 minutes per week.

Table S2.2: Sensitivity analysis (women without multiple participation aged 50 and 51) – Table of PCA loadings by principal components

	RC1	RC2	RC3
Level of education		0.704	
Relative income position		0.726	0.334
Partnership status			0.955
Social network index			0.942
Health insurance status		0.848	
Family history of breast cancer			
FOBT	0.646		
Colonoscopy	0.552		
Skin cancer screening	0.586		
Clinical breast examination	0.908		0.162
Cervical smear	0.790	0.182	0.109
Hormone replacement therapy	0.317		
Contraceptive pill	0.191		
Flu vaccination	0.309	-0.224	
Smoking status			-0.271
Body mass index	-0.129	-0.426	

FOBT: Fecal Occult Blood Test
RC: Rotated Components

Table S2.3: Sensitivity analysis (women without multiple participation aged 50 and 51) – Table with information on the loadings and variance of the PCA according to principal components

	RC1	RC3	RC2
Loadings	2.783	2.062	2.033
Proportion Variance	0.174	0.129	0.127
Cumulative Variance	0.174	0.303	0.430

RC: Rotated Components

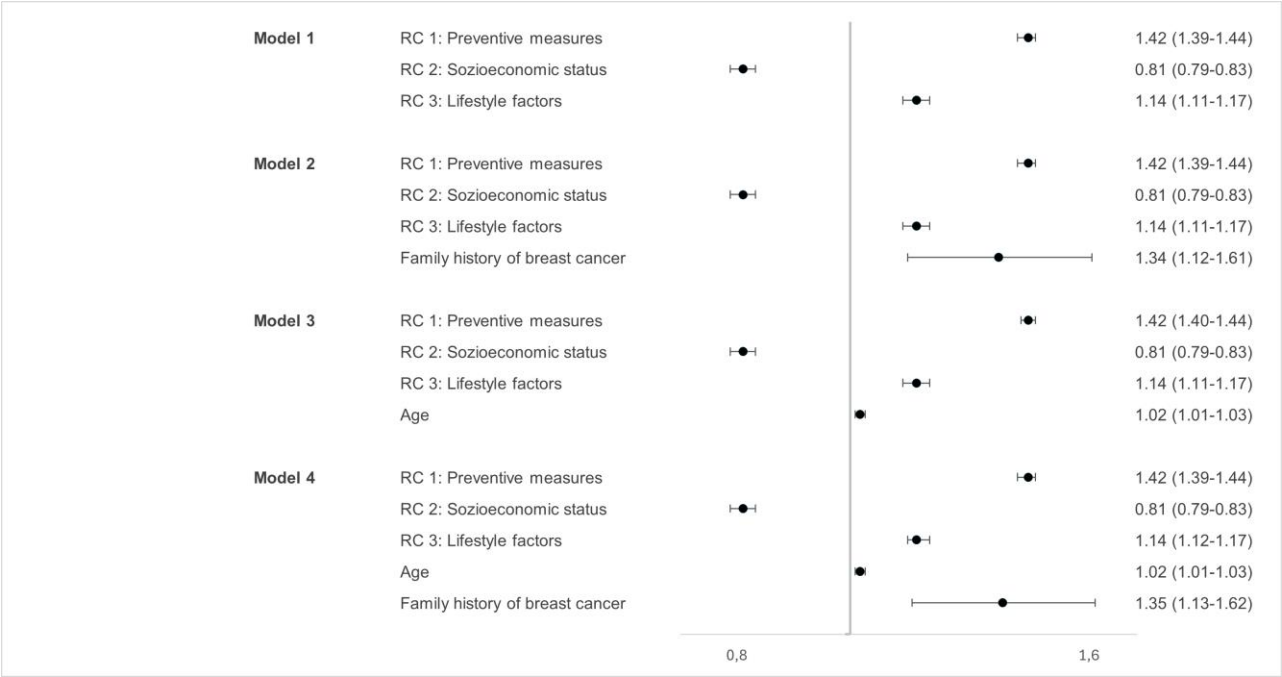

Figure S2.1: Sensitivity analysis (women without multiple participation aged 50 and 51) – Forest plot of multivariate regression analyses of specific factors and principal components and the dependent variable participation in MSP (never/ever)

FOBT: Fecal Occult Blood Test