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Socioeconomic differences in metabolic syndrome development among males and females, and the mediating role of health literacy and self-management skills

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A R T I C L E I N F O

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Metabolic syndrome
Socioeconomic factors
Health literacy
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Mediation

A B S T R A C T

Background: Our aim was to investigate sex differences in the associations between socioeconomic position (SEP) and metabolic syndrome (MetS) development, and to what extent these associations are mediated by health literacy and self-management skills.

Methods: A subsample (n = 88,384, 59.5% female) of the adult Lifelines Cohort Study was used. MetS development according to NCEP-ATPIII criteria was assessed on average 3.8 years after baseline. SEP-MetS associations were assessed for moderation by sex, and sex-stratified accordingly. Associations between SEP measures (education, income and occupational prestige), health literacy and self-management skills, and MetS development were investigated using logistic regression analyses. The mediating effects of health literacy and self-management skills on the SEP-MetS associations were investigated using the Karlson-Holm-Breen method.

Results: Among males and females, respectively 9.4% and 7.1% developed MetS. For males, education was inversely associated with MetS development; health literacy (7.1%) and self-management skills (1.9%) mediated a proportion of these educational differences. For females, education, income and occupational prestige were inversely associated with MetS development; health literacy (respectively 5.9% and 6.4%) and self-management skills (respectively 4.1% and 3.7%) mediated a proportion of the educational and occupational differences in MetS development. Neither health literacy nor self-management skills mediated female income differences in MetS development.

Conclusions: Socioeconomic differences in MetS development differ between males and females. Both for males and females, health literacy and self-management skills mediated a small proportion of socioeconomic differences in MetS development.

1. Introduction

Metabolic syndrome (MetS) is defined as a cluster of interrelated risk factors, consisting of abdominal obesity, elevated triglyceride levels, reduced high-density lipoprotein (HDL) cholesterol levels, elevated blood pressure, and elevated fasting blood glucose levels (Alberti et al., 2009). Having MetS is a risk factor for disorders like cardiovascular diseases, and can lead to high healthcare expenditures (Ford, 2005; *Rijksinstituut voor Volksgezondheid en Milieu*, 2017). Since the prevalence of MetS is continuing to increase, a better understanding is needed of the risk factors involved (Saklayen, 2018).

A lower socio-economic position (SEP) (e.g., low education, income or occupational prestige) is associated with developing MetS (Hoveling et al., 2021; Blanquet et al., 2019). SEP is a multi-dimensional concept. Individual differences in education may reflect differences in health-related knowledge and skills, differences in income may reflect differences in financial opportunities, and constraints and differences in occupational prestige may reflect differences in social status. All of these

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factors seem to be linked to health via different pathways (Adler and Newman, 2002; Galobardes et al., 2006a; Fujishiro et al., 2010; Galobardes et al., 2006b). A previous study showed that socioeconomic differences in MetS development differ per SEP measure used, indicating that investigations of associations between SEP and MetS development should take all three SEP indicators into account (Hoveling et al., 2021).

In order to elucidate the above-mentioned pathways, sex differences in the associations between SEP measures and MetS development should also be taken into account. In the literature, SEP seems to be more strongly related to MetS prevalence in females than in males (Dallongeville et al., 2005; Loucks et al., 2007; Park et al., 2012; Santos et al., 2008). Although the etiology of this sex difference remains largely unknown, some mechanisms have been proposed. For example, low SEP in females is associated with having more children, and childbirth is in turn associated with greater central adiposity and lower HDL cholesterol levels than before pregnancy (Gunderson, 2004; Gunderson et al., 2004; Van Agtmaal-Wobma and Van Huis, 2008). Another mechanism may be that females with low SEP have more psychosocial risks (e.g., stress about poverty, single parenting, and depressive symptoms) than males with low SEP (Lorant et al., 2003). These psychosocial risk factors may have an association with the risk of MetS-related conditions (Osborne et al., 2020). Yet another mechanism may be that males in lower SEP groups are more involved in professions with more physically demanding activities, which increase their energy expenditure, resulting in a lower risk of MetS (Santos et al., 2008). Several possible pathways may explain the greater SEP gradient in MetS prevalence among females than among males. It has, however, not yet been investigated whether sex differences are also present in the associations between SEP measures and MetS development.

Besides examining potential sex differences in the association between SEP and MetS development, identifying factors underlying these associations is crucial in order to decrease SEP differences on MetS development. Health literacy (the cognitive ability to understand and use information to promote good health (Kwan et al., 2006)) and self-management skills (the ability to realize and sustain well-being (Steverink et al., 2005)) are especially likely to be such factors, for the following reasons. First, compared to their higher educated counterparts, individuals with lower education reported both lower health literacy and lower self-management skills (Stormacq et al., 2019; Cramm and Nieboer, 2019). Second, lower health literacy and lower self-management skills were found to increase MetS-related conditions (Magnani et al., 2018; Michou et al., 2018; Grady and Gough, 2018). Third, the way SEP influences MetS development through health literacy and self-management may differ between males and females. A previous study showed that females with low health literacy were more likely than their male counterparts to have a MetS-related condition (Quartuccio et al., 2018). Compared to males, females utilize more health resources, such as preventive care measures (Pinkhasov et al., 2010). Not having a level of health literacy to understand how to use these health resources, or not having the self-management skills to utilize them, may therefore have a greater effect on female health than on male health. To conclude, investigation of health literacy and self-management as mediating factors in the associations between SEP measures and MetS is promising, and may also explain potential differences between males and females in how SEP measures affect MetS development.

To our knowledge, this is the first longitudinal study to investigate: 1) sex differences in the associations between different SEP measures (education, income, and occupational prestige) and MetS development, and 2) whether and to what extent health literacy and self-management skills mediate SEP differences in MetS development (Fig. 1).

2. Methods

Longitudinal data were derived from the Lifelines Cohort Study (Scholtens et al., 2015; Sijtsma et al., 2021). Lifelines is a multidisciplinary prospective population-based cohort study examining, in a unique three-generation design, the health and health-related behaviors of 167,729 persons living in the north of the Netherlands. Lifelines employs a broad range of investigative procedures to assess biomedical, socio-demographic, behavioral, physical and psychological factors that contribute to the health and disease of the general population, with a special focus on multi-morbidity and complex genetics. The Lifelines cohort profile, and recruitment and data collection, are described elsewhere (Scholtens et al., 2015; Sijtsma et al., 2021). Baseline assessment (T1), consisting of a physical examination, blood and urine samples, interviews and self-report questionnaires, was conducted between 2006 and 2013. Participants were followed up approximately every 5 years with a physical examination, including drawing blood samples, collecting urine samples, and testing cognitive performance (T4).

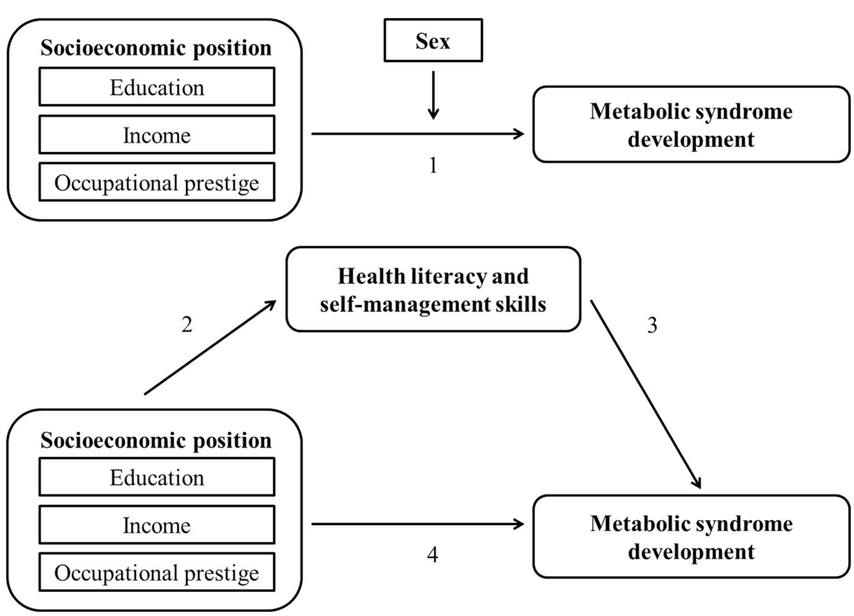

Fig. 1. Graphical representation of direct associations between socioeconomic position, health literacy and self-management skills, and metabolic syndrome development, and the moderating role of sex and indirect associations via health literacy and self-management.

Meanwhile, participants were followed-up on average every 1.5 years by additional questionnaires, including questions about health literacy and self-management skills (T2 and T3) (Supplementary Fig. 1) (Scholtens et al., 2015; Sijtsma et al., 2021).

The current study was a longitudinal study in which all participants underwent two comprehensive assessments: a baseline assessment (T1), followed by a second assessment after a median follow-up time of 3.8 years (T4). Health literacy and self-management skills were assessed on average 2.5 (standard deviation (SD) 0.9) years after baseline (T3). A subsample was used of 126,332 participants aged 18 years and older, who had complete data for ≥70% of the variables needed for this study at T1 and T3 (i.e., demographic-, socioeconomic-, MetS related variables at T1, and health literacy and self-management skills at T3), and without MetS at T1. Participants not participating at T4 ($n = 31{,}408$), for whom no MetS status could be determined based on data of T4 ($n = 6508$), or who had >30% missing values of the variables needed for this study at T4 ($n = 32$) were excluded from the analysis. Finally, 88,384 participants were included in the analysis. An attrition analysis was performed to assess differences between the study population and the excluded individuals.

2.1. Components and procedures

2.1.1. Socioeconomic position

SEP was defined based on years of education, equivalized household income, and occupational prestige measured at T1. *Education* was coded as years of education, using the number of years it would take to complete each educational degree by the fastest route possible (see Supplementary Table 1 for measurements of the relevant variables in the Lifelines Cohort Study) (De Graaf et al., 2000). Equivalized household *income* was calculated by dividing the midpoint of each participant's income category by the square root of his or her household size (OECD, 2018). Amounts were divided by 100; the model estimates thus indicate the differences in odds ratio (OR) for a 100-euro difference in equivalized household income. *Occupational prestige* was recoded from the International Standard Classification of Occupations 2008 (ISCO08) to the continuous Standard International Occupational Prestige Scale 2008 (SIOPS08) (Ganzeboom, 2014) and divided by 10; the model estimates thus indicate the differences in OR for a 10-point difference in occupational prestige score. SIOPS08 is a continuous scale ranging from 0 to 100, indicating low to high occupational prestige (Hope and Treiman, 1980).

2.1.2. Metabolic syndrome

MetS was defined as having at least three of the five components according to the National Cholesterol Education Program's Adult Treatment Panel III (NCEP-ATPIII) (Alberti et al., 2009). The criteria are: 1) Waist circumference ≥ 102 cm among males or ≥ 88 cm among females; 2) Systolic blood pressure ≥ 130 mmHg or diastolic blood pressure ≥ 85 mmHg or use of blood pressure lowering medication; 3) Triglycerides ≥150 mg/dL (1.7 mmol/L) or use of medication for elevated triglycerides; 4) HDL cholesterol <40 mg/dL (1.0 mmol/L) among males or < 50 mg/dL (1.3 mmol/L) among females, or use of lipid-lowering medication; 5) Fasting blood glucose level ≥ 100 mg/dL (≥ 5.6 mmol/L) or diagnosis of type 2 diabetes or use of blood glucose-lowering medication. Medication use at T1 was classified according to the Anatomical Therapeutic Chemical coding scheme (WHO, n.d.), and at T4 classified with a general question about current medication use (yes/no). For all participants, MetS status was dichotomized (yes/no).

2.1.3. Health literacy and self-management skills

Health literacy and *self-management skills* were measured using the questionnaire at T3, which was conducted on average 2.5 (SD 0.9) years after T1. *Health literacy* was measured with the validated Brief Health Literacy Screening (BHLS) (Chew et al., 2004), indicating health literacy with three questions on understanding medical information. Participants answered these questions on a 5-point scale (range 3–15). Scores were categorized into three categories: low health literacy (BHLS score of <12), moderate health literacy (BHLS score of ≥12 and < 15), and high health literacy (BHLS score of 15). *Self-management skills* were measured with the validated Self-management Ability Score (SMAS) (Schuurmans et al., 2005), based on the theory of self-management of well-being (Steverink et al., 2005). The SMAS measures six self-management skills (taking initiative, self-efficacy beliefs, investment behavior, positive frame of mind, multi-functionality of resources and variety in resources), resulting in subscores per skill and a total sum score ranging from 0 to 100. Scores were categorized into three categories: low self-management skills (SMAS score of <57.17), moderate self-management skills (SMAS score of ≥57.17 and < 74.33), and high self-management skills (SMAS score of ≥74.33). Due to the strongly skewed distribution and non-linear relationship between SEP and BHLS and SMAS, respectively, cut-off values for BHLS and SMAS were based on the study percentiles of the variables (beneath the 20th percentile for low, between the 20th and 80th percentiles for moderate, and above the 80th percentile for high).

2.1.4. Covariates and potential confounders

Age at T1 and time between T1 and T4 were used as control variables in all models. If sex moderated the associations between SEP measures and MetS, stratified analyses were conducted. In all other cases, sex was added as a covariate.

2.2. Statistical analysis

Characteristics concerning demographics, socioeconomics, MetS indicators, health literacy and self-management skills were described. Effect modification by sex was tested by adding two-way interaction terms between sex and measures of SEP to logistic regressions of the associations between SEP measures and MetS development. When effect modification was present (p-value for interaction<0.01) for at least one SEP measure, for reasons of consistency, analyses with all SEP measures were sex-stratified. Multivariable logistic regression analysis, controlling for age, other SEP measures and time between T1 and T4, was used to assess the direct associations between SEP, and MetS development. Direct associations between the SEP measures, health literacy and self-management skills, and MetS development were assessed using multivariable logistic regression analyses controlling for age, other SEP measures and time between the respective measures. Total-, direct- and indirect associations between the SEP measures and MetS development via health literacy and self-management skills, and their mediating percentages were estimated using the Karlson-Holm-Breen (KHB) method (Breen et al., 2013). The KHB method was chosen because it adjusts for the rescaling of the error variance associated with nested non-linear models by fixing the residual variance. This method also accounts for differences in error distributions across models. The method provides mediating percentages, which indicate the percentage of the total effect accounted for by the indirect effect. The results of all steps are presented as odds ratios (ORs) with 99% Confidence Intervals (CI), using high health literacy and high self-management skills as reference categories. Missing values on the SEP measures, as well as on health literacy and self-management skills, were imputed using the Multiple Imputation by Chained Equation (MICE) method (Azur et al., 2011). MICE was used, and 10 datasets were created with 100 iterations for each dataset. Auxiliary variables length and weight were used to provide extra information about the incomplete values (White et al., 2011). The imputation model included the independent variables, covariates, mediating variables, dependent variables, and auxiliary variables. All analyses were performed using StataMP 13 (64-bit), and to allow for multiple testing, p-values of <0.01 were considered significant.

2.2.1. Sensitivity analyses

Two sensitivity analyses were performed to assess the robustness of our findings. Since occupational prestige is applicable only to occupationally active participants, a sensitivity analysis was performed among occupationally active participants ($n = 69{,}104$). To assess the potential role of misclassification from medication use at T4 (i.e., measured only with a general question about current medication use), the analyses were repeated for a sample including only participants not using medication at T4 ($n = 45{,}977$). To ensure homogeneity, the sensitivity analyses were also tested for effect modification by sex, and sex-stratified based on the modification effect found in the main analysis.

3. Results

3.1. Sample characteristics

The largest percentage of the study sample consisted of females (59.5%, $n = 52{,}260$) (Table 1). Compared to males, females reported on average lower age, years of education, equivalized household income and occupational prestige. Both for males and females, the median health literacy score was 14 (interquartile range (IQR) 12 to 14). Males reported a median self-management skills score of 63.7 (IQR 57.3 to 70.5) and females reported a median self-management skills score of 66.8 (IQR 60 to 73.8). Overall, differences in characteristics between the study sample ($n = 88{,}384$) and the excluded participants ($n = 37{,}948$) were small (< 5%) (Supplementary Table 2).

Table 1
Characteristics of the study population ($n = 88{,}384$), stratified by sex.

Characteristics	Male population (n = 35,764)[a]	Missing values (%)	Female population (n = 52,620)[a]	Missing values (%)
Baseline measurement:				
Demographic				
Age (years), mean (SD)	45.8 (12.9)	0.0	44.6 (12.4)	0.0
Socioeconomic				
Education (years), mean (SD)	12.4 (2.5)	1.5	12.2 (2.3)	2.3
Equivalized household income (euros), mean (SD)	1630.0 (564.2)	12.9	1507.6 (574.0)	17.7
Occupational prestige (SIOPS08), mean (SD)	45.6 (12.8)	3.6	42.5 (13.7)	3.6
Metabolic syndrome indicators, meeting condition[b]				
Waist circumference[c]	14.7	0.0	35.1	0.0
Triglyceride level[d]	20.0	0.0	6.9	0.0
HDL cholesterol[e]	11.0	0.0	13.7	0.0
Blood pressure[f]	44.4	0.0	22.6	0.0
Glucose level[g]	10.0	0.8	4.0	0.7
Measurement 2.5 years after baseline:				
Brief health literacy score[h]		25.7		23.0
Low health literacy[i]	10.0		10.6	
Moderate health literacy[j]	48.5		49.0	
High health literacy[k]	15.8		17.3	
Self-management skills[l]		26.5		24.2
Low self-management skills[m]	18.3		13.0	
Moderate self-management skills[n]	44.4		45.5	
High self-management skills[o]	10.8		17.4	

SD: standard deviation; SIOPS08: Standard International Occupational Prestige Scale 2008; HDL: high-density lipoprotein; BHLS: Brief Health Literacy Screening; SMAS: Self-management Ability Score; [a] % are presented, unless indicated otherwise; [b] According to definition of metabolic syndrome by NCEP-ATPIII; [c] ≥ 102 cm among males or ≥ 88 cm among females; [d] ≥ 1.70 mmol/L or use of medication for elevated triglycerides; [e] < 1.0 mmol/L among males, < 1.3 mmol/L among females, or use of lipid-lowering medication; [f] Systolic blood pressure ≥ 130 mmHg, diastolic blood pressure ≥ 85 mmHg, or use of blood pressure-lowering medication; [g] Fasting blood glucose level ≥ 5.6 mmol/L, diagnosis of type 2 diabetes, or use of blood glucose-lowering medication; [h] Measured with the Brief Health Literacy Screening (BHLS) tool on a continuous scale ranging from 3 to 15; [i] BHLS score of <12; [j] BHLS score of ≥12 and < 15; [k] BHLS score of 15; [l] Measured with the Self-management Ability Score on a continuous scale ranging from 0 to 100; [m] SMAS score of <57.17; [n] SMAS score of ≥57.17 and < 74.33; [o] SMAS score of ≥74.33.

3.2. The moderating role of sex on the association between socioeconomic position and metabolic syndrome development

Effect modification by sex was observed for education and occupational prestige, therefore all analyses were sex-stratified. At T4, 9.4% of the male participants and 7.1% of the female participants developed MetS. More highly educated males and females had lower risks of developing MetS (OR 0.92; 99% CI: 0.90, 0.95 for males and OR 0.91; 99% CI: 0.89, 0.93 for females) (Table 2, path 1). For females only, inverse associations between income (OR: 0.99, 99% CI: 0.98, 1.00) and occupational prestige and developing MetS were found (OR: 0.94, 99% CI: 0.90, 0.98).

3.3. Socioeconomic position differences in metabolic syndrome development mediated by health literacy and self-management skills

For both males and females, a higher SEP was associated with a decreased likelihood of low health literacy or low self-management skills (Table 2, path 2). Low health literacy was associated with an increased likelihood of the development of MetS, for both males and females (Table 2, path 3). Females with low or moderate self-management skills were more likely to develop MetS than females with high self-management skills. For males, MetS development was not shown to be influenced by self-management skills.

For males, educational differences in MetS development were for 7.1% and 1.9% mediated by health literacy and self-management skills, respectively (Table 3). For females, educational differences in MetS development were for 5.9% and 4.1% mediated by health literacy and self-management skills, respectively. Occupational differences between MetS development among females were for 6.4% and 3.7% mediated by health literacy and self-management skills, respectively. Income differences in MetS development among females were not mediated by health literacy and self-management skills.

3.4. Sensitivity analyses

Although no effect modification of SEP measures by sex on MetS development was observed in the sensitivity analyses, both the analysis with occupationally active participants and that with participants not using medication at T4 showed results similar to those of the main analysis (Supplementary Tables 3–6).

4. Discussion

We investigated the moderating role of sex in the associations between SEP (i.e., education, income and occupational prestige) and MetS development, and whether and to what extent health literacy and self-management skills mediated the associations between SEP and MetS development. We found that socioeconomic differences in MetS development differ between males and females, and that health literacy and self-management skills partly mediated these differences.

Our findings suggest that sex differences are present in the educational and occupational prestige differences in MetS development. Of the SEP measures used in this study, only education influenced male MetS development. For females, occupational prestige and income also influenced MetS development, although for the latter only marginally.

Table 2
Multivariable logistic regression analysis of direct associations between socioeconomic position, health literacy, self-management skills, and metabolic syndrome development, stratified by sex.

	Males			Females		
	Education	Income	Occupational prestige	Education	Income	Occupational prestige
	OR (99% CI)	OR (99% CI)	OR (99% CI)	OR (99% CI)	OR (99% CI)	OR (99% CI)
Path 1 (SEP and MetS)	0.92 (0.90, 0.95)*	1.00 (0.99, 1.01)	0.98 (0.94, 1.03)	0.91 (0.89, 0.93)*	0.99 (0.98, 1.00)*	0.94 (0.90, 0.98)*
Path 2 (SEP and mediators)						
Health literacy						
Low health literacy[a]	0.70 (0.68, 0.72)*	0.96 (0.95, 0.97)*	0.84 (0.79, 0.88)*	0.73 (0.71, 0.75)*	0.96 (0.95, 0.97)*	0.77 (0.74, 0.81)*
Moderate health literacy[b]	0.85 (0.84, 0.87)*	0.99 (0.98, 0.99)*	0.92 (0.89, 0.96)*	0.87 (0.86, 0.89)*	0.98 (0.98, 0.99)*	0.90 (0.87, 0.93)*
Self-management skills						
Low self-management skills[c]	0.89 (0.87, 0.91)*	0.98 (0.97, 0.99)*	0.91 (0.87, 0.96)*	0.86 (0.84, 0.88)*	0.97 (0.96, 0.98)*	0.91 (0.88, 0.95)*
Moderate self-management skills[d]	0.95 (0.92, 0.97)*	0.99 (0.99, 1.00)	0.96 (0.92, 1.00)	0.94 (0.92, 0.95)*	0.99 (0.98, 1.00)*	0.94 (0.91, 0.97)*
Path 3 (mediators and MetS)						
Health literacy						
Low health literacy[a]	1.47 (1.24, 1.75)*	1.47 (1.24, 1.75)*	1.47 (1.24, 1.75)*	1.43 (1.19, 1.71)*	1.43 (1.19, 1.71)*	1.43 (1.19, 1.71)*
Moderate health literacy[b]	1.20 (1.04, 1.39)*	1.20 (1.04, 1.39)*	1.20 (1.04, 1.39)*	1.14 (0.98, 1.34)	1.14 (0.98, 1.34)	1.14 (0.98, 1.34)
Self-management skills						
Low self-management skills[c]	1.15 (0.97, 1.36)	1.15 (0.97, 1.36)	1.15 (0.97, 1.36)	1.56 (1.33, 1.83)*	1.56 (1.33, 1.83)*	1.56 (1.33, 1.83)*
Moderate self-management skills[d]	0.97 (0.82, 1.14)	0.97 (0.82, 1.14)	0.97 (0.82, 1.14)	1.18 (1.03, 1.34)*	1.18 (1.03, 1.34)*	1.18 (1.03, 1.34)*

OR: odds ratio; CI: confidence interval; SEP: socioeconomic position; MetS: metabolic syndrome; BHLS: Brief Health Literacy Screening; SMAS: Self-management Ability Score; analyses were independent of other SEP measures, age and follow-up time; reference category for health literacy was high health literacy (BHLS score = 15 points) and for self-management skills, high self-management skills (SMAS score of ≥74.33); [a] BHLS score of <12; [b] BHLS score of ≥12 and < 15; [c] SMAS score of <57.17; [d] SMAS score of ≥57.17 and < 74.33; *$P < 0.01$.

Table 3
Multivariable mediation analysis of health literacy and self-management skills in associations between socioeconomic position components and metabolic syndrome development, using the Karlson-Holm-Breen method, stratified by sex.

	Males			Females		
	Education	Income	Occupational prestige	Education	Income	Occupational prestige
	OR (99% CI)	OR (99% CI)	OR (99% CI)	OR (99% CI)	OR (99% CI)	OR (99% CI)
Total association SEP and MetS	0.92 (0.90, 0.95)*	1.00 (0.99, 1.01)	0.98 (0.94, 1.03)	0.91 (0.89, 0.93)*	0.99 (0.98, 1.00)*	0.94 (0.91, 0.98)*
Direct association SEP and MetS						
Independent of health literacy and self-management skills	0.93 (0.91, 0.95)*	1.00 (0.99, 1.01)	0.98 (0.94, 1.03)	0.92 (0.90, 0.94)*	0.99 (0.98, 1.00)	0.95 (0.91, 0.99)*
Indirect association SEP and MetS						
Via health literacy and self-management skills	0.99 (0.99, 1.00)*	1.00 (1.00, 1.00)*	1.00 (0.99, 1.00)*	0.99 (0.99, 1.00)*	1.00 (1.00, 1.00)*	0.99 (0.99, 1.00)*
	Percentage	Percentage	Percentage	Percentage	Percentage	Percentage
Mediating effect SEP and MetS						
Health literacy	7.1	128.1	14.3	5.9	6.4	6.4
Self-management skills	1.9	112.3	5.7	4.1	7.2	3.7
Combined	9.0*	230.4[a]	20.0	10.0*	13.6	10.1*

OR: odds ratio; CI: confidence interval; SEP: socioeconomic position; MetS: metabolic syndrome; BHLS: Brief Health Literacy Screening; SMAS: Self-management Ability Score; analyses were independent of other SEP measures, age and follow-up time; reference category for health literacy was high health literacy (BHLS score = 15 points), and for self-management skills, high self-management skills (SMAS score of ≥74.33); [a] mediating percentages were calculated by dividing indirect associations (via health literacy and self-management skills) by the total SEP-MetS association. These high percentages thus arise when indirect association is greater than total association. *$P < 0.01$.

These findings are in accordance with previous cross-sectional studies (Santos et al., 2008; Pucci et al., 2017); however our study is the first to show occupational prestige to be of greater influence on female MetS development than that of males. An explanation for the finding that male MetS development was not influenced by occupational prestige may be that, compared to females, males with low occupational prestige are more likely to have physically active occupations (Beenackers et al., 2012), which could protect them from developing MetS (Hoveling et al., 2021). In contrast to other studies (Dallongeville et al., 2005; Loucks et al., 2007), our study showed the effect of income on MetS development to be only marginal, which may also explain the absence of sex differences in this association. In the Netherlands, compared to other countries, weaker associations between income and health outcomes have previously been described (Vart et al., 2013), and may be explained by the fact that the Netherlands is a welfare state in which access to health care is not strongly dependent on material resources.

Consistent with previous studies, our results show that for both males and females, a higher SEP was associated with higher health literacy and better self-management skills (Stormacq et al., 2019; Cramm and Nieboer, 2019). Furthermore, in our study, having low health literacy considerably increased the risk of developing MetS; this finding is in accordance with findings of cross-sectional studies (Magnani et al., 2018; Michou et al., 2018). Explanations could be that individuals with low health literacy may not be able to understand health promoting messages to prevent MetS. Further, females in our study with either low or moderate self-management skills seem to be more susceptible to developing MetS than their male counterparts, a finding not previously described. An explanation for this sex difference could be that for females, not having the skills to successfully use resources may have a greater influence on MetS development than for males, because females are more reliant on health resources (Pinkhasov et al., 2010): females visit their general physicians more often, are more likely to seek preventive health care measures and engage in far more health promoting behavior (Pinkhasov et al., 2010). It is therefore plausible that lacking the skills to effectively use these health resources to achieve well-being is of greater effect on female than on male health. It should be noted that health literacy and self-management were measured only 1.3 years before MetS measurement, which raises the question whether these factors could influence MetS development over such a short period. It is, however, likely that health literacy and self-management scores measured 2.5 years after baseline are representative of one's baseline scores. Studies have found inverse associations between age and health literacy levels and self-management skills, but these findings were observed only when comparing older (>65 years of age) with younger individuals, or within a population consisting only of older people (Schuurmans et al., 2005; Paasche-Orlow et al., 2005). Since the current study is comprised of participants younger than 65 years, we deem it likely that the time between baseline, and health literacy and self-management skills measurement, was not significant.

Our results show that for both males and females the educational differences in MetS development were partly mediated by health literacy, consistent with a study reporting similar educational health differences (Stormacq et al., 2019). Based on our findings, health literacy seems to play a larger role than self-management skills in mediating socioeconomic differences in MetS development. Health literacy is focused on maintaining good health (Kwan et al., 2006), whereas self-management skills are focused on maintaining subjective well-being (Steverink et al., 2005). The more prominent role of health literacy may be explained by the fact that maintaining good health has a more direct relation to developing a health outcome such as MetS than does maintaining subjective well-being. Nevertheless, important to note is that our study showed only a minor mediating effect of health literacy and self-management skills on SEP differences in MetS development. SEP-MetS pathways seem to be very indirect, with many underlying factors; this seems to be indicated by the small explanatory role of individual factors such as health literacy and self-management skills.

Our study has several strengths. Its longitudinal design allowed us to study the associations between three different SEP measures and MetS development, focusing on potential moderators and mediators. It is the first study to extensively investigate health literacy and self-management skills in the context of MetS development. Moreover, the study is generalizable to the population of the north of the Netherlands, owing to the representativeness of the Lifelines cohort (Klijs et al., 2015). A limitation of our study is that MetS at T4 was determined without measurement of specific medication use. Nevertheless, a sensitivity analysis including only participants without medication use did not produce substantially different results. Due to the size of the Lifelines cohort, the BHLS and SMAS questionnaires were self-administered. This resulted in a high percentage of missing values for both health literacy and self-management skills. We hypothesize that individuals with low health literacy may have trouble with filling out health-related questionnaires. Furthermore, individuals with lower self-management skills may also lack the self-efficacy and motivation required to fill in questionnaires. For these reasons, response bias may have occurred, possibly causing an overestimation of the actual health literacy level and self-management skills of our study population.

Findings in our study suggest that future studies of socioeconomic differences in MetS development could be conducted on males and females separately. Further, given the relatively limited role of health literacy and self-management skills in mediating the socioeconomic differences in MetS development in this study, future studies should also focus on identifying other factors, and the interplay between these factors, as contributing to the socioeconomic differences in MetS development. Given the indirect nature of the SEP-MetS pathway, future interventions may be effective only when simultaneously targeting multiple domains such as health behaviors, chronic stress, health literacy and self-management skills.

5. Conclusion

Based on this large-scale population longitudinal study, we conclude that associations between the SEP measures education and occupational prestige and MetS development differ for males and females. More years of education, a higher income, and a higher occupational prestige were associated with decrease in the risk of MetS development for females, while for males, only more years of education were associated with a decrease in this risk. Health literacy and self-management skills mediated a small proportion of the educational differences in MetS development for males. Health literacy and self-management skills also mediated a small proportion of the educational and occupational prestige differences in MetS development for females. In conclusion, increasing health literacy and self-management skills in low SEP groups is important, but will not resolve all SEP differences in MetS development.

Ethics approval and consent to participate

Ethical approval for the Lifelines Cohort Study was provided by the Medical Ethical Committee of the University Medical Center Groningen, the Netherlands (Ethics Approval ID: 2007/152). Respondent participation was voluntary; informed consent was obtained from all individual participants, and they were free to withdraw at any time without consequence or penalty. Data were collected and analyzed anonymously. All procedures were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

Data availability statement

The data that support the findings of this study are available from the Lifelines Cohort Study. Restrictions apply to their use: as they were used under license for the current study, they are not publicly available. However, data may be made available by the authors upon reasonable request and with permission of the Lifelines Cohort Study (www.lifelines.nl).

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Author contributions

Conceptualization, H.K.K., L.A.H., and N.S.; Methodology, H.K.K., L.A.H., A.C.L., U.B. and N.S.; Validation, H.K.K., L.A.H., A.C.L., U.B. and N.S.; Formal analysis, H.K.K. and L.A.H.; Writing – Original Draft, H.K.K.; Writing – Review & Editing, H.K.K., L.A.H., A.C.L., U.B. and N.S.; Visualization, H.K.K.; Supervision, N.S.; Project Administration, N.S.; Funding Acquisition, A.C.L., U.B. and N.S.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2022.107140.

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