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THE FACTORS ASSOCIATED WITH BODY MASS INDEX IN ADULTS FROM THE STUDY OF HEALTH IN POMERANIA (SHIP-0), GERMANY

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Objective: To investigate the relation between dental status, BMI and systemic diseases and to evaluate the risk factors for having a higher BMI. Materials and Methods: A population based cross sectional study of 6248 subjects aged 18-80 years (response of 68.8%, n=4310) was conducted in the Study of Health in Pomerania (SHIP-0). Socio-demographic, medical and oral health information was recorded by 5 dentists at two similarly equipped medical/dental services in the cities of Greifswald and Stralsund. Bivariate statistics, multivariate statistics, linear and logistic regression models were performed to assess the relationship between following covariates: gender, educational level, family status, social activities, income, quality of life (SF-12), smoking, alcohol abuse, diabetes, renal disease, high blood pressure, dental status and high physical activity. Results: Significant risk factors for subjects having a higher BMI were: high blood pressure (OR=2.28), diabetes (OR=2.10), educational level (low: OR=1.49; medium OR=1.27), male (OR=1.32) and former smoker (OR=1.20). whereas young age, being single and being dentate (natural teeth, replaced teeth or fixed teeth) was shown to be protective for having a "high" BMI. Conclusion: The most important predictors of BMI were shown to be social and medical factors. Dental factors are most significantly influenced by social factors and also exhibit an important impact on BMI.

Key words: *oral health, BMI, general health, cross-sectional study*

INTRODUCTION

Oral health and dental status have a significant influence on the body mass index (BMI) of humans, especially the elderly (1-4). Dental status can have an impact on food choice and on the intake of key nutrients. Previous studies provide scientific evidence for 20 or more natural teeth being a reasonable threshold for acceptable oral health and a functional dentition into old age (5). It is shown that having 21 or more teeth is consistent with a good dietary capability and optimum nutritional intake (6). Maintaining a healthy functional occlusion has an important additional role to play in maintaining a healthy BMI (7).

Total or partial tooth loss is obviously related to deterioration in general health, reduction in physical, psychological and social capability. In addition, significant relationship has been observed between smoking and total tooth loss (8). Edentulousness is thus a determining factor in the general health of elderly people (9). Social, economic, physiological and psychological factors, as well as adverse health conditions, may influence eating habits and thus the adequacy of dietary intake of older persons. In particular, income level, social isolation, sex, race, level of education, mental and physical condition, consumption of alcohol and drugs, and functional status have been associated with the inadequate intake of calories and nutrients (10, 11).

The widespread prevalence of tooth loss seen in the elderly and the impact of impaired masticatory ability on food selection patterns is often overlooked (3, 12-14). The relationships between masticatory efficiency, diet, and dental status have received considerable attention. There is a general agreement that decreasing quality of natural dentition is associated with decreased efficiency, despite high individual variation (2). Many studies have strongly suggested that the number of occluding teeth, especially in the posterior segments, is correlated with masticatory efficiency (2, 15-17). However, it has been known that the effect of removable partial dentures (RPD) on masticatory efficiency provides only a slight improvement in masticatory performance, with a somewhat greater improvement where it opposes natural teeth, but chewing efficiency is still inferior to that enjoyed with intact natural dentition (2, 18). There is general agreement in the literature that masticatory efficiency with complete dentures is inferior to that with intact dentition (2, 19). A controversial issue is how the role of tooth loss among the elderly is related to nutritional status. A study by Mojon *et al.* found that institutionalized elderly with loss of teeth had an average BMI of 21 kg/m^2 which is low (20). However, Johansson *et al.* (21) reported in their cross-sectional study on edentulous people aged 25-64 years that those who lost the teeth have a higher BMI than dentate individuals (21) (edentulous: men BMI=26.7 and women BMI = 26.8; dentate: men BMI=25.8 and women BMI=25.0).

Several studies have established associations between nutrient intake, nutritional status, and various systemic diseases (22). In addition, recent studies have clearly demonstrated an inverse association between nutrients and the

development of cardiovascular disease (23, 24), stroke risk (25), and cancer (26-29). Oral health status is also related to some systemic conditions, such as cardiovascular disease, pneumonia, diabetes mellitus (30), and nutritional deficiencies (31). Older adults who are under- or overweight should be evaluated for oral health conditions that may affect their nutritional status (32).

Recapitulating diet and BMI are dependent on a complex interaction of biological, environmental, cultural and behavioural influences (1, 3) and is summarized in a theoretical model by Ritchie *et al.* (1). But this interaction has never been computed and confirmed within a large study population.

To understand how various diseases and BMI relate to one another and to prosthetic status a database from a large cross-sectional representative study, the Study of Health in Pomerania (SHIP-0) was evaluated. The hypothesis tested is that there are associations between dental status, BMI, and systemic disease. Secondly, from these associations we aimed to describe the risk factors for having a BMI above the normal range ("high" BMI).

MATERIAL AND METHODS

Data collection

A total of 6248 subjects aged 18 to 80 years were invited to participate in SHIP. The participants gave their written informed consent and the study was approved by the local ethics committee. The sample had been randomly drawn after stratification by age and gender from official inhabitant lists that are representative of the population (33, 34). Overall 69% (4,310) gave their consent and were examined. The medical and dental examinations took place in two similarly-equipped medical / dental facilities in the cities of Greifswald and Stralsund. The examination was performed by 5 dentists (alternating daily) from the Dental School of the University of Greifswald. All examiners received formal training in assessing these measures and indices, both before and twice a year during data collection. Dental experts in the oral indices and measures used in the clinical protocol served as standards for training the field examination teams. The protocol aimed to reduce systematic and random measurements errors. Replicate examinations were conducted periodically throughout data collection to maintain both intra- and inter-examiner calibration. Details of the study have been described previously, for the study design see John *et al.* (34), for the dental part see Hensel *et al.* (33).

Classification of covariates

Social factors comprised variables on age, gender, educational level, income, and family status. Age, gender, educational level and family status were derived from the medical interview. Educational level was classified into three groups: < 8 years (low), 8 to 11 years (medium), and > 11 years (high). Responses regarding monthly household-income were classified into 22 groups from less than DM 400 (~200 €) to DM 15,000+ (~7,500 €). For statistical purposes, income is considered as continuous variable. Family status was classified into five groups: married-live together; married-live apart; single; divorced; and widowed.

As psychosocial factors, we considered the number of friends or relations which have contact with the subject at least once a week (meeting at least twice was considered as having regular friendships) and the number of weekly activities (*i.e.* having a hobby or being in a club at least once a week). These variables were taken from the self reported questionnaire.

As a marker for Quality of Life (QoL) the Short-Form 12 (SF-12) presented by psychological and physical scale was used (35, 36).

Participants smoking cigarettes, cigars or pipes on a regular basis were considered as current smokers. Smokers who had quit smoking or did not smoke regularly were considered as former smokers. Subjects smoking more than 15 cigarettes daily were considered as heavy smokers. The questions on smoking were taken from the health related interview.

To validate questions on alcohol consumption, the marker for alcohol abuse, Carbohydrate Deficient Transferrin (CDT), was taken from blood analyses of the subjects (37). Participants with a CDT ≥ 6% and positive according to Luebeck Alcohol Dependence and Abuse Screening Test (LAST) (37) were considered as alcohol abusers. The questions to identify alcohol abusers were taken from the interview and the questionnaire.

The 13 most frequent diseases in Germany were chosen as medical factors (38). To validate questions on diabetes, the marker for diabetes, Haemoglobin A_{1C} (HbA_{1C}), was taken from blood analyses (39). Participants having an HbA_{1C} of ≥ 7% were considered as diabetics. The following diseases were recorded from the interview: renal disease, rheumatism, heart failure, high blood pressure, any cancer, allergy, stroke, intestinal diseases, arthrosis, chronic bronchitis, arthritis, osteoporosis, vertebral degeneration, blood diseases.

To identify participants who exhibited a healthier lifestyle, physical activity data from a self administered questionnaire were taken. Subjects performing physical activity more than 60 min per week were considered as sportive or as having a healthy lifestyle (40). The measurement of weight and height were taken during the medical examination by the medical staff of SHIP. The BMI is computed as weight (kg) divided by height (m) squared (kg/m^2). The classification of subjects having a BMI above the normal range ("high" BMI) (41) is presented in *Table 1*.

To determine the dental condition of the participants, dental status was classified into four groups according to tooth loss. Group CD was comprised of participants who were missing all teeth and who wore a complete denture in either the upper or lower jaw or both. Group RPD was comprised of participants who had a removable partial denture in either the upper or lower jaw or both. Group 10T+ consisted of participants who had no removable denture and 10 or more natural teeth in at least one jaw with or without a fixed prosthesis in either the upper or lower jaw or both. Group 9T- consisted of participants who had no removable denture and less than 10 natural teeth with or without fixed prosthesis in either the upper or lower jaw or both.

Participants in group 10T+ or 9T- had, on average, less than one pontic (tooth gap treated with FPD) in each jaw and were considered as having fixed prosthesis.

The maximum number of teeth in this study was 28 (3^{rd} molar not included).

Statistical analyses

All continuous variables were tested according to normal / non-normal distribution by P-P plot and Kolmogorov-Smirnov-Test to show that they followed a non-normal distribution. Results are therefore presented as medians and Inter Quartile Ranges (IQR) or as percentages.

Table 1. Body Mass Index (BMI) above the normal range classified as "high" BMI in various age groups according to Schafer (Schafer, 1998)

age	regular BMI	“high” BMI
19-24 yr	19-24 kg/m^2	>25 kg/m^2
25-34 yr	20-25 kg/m^2	>26 kg/m^2
35-44 yr	21-26 kg/m^2	>27 kg/m^2
45-54 yr	22-27 kg/m^2	>28 kg/m^2
55-64 yr	23-28 kg/m^2	>29 kg/m^2
65+ yr	24-30 kg/m^2	>30 kg/m^2

For the purpose of analyses, an estimated household income was computed as the midpoint between the interval limit of the income class to which the subject belonged. The estimated income followed a normal distribution according to a P-P plot.

Table 2. Distribution of covariates which show a significant correlation to BMI in various age-groups

	18-34 yr n (%)	35-54 yr n (%)	55-74 yr n (%)	75-79yr n (%)	missing n (%)
gender male	447 (46.0)	707 (46.9)	798 (52.2)	164 (54.5)	1 (0)
female	525 (54.0)	800 (53.1)	731 (47.8)	137 (45.5)	
educational level					
low	94 (9.8)	292 (19.5)	1090 (71.9)	238 (80.1)	
medium	655 (68.0)	948 (63.2)	269 (17.7)	44 (14.8)	33 (0.8)
high	214 (22.2)	260 (17.3)	158 (10.4)	15 (5.1)	
family status					
married, live together	316 (32.5)	1120 (74.4)	1153 (75.9)	148 (49.7)	
married, live apart	13 (1.3)	44 (2.9)	7 (0.5)	1 (0.3)	
single	608 (62.6)	132 (8.8)	54 (3.6)	1 (5.7)	16 (0.4)
divorced	32 (3.3)	173 (11.5)	104 (6.8)	1 (4.7)	
widowed	2 (0.2)	36 (2.4)	202 (13.3)	11 (39.6)	
activities (yes)	320 (33.1)	383 (25.9)	304 (20.7)	4 (14.2)	109 (2.5)
(no)	646 (66.9)	1098 (74.1)	1168 (79.3)	24 (85.8)	
smoking	375 (20.4)	614 (33.3)	691 (37.5)	162 (8.8)	
former smoker	474 (22.5)	839 (39.8)	673 (31.9)	122 (5.8)	1 (0)
< 15 cig/d	206 (32.2)	315 (49.3)	111 (17.4)	7 (1.1)	
≥ 15 cig/d					
diabetes (yes)	5 (0.5)	46 (3.1)	136 (9.0)	37 (12.4)	68 (1.6)
(no)	947 (99.5)	1437 (96.9)	1373 (91.0)	261 (87.6)	
renal disease (yes)	63 (6.5)	102 (6.8)	273 (18.1)	82 (27.7)	39 (0.9)
(no)	903 (93.5)	1397 (93.2)	1237 (81.9)	214 (72.3)	
high blood pressure (yes)	204 (21.7)	555 (37.3)	793 (52.5)	178 (59.9)	75 (1.7)
(no)	738 (78.3)	931 (62.7)	717 (47.5)	119 (40.1)	
prosthetic status					
CD	4 (0.4)	86 (5.7)	547 (35.9)	210 (70.0)	
RPD	34 (3.5)	302 (20.1)	455 (29.9)	55 (18.3)	21 (0.5)
10+T	912 (94.4)	1022 (68.2)	395 (25.9)	15 (5.0)	
9-T	16 (1.7)	89 (5.9)	127 (8.3)	20 (6.7)	
physical activities (yes)	199 (20.6)	211 (14.4)	146 (10.0)	13 (4.7)	133 (3.1)
(no)	765 (79.4)	1259 (85.6)	1319 (90.0)	265 (95.3)	
monthly income € (median (IQR))	1218 (1218)	1667 (1087)	1368 (703)	1218 (703)	250 (5.8)
QoL physical scale	53.8 (6.1)	52.2 (7.4)	47.7 (15.0)	44.2 (17.0)	250 (5.8)
psychological scale (median (IQR))	52.6 (8.8)	53.7 (8.4)	55.6 (9.1)	56.0 (10.3)	
BMI (median (IQR))	23.8 (5.5)	26.7 (6.2)	28.3 (5.4)	28.1 (5.2)	250 (5.8)

CD = subjects that had a complete denture in either the upper or lower jaw or both.
RPD = subjects that had no complete denture but a removable partial denture in either the upper or lower jaw or both.
10T+ = subjects having no removable denture and 10 or more natural teeth in at least one jaw with or without fixed prosthodontics in either the upper or lower jaw or both.
9T- = subjects having no removable denture and less than 10 natural teeth with or without fixed prosthodontics in either the upper or lower jaw or both.
IQR = inter quartile range
BMI = Body Mass Index

All variables were age adjusted and checked for significance according to BMI by using univariate analysis.

To describe how oral health and BMI might relate to the different lifestyle factors, a linear regression analysis was used to identify risk markers with BMI as dependent variable using a stepwise backward method with a cut-off point of 0.20 for removal and 0.15 for re-entering the variable. The covariates were entered into four blocks. The first block contains variables on social factor, psychosocial factors, QoL, smoking and drinking. The second block contains the prosthetic status, the third diseases and the last physical activity. Age was classified into four groups: 34 years or less, 35 to 54 years, 55 to 74 years, and 75 to 79 years to avoid residual confounding. The odds *ratio* (OR) and 95% confidence interval (CI) were computed from the β coefficient. Significance was considered when a p-value of 0.05 or less was found. The linear regression model was re-analyzed with different variations of the variable age (categorized and continuous, age^2) in order to control for this confounding. The analysis yielded similar results with respect to the hypothesized association.

To describe the risk factors for subjects having a BMI above the normal range ("high" BMI), we used a logistic regression analysis with "high" BMI as the dependent variable. The covariates and statistical adjustment were the same as was used in the linear regression analysis.

RESULTS

The distribution of 4,310 participants show that 972 subjects were in the age cohort 20 to 34 years (22.6%), 1508 subjects in the age cohort 35 to 54 years (34.9%), 1529 subjects in the age cohort 55 to 74 years (35.5%) and 301 subjects in the age cohort 75 to 79 years (7.0%). The following covariates showed a significant correlation to BMI using bivariate analysis: gender, educational level,

Table 3. Final linear regression model with BMI as the dependent variable

	non stand. coefficient B	stand. coefficient Beta	significance	coll. statistic VIF
Income	-0.0002	-0.050	0.005	1.44
gender (males)	0.432	0.044	0.007	1.20
age <35	-2.024	-0.179	0.000	1.69
age 55-74	0.106	0.011	0.613	1.95
educational level low	0.641	0.061	0.003	1.82
educational level high	-0.381	-0.029	0.079	1.23
married live together	0.009	0.001	0.946	1.72
divorced	-0.430	-0.024	0.166	1.31
physical scale	-0.045	0.081	0.000	1.23
psychological scale	0.036	0.063	0.000	1.07
former-smoker	0.520	0.053	0.001	1.17
≥10 teeth	-0.173	-0.017	0.364	1.67
≤9 teeth	0.646	0.031	0.052	1.12
physical activity	-0.401	-0.029	0.057	1.05
high blood pressure	2.327	0.234	0.000	1.10
diabetes	2.338	0.099	0.000	1.06
renal diseases	-0.772	-0.049	0.001	1.05

family status, social activities, smoking, diabetes, renal disease, high blood pressure, prosthetic status, physical activities, and quality of life. The distribution of significant covariates by age groups is shown in *Table 2*.

The relationship between dental status, BMI and systemic diseases are presented in *Table 3*. Significant factors for a lower BMI include age less than 35 yr, better physical condition (high physical scale) and suffering from renal disease. In addition, a high educational level (p=0.079) and more physical activity (p=0.057) show a tendency towards being significant factors for a low BMI. Significant factors associated with a higher BMI are male gender, low educational level, feeling psychological well (high psychological scale), former smoker, having high blood pressure and diabetes. Having 9 teeth or less in at least one jaw is also significant (p=0.052).

Risk factors for having a BMI above the normal range ("high" BMI, 38.4%) are presented in *Table 4*. Significant odds ratios of 1 or more are shown by gender (males: OR=1.32), low educational level (OR=1.49), middle educational level (OR=1.27), former smoker (OR=1.20), having diabetes (OR=2.10) and having high blood pressure (OR=2.28). Protective factors against having a "high" BMI which have significant odds ratios below 1 are being single (OR=0.69), having 10 or more teeth (OR=0.66), having a RPD (OR=0.71), having a complete denture (OR=0.59) or suffering from renal disease (OR=0.67).

Table 4. Final logistic regression model with "high" BMI as the dependent variable

		Regression coefficient B	Significance	OR	95%CI
Age		-0.021	0.000	0.98	0.97-0.99
gender (male)		0.277	0.000	1.32	1.13-1.54
educ. level	low	0.396	0.002	1.49	1.16-1.90
educ. level	medium	0.235	0.030	1.27	1.02-1.56
educ. level	high (ref)		0.007		
Single		0.363	0.042	0.69	0.49-0.99
physical scale		-0.018	0.000	0.98	0.97-0.99
psychological scale		0.130	0.002	1.01	1.00-1.02
former smoker		0.184	0.015	1.20	1.04-1.39
10+ teeth		-0.410	0.009	0.66	0.49-0.90
RPD		-0.341	0.035	0.71	0.52-0.98
complete denture		-0.522	0.002	0.59	0.43-0.82
renal disease		-0.396	0.001	0.67	0.54-0.84
diabetes		0.742	0.000	2.10	1.53-2.89
high blood pressure		0.825	0.000	2.28	1.98-2.64

Nagelkerke r^2: 0,115
OR = Odds Range
95%CI = 95 % Confidence Interval
Ref = Reference Group

DISCUSSION

Multiple factors such as the number of teeth, dental (prosthetic) status, age, sex, educational level, family status, quality of life, specific diseases, smoking, and physical activity influence the BMI (1, 7, 10, 11).

To our knowledge this is the first study that is powerful to compute a previously developed theoretical model (1) based on numerous risk factors related to BMI. The most noteworthy finding in this study was that prosthetic status has an impact on BMI and there is no doubt that the number of teeth - independent of whether they are replaced or natural - has an impact on BMI, which is an indicator of nutrition status. It is well known that individuals without teeth or prosthetic devices to replace missing teeth avoid hard foods and prefer soft food that can be mashed by the alveolar bone or the tongue (2). Previous studies have reported a close relationship between the number of occluding molars and chewing efficiency (2, 15). In this study, we found that the dental status is significantly associated with a high BMI. In other words, dentate patients or patients wearing prosthetic tooth replacements appear to have a lower BMI than those who are edentate or who have not replaced their missing teeth. This was confirmed using bivariate analysis in 1994 by Johansson *et al.* (21) In the same study, using a logistic regression analysis of age, education, diet and CVD risk factors simultaneously on dental status (teeth/no teeth), BMI showed no significant correlation in the final model for males (OR = 1.13, $p>0.05$) but significant correlation for females (OR=1.34, $p<0.01$). However, in 1999 Mojon *et al.* (20) reported the contrary: elderly with low dentition and a BMI of 21kg/m^2 or less were considered to be malnourished. However, their study was done among institutionalized subjects aged 85+ years and thus cannot be compared directly to the population of SHIP.

Metabolic diseases have the greatest impact on BMI: diabetes (OR = 2.1), high blood pressure (OR = 2.28) and renal disease (OR = 0.67) as presented in *Table 4*. Although not found in this study, other diseases that have been established to be associated with nutrition and BMI include cardiovascular disease (23, 24, 43), stroke (25), and cancer (22, 26-29). Increased BMI was associated with increased prevalence of diabetes mellitus, hypertension and dyslipidaemia in some studies (43).

Bivariate analysis to screen for risk factors in multivariate analysis is controversial (44). Nevertheless, we tested the significance of all covariables against BMI for incorporation into the regression analysis. Based on bivariate analysis of the 13 most common diseases in Germany, only three, diabetes, high blood pressure, and renal disease, were shown to be significantly related to BMI. Our final model could be different if all common diseases had been incorporated.

Another important influence on BMI is the social environment. Two factors are representative of social status: educational level and income. The lower the educational level (low educational level OR = 1.49) and the lower the monetary

income, the higher the BMI. Social status has also been found to have an influence on the health consciousness of people and on their prosthetic status (45). An underdeveloped interest in health, which could lead to few medical and dental check ups, was shown to be related to the number of natural teeth and the manner and quality of prosthetic treatment (45).

Age is also an important factor. Young subjects normally have lower BMI's than the elderly. In this study, the young participants may have had a more highly developed consciousness of their overall health status. This can also be seen in their physical activity patterns (46). Some studies have shown an association between low physical activity, high BMI and inadequate dietary patterns (43, 47). Almost all of the 20-34 yr old participants report that they participate in sports regularly, with a decreasing percentage as age increases. Physical activity in this study appeared to have little impact on BMI. This might be because the tool for measuring physical activity was not sensitive enough to detect differences. There are controversial results on the relationship between smoking and BMI. For example, it was shown that Canadian school youth who are less physically activate and who smoke have an increased risk for obesity (48). On the other hand adolescents who were regular smokers had shown significantly low BMI (49). In this study, smoking had a minor impact on BMI, but former smokers seemed to have higher BMI's. One reason for this finding might be due to the numerous covariates entered in the regression analysis.

Quality of life expressed by physical contentment (physical scale) leads to low BMI while psychological contentment (psychological scale) increases it. This is confirmed by a study in which the author investigated the relationships between scores on the mental and physical components of the SF-12 and BMI (controlling for age, sex, and family income). He showed that quality of life scores were optimal when BMI was in the normal range (50).

No influence at all has been attributed to the number of friends, amount of leisure activities, and quantity of alcohol used. In this study, alcohol abuse was not found to be important. However, that could be due to the fact that few alcoholics participated in SHIP and the criteria used to classify alcohol abuse were set very high.

The most important factors associated with BMI are social and medical factors. Dental factors are influenced by social factors (10, 11, 45) but, as shown in the study, also have an indirect and important impact on BMI (1-3, 15).

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