Margreet S. Duetz[1], **Thomas Abel**[1], **Christoph E. Minder**[2]

[1] *Division of Social and Behavioural Health Research, Department of Social and Preventive Medicine, University of Bern*
[2] *Department of Social and Preventive Medicine, University of Bern*

Clarifying gender interactions in multivariate analysis

Summary

Objectives: To examine a linear regression model to predict physical fitness using an alternative concept to analyse gender interactions.
Methods: Data were obtained from the Berne Lifestyle Panel, a survey on health and lifestyles of 56–66 years old Bernese citizens. A measure of physical fitness was regressed on gender, education and their interaction as central explanatory variables and age as confounding factor. For ease of interpretation, two dummy variables of education are introduced, one for female, the other for male education. The model with education dummy variables is compared to a linear regression model without interaction stratified by gender, and with a model with the multiplicative gender-education interaction term without stratification.
Results: The use of dummy variables ensures an accurate description of both women's and men's associations of education with the dependant variable, without losing any explanatory power due to stratification.
Conclusion: The results show that the use of dummy variables is a rewarding alternative to stratification and conventional gender interaction analysis, providing both sufficient statistical information and a basis for straightforward interpretation.

Keywords: Gender – Regression analysis – Interaction – Lifestyle – Fitness.

Working on regression models with gender as an explanatory variable of central importance, we often are faced with the question how to quantify its effects while ensuring both clarity and accuracy in the final presentation. In case gender shows relevant interactions with other explanatory factors, the choice of a model is even more challenging. In 1996, Kunkel and Atchley suggested multivariate analysis stratified by gender as a first choice of presentation. Stratified analysis estimates effects for each explanatory variable separately for each stratum, for instance women and men. Differential effects of explanatory variables between men and women are easily noticeable by comparing the measures of effect of the cofactor in question between gender strata. The comparison between single coefficients may not always be valid, however, as confounding is accounted for to different extents by the various co-variables in both gender strata. Stratified analysis, moreover, goes along with loss of power by reducing sample sizes and necessitates the use of twice as many statistical parameters, which sometimes complicates communication.

Models using multiplicative interaction terms of gender with the variable of interest with both men and women in the sample circumvent the disadvantages of stratified analysis.

Both sample size is kept and measures of statistical significance are ensured, resulting in a high share of variance to be explained, a relatively simple model and quantified evidence of interaction. Often readers struggle, however, with the interpretation of the coefficients of the interaction terms, and a differential description of effect of the interacting cofactor in men and in women is not obvious.

The goal of this paper is to examine an alternative method of modelling and presenting gender interaction and compare it with stratified analysis and conventional multiplicative gender interaction analysis.

The model of differential gender effects proposed in the present study applies the well-established concept of measuring differential effects by using variables carrying data concerning one gender at a time. From hereon we will refer to these variables as “dummy-variables”, in absence of a more suitable term. Such models are mathematically equivalent to models

Soz.- Präventivmed. 48 (2003) 252–256
0303-8408/03/040252–04
DOI 10.1007/s00038-003-2088-5

using multiplicative interaction terms, yet dummy variables have been rarely applied in the context of gender interactions (Retherford & Choe 1993; Goodman et al. 1997; Palazzo & Evans 1993; Rutledge et al. 1996). In our opinion, however, this procedure serves the understanding of gender as a category showing close and complex associations with other social, psychological and environmental factors (Chen et al. 2002).

In this paper, the principles of showing differential gender effects making use of dummy variables are demonstrated by means of analyses of a sample of 56 to 66 years old Swiss men and women (Abel et al. 1999). The basic linear regression model considers physical fitness as dependent variable and gender, age and education as explanatory variables. The gender specific effects of education will be examined by the introduction of dummy variables measuring "female education", and "male education".

Methods

Data were used from the Berne Lifestyle Study, a survey on health-related lifestyles. The survey was carried out in three waves from 1996 to 1998. In 1996, 1 119 (64.4 %) of the 1913 sampled men and women participated, 923 (82.9 %) of whom participated also in the second wave (Abel et al. 1999). In this paper, only data of the second wave were used. The data were gathered using CATI, a computer-assisted telephone interview technique.

In order to assess *physical fitness*, a 12-item questionnaire developed by Bös et al. was used (2002). This scale measures physical fitness in four dimensions: muscle strength, endurance, agility, and co-ordination. Each of those dimensions is covered by three questions. The end score consisted of the mean score of the 12 items and had a maximum of five points. In regression analysis, a *z*-standardized version of the fitness variable was used.

Highest level of *education* was recorded in seven categories: primary school, secondary school, commercial school, vocational school, grammar school, college of education, and university. The educational categories are well ordered, the numerical of each category indicating its rank. Higher scores on this education scale indicate a higher level of education on any level of the scale. The *age* variable was calculated out of the year of birth and year of interview and ranged from 56 to 66 years. A conventional multiplicative *interaction term* of gender and education was created. For this purpose, a z-standardised version of the education variable was used and the gender variable was coded 1 for women and 2 for men.

Two new variables were created, one carrying the educational status in seven categories for women and a zero score for men, the other carrying educational status in seven categories for men and a zero score for women.

Statistical analysis

Table 1 shows general statistical characteristics of the variables physical fitness, age, and education. Statistical significance of gender differences was tested for with T-tests for independent samples. The corresponding results are indicated in column "Mean women/men". Correlation values, expressed in Spearman's r, of all basic indicators are listed in Table 2 for women and men separately. Multivariate analysis was performed using linear regression models, applying the standardized version of the dependent variable physical fitness (Tab. 3–5).

Table 1 Basic statistical information

Variable	Range (minimal/ maximal)	Total mean	Total median	Total SD	Mean women/ men	p-value mean[1]	Median women/ men	SD women/ men	Numer (N) women/ men
Fitness[2]	1/5	3.63	3.75	0.88	3.33/ 4.01	0.000	3.42/4.21	0.85/0.77	509/412
Age	56/66	60.99	61	3.24	61.16/60.77	0.073	61/61	3.21/3.27	509/412
Education	1/7	3.13	3	1.74	2.64/ 3.73	0.000	3/3	1.40/1.93	509/412

[1] Statistical significance of gender differences: T-Test for independent samples
[2] For regression analysis, the fitness variable was z-standardized

Table 2 Bivariate correlations; Spearman's r

Women: n = 509 Men: n = 412		Women		Men	
		Spearman's r	P-value (two-sided)	Spearman's r	P-value (two-sided)
Physical fitness by	Age	−0.169	0.000	−0.209	0.000
	Education	0.207	0.000	0.090	0.069
Age by	Education	−0.112	0.011	−0.082	0.096

Table 3 Regression of physical fitness on age and education, stratified by gender

n = 509 (women), 412 (men)	Physical fitness					
	Women			Men		
	β-coefficients (not standardized)	Standardized Beta-coefficients	P-value	β-coefficients (not standardized)	Standardized β-coefficients	P-value
Age	−0.042	−0.140	0.001	−0.048	−0.180	0.000
Education	0.140	0.204	0.000	0.038	0.084	0.085
R^2	0.069			0.042		

Results

In both men and women, age correlates negatively and statistically significantly above the p = 0.05 level with physical fitness and level of education. The negative correlation of age and education is only statistically significant in women. Fitness and education are positively and significantly correlated only in women. The first basic linear regression model, presented in Table 3, consisted of physical fitness as dependent variable and age and education as explanatory variables, calculated separately for female and male participants.

Table 4 Regression of physical fitness on gender, age, education and the multiplicative interaction term of gender and education

Physical fitness			
N = 921	β-coefficients (not standardized)	Standardized β-coefficients	P-value
Gender	0.984	0.489	0.000
Age	−0.045	−0.145	0.000
Education	0.241	0.419	0.000
Interaction: Gender* Education	−0.101	−0.371	0.006
R^2	0.198		

Table 5 Regression of physical fitness on gender, age, "female education" and "male education"

Physical fitness				
N = 921	β-coefficients (not standardized)	Standardized β-coefficients	P-value	P-value of gender difference
Gender	0.984	0.489	0.000	
Age	−0.045	−0.145	0.000	
Female education	0.139	0.234	0.000	
Male education	0.038	0.087	0.095	−0.006 [1]
R^2	0.198			

[1] From model with multiplicative gender-education interaction term (Tab. 4)

β-coefficients of age in this model were statistically significant for both genders, whereas the education β-coefficient only was significant for the female sample. The second model (Tab. 4) was calculated using the aggregated sample with both genders, with the gender variable as well as a standard multiplicative interaction term of gender and education added to the first basic model. The interaction between the associations of gender with fitness and that of education and fitness is shown by a negative and statistically significant β-coefficient of the multiplicative interaction term. In the last model, the education variable and interaction term were replaced by two dummy variables of the education measure, one concerning female, the other concerning male education (Tab. 5). As in the multiplicative interaction model, the gender variable must be included in the model with the education dummy variables, in order to prevent distortion due to gender dependent base line differences. In Table 5, the differential associations of education with physical fitness in men and women are presented in a model using the segregated sample. The near-absence of association in men and the statistically significant positive association in women are confirmed. The P-value of interaction stems from the multiplicative interaction analysis in Table 4.

In the last two models that deal with gender interaction in different ways, subjects with missing values in either of the interaction variables were excluded. Missing values would have led to different degrees of freedom in the two interaction models, as a different number of explanatory variables would have been involved. Apart from consequences of eventual missing values, these two models are mathematically equivalent.

Discussion

Gender-stratified regression analysis of physical fitness on age and education shows a near- absent association of education and fitness in men and a significant positive association in women. Analysis with a multiplicative gender-education interaction term shows the statistical significance of this differential association.

Without having knowledge of the table with stratified results, the interpretation of the gender-education interaction is difficult. The sign of the coefficient to the interaction term would indicate that the association between education and fitness must be stronger in women than in men. Also, as the plain education variable shows a significantly positive β-coefficient, the overall association of education with fitness must be positive. One wouldn't know, however, whether this situation is due to a slightly negative association in men and a positive association in women, or with positive associations in both genders, if more strongly so in women. Therefore, both possibilities must be considered. The analysis using dummy-variables straightforwardly confirms the latter explanation and, moreover, quantifies the fitness-education associations in both women and men without loosing any of the model's power.

Although interaction analysis using dummy variables is mathematically equivalent to conventional interaction analysis, it represents a slightly different view on gender interaction. Conventional interaction analyses would suggest that gender influences educational effects, or the other way around. The model using dummy variables, by virtue of its use of two independent variables for education rather suggests a fundamentally different character of "female education" as compared to "male education". The differential coefficients of the central explanatory variable, in the present example male and female education, illustrate and clarify the different consequences of certain characteristics for both sexes.

Introducing gender dummies does not immediately provide statistical information on the significance of the gender interaction. It may therefore be helpful to mention the confidence interval or p-value of the analogue conventional multiplicative interaction term together with the statistics for the variables "female education" and "male education" (Tab. 5). Alternatively, the fit of the model with multiplicative interaction terms can be compared with those of the model using gender differential dummy variables, in case the applied statistical software provides this function.

A general drawback of multivariate analysis which, unfortunately, cannot be solved by expressing interactions using dummy variables, is the bias caused by the exclusion of subjects with missing values. Multivariate analysis often is the method of first choice to tackle bias caused by confounding, which then is replaced by bias caused by the selection of complete data. Another problem is that in a strict sense, the education variable is an ordered categorical variable which is treated like a numeric variable in the linear regression models. Further analysis, however, showed that we can safely assume education to be linearly related to physical fitness. The categorization of the educational variable is strongly related to the duration of education, which might partly explain the linear character of the variable.

The basic regression model used in this study explaining the variance of physical fitness by gender, age, education and gender-education interaction is a reduced and simplified version of an earlier documented model and serves but the goal of illustrating the different means of presenting gender interactions (Duetz et al. 2003). Additional indicators of socio-economic status, psycho-social resources and further interaction terms would contribute substantially to the strength of the model, but have been omitted for clarity of presentation.

In conclusion, analysis and presentation of gender interactions in linear regression using dummy variables may serve as a rewarding alternative to stratified analysis and conventional gender interaction analysis, providing both sound statistical information and a basis for straightforward interpretation.

Acknowledgement
The Berne Lifestyle Survey was facilitated by a grant from the Swiss National Foundation (Schweizerischer Nationalfonds).

Zusammenfassung

Zur Untersuchung von Gender-Interaktionen in multivariaten Analysen

Fragestellung: Überprüfung eines linearen Regressionmodells, welches auf einem alternativen Konzept zur Analyse von Interaktionen mit der Variable Gender basiert.

Methoden: Es wurden Daten aus dem Berner Lebensstil-Panel verwendet, einer Bevölkerungsstudie zu gesundheitsrelevanten Lebensstilen von Berner und Bernerinnen im Alter vom 56–66 Jahren. Ein Regressionsmodell mit einem Indikator für physische Fitness als abhängige Variable und den zentralen erklärenden Variablen Gender, Bildung, deren Interaktion sowie Alter als Verzerrungsfaktor wurde getestet. Zur Vereinfachung der Interpretation wurden zwei Dummyvariablen eingeführt: Bildung bei Frauen und Bildung bei Männern. Das Modell mit den Dummyvariablen zu Bildung wurde mit einem linearen Regressionsmodell ohne Interaktionen mittels des nach Gender stratifizierten Datensatz verglichen, sowie mit einem Modell der multiplikativen Interaktion von Gender und Bildung ohne Stratifikation.

Ergebnisse: Der Einsatz von Dummyvariablen gewährleistet eine akkurate Beschreibung des Zusammenhangs von Ausbildung mit der abhängigen Variable physische Fitness sowohl bei Frauen als auch bei Männern, ohne dass die durch Stratifikation aufgeklärte Varianz verloren geht.

Schlussfolgerungen: Die Anwendung von Dummyvariablen erweist sich als lohnende Alternative zur Stratifizierung sowie zur konventionellen Analyse von Interaktionen mit Gender, und ermöglicht sowohl wichtige statistische Kennwerte als auch eine eindeutige Interpretation.

Résumé

Etude des interactions de genre par l'analyse multivariée

Objectifs: Le but de cet article est d'examiner un modèle de régression linéaire pour prévoir la santé physique en utilisant un concept alternatif pour analyser des interactions de genre.

Méthodes: Des données ont été obtenues à partir du Berner Lebensstil Panel, une étude sur la santé et des modes de vie des citoyens Bernois de 55 à 65 ans. Une mesure de santé physique a été régressée sur le genre, l'éducation et leur interaction comme variables explicatives centrales ainsi que sur l'âge comme facteur de confusion. Pour la facilité de l'interprétation, deux variables dichotomiques d'éducation sont présentées, l'une pour les femmes, l'autre pour les hommes. Le modèle avec les variables dichotomiques d'éducation est comparé à un modèle de régression linéaire sans interaction, stratifiée pour le genre, et avec un modèle incluant l'interaction multiplicative genre-éducation calculée pour l'échantillon total.

Résultats: L'utilisation des variables dichotomiques assure une description précise des associations de l'éducation avec la variable dépendante (santé physique) pour les femmes et les hommes, sans perdre de la puissance explicative due à la stratification.

Conclusion: Les résultats montrent que l'utilisation des variables dichotomiques est une alternative enrichissante pour l'analyse stratifiée et l'analyse conventionnelle d'interaction de genre, fournissant l'information statistique suffisante et une simplicité d'interprétation.

References

Abel T, Walter E, Niemann S, Weitkunat R (1999). The Berne-Munich Lifestyle Panel. Background and baseline results from a longitudinal health lifestyle survey. Soz Praventiv Med *44*: 91–106.

Bös K, Abel T, Wol A, Niemann S, Tittlbach S, Schot, N (2002). Der Fragebogen zur Erfassung des motorischen Funktionsstatus (FFB-Mot). Diagnostica *48*: 101–11.

Chen J, Krieger N, Van Den Eeden S, Quesenberry C (2002). Different slopes for different folks: socioeconomic and racial/ethnic disparities in asthma and hay fever among 173,859 U.S. men and women. Environ Health Perspect *110*: 211–6.

Duetz M, Abel T, Niemann S (2003). Health measures: differentiating associations with gender and socio-economic status. Eur J Public Health (in print).

Goodman E, Amick BC, Rezendes MO, Tarlov AR, Rogers WH, Kagan J (1997). Influences of gender and social class on adolescents' perceptions of health. Arch Pediatr Adolesc Med *151*: 899–904.

Kunkel SR, Atchley RC (1996). Why gender matters: being female is not the same as not being male. Am J Prev Med *12*: 294–6.

Palazzo M, Evans R (1993). Logistic regression analysis of fixed patient factors for postoperative sickness: a model for risk assessment. Br J Anaesth *70*: 135–40.

Retherford RD, Choe MK (1993). Multiple regressions. In: Statistical models for causal analysis. New York: Wiley & Sons: 29–68.

Rutledge PC, Hancock RA, Rutledge JH (1996). Predictors of thought rebound. Behav Res Ther *34*: 555–62.

Address for correspondence

Dr. med. Margreet S. Duetz
Division of Social and Behavioural Health Research
Department of Social and Preventive Medicine
Niesenweg 6
CH-3012 Bern
Tel.: +41 31 631 35 26
Fax: +41 31 631 34 30
e-mail: duetz@ispm.unibe.ch

Soz.- Präventivmed. 48 (2003) 252–256