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Compliance with dietary recommendations of the German Nutrition Society is associated with reduced risk of frailty

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Summary

The nutritional habits of 192 community-dwelling senior citizens (75 years of age or older) were documented using a Healthy Eating Index (HEI-GFP, max. 110 points) based on the dietary recommendations of the German Nutrition Society (DGE). Frailty was defined by following criteria: weight loss, fatigue, low physical activity, low handgrip strength and slow walking speed. The HEI-GFP was significantly lower in frail subjects than in pre-frail and non-frail subjects (61.0 ± 8.4 vs. 65.1 ± 10.3 vs. 66.5 ± 9.3; $p < 0.05$). The risk of frailty was significantly reduced in the highest quartile of the HEI-GFP (≥ 71.25 points) (odds ratio [OR] 0.07; 95 % confidence interval [95 %-CI] 0.01–0.58). Conclusion: In persons over 75 years of age living at home, a stronger adherence to the dietary recommendations of the DGE was associated with a reduced risk of frailty.

Keywords: frailty, Healthy Eating Index, dietary recommendations, inflammation

Introduction

The geriatric syndrome frailty is characterised by a reduced tolerance for internal and external stressors and is associated with a loss of physical functionality and numerous negative health-related consequences, such as cardiovascular and pulmonary diseases and the loss of independence [1–3].

With a prevalence of approximately 17 %, frailty is also very widespread throughout the world among senior citizens living at home [4]. Besides hormonal changes and inflammatory processes, nutrition is being discussed as an important factor influencing the emergence of frailty. Here, in addition to sufficient food intake, the content of nutritive substances in the diet appears to be of particular importance [5–9].

However, data on the intake of nutrients do not necessarily reflect the overall dietary quality. In order to describe this food-based indices are used, of which the most widely used index is the Healthy Eating Index (HEI) [10]. The HEI is a score, in which a high intake of foods considered to be healthy are acknowledged with a higher score, while the consumption of foods considered to be unhealthy is assigned a lower score. The original HEI and variations thereof were tested for their ability to predict risks for disease. Negative correlations with overweight, diabetes mellitus type 2 [11], colorectal cancer [12], cardiovascular diseases [13] and inflammatory markers in the blood [14] were found. Accordingly, health-promoting dietary habits can prevent different diseases which, according to Fried [3] are closely associated with frailty. We therefore proposed the hypothesis that there is a direct correlation between diet quality, quantified as the Healthy Eating Index, and frailty.

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Methods

Study design

In this cross-sectional study 206 voluntary study participants were recruited in the Nuremberg region from August 2009 to September 2010. The participants were found by an announcement in the local newspaper and via personal contacts in a cooperating day hospital and a cooperating rehabilitation centre. The inclusion criteria were an age of at least 75 years, an independent

life at home, no acute disease and no cognitive impairment (Mini Mental State Examination ≥ 24 of 30 points [15]). The study was approved by the Ethics Commission of the Friedrich-Alexander University of Erlangen-Nuremberg. All study participants signed a written declaration of consent. The participants visited the study centre once or were visited at home if they were not able or willing to do so.

Random sample characteristics

The date of birth, housing situation (living alone/not living alone), level of education (secondary school/further school/school leaving examination and higher) and difficulties with chewing and swallowing (yes/no) were enquired in a standardised personal interview. The body mass index (BMI) was calculated from the standardised weight and height measured. The tendency to depressive moods was ascertained with the Geriatric Depression Scale (GDS, max. 15 points [16]). The number of medicines stated was documented as "more than three medicines" or "less than three medicines". The degree of independence in daily life was determined using the questionnaire for instrumental activities in daily life (IADL, eight questions, max. 8 points) of LAWTON and BRODY [17], with a higher score indicating a greater degree of independence. In addition, two of the IADL questions about dependence on assistance with shopping and cooking were evaluated separately ("goes shopping independently" and "cooks all meals independently"). In order to determine the degree of comorbidity, the Charlson Comorbidity Index was used. This index is a total score of 19 weighted (1, 2, 3 or 6 points) diseases associated with increased mortality risk. A higher score represents a higher mortality risk [18]. In addition, the question was asked whether the study participant had taken dietary supplements during the last two years.

Survey of frailty

Frailty was determined according to FRIED et al. [3] on the basis of the following five criteria: stated loss of more than 4.5 kg weight in the last year, fatigue (the feeling that everything was an effort or that one did not get going > twice per week), low handgrip strength measured with a dynamometer (Jamar®, Sammons Preston Rolyan, Illinois, USA) (men ≤ 29–32 kg, women ≤ 17–21 kg, according to BMI), slow walking speed (> 6–7 seconds/4.57 m, according to sex and height) and low physical activity (men < 383 kcal/week, women < 270 kcal/week). The latter was determined with the shortform of the Minnesota Leisure Time Activities Questionnaire, which documents the time spent with selected physical activities during the last two weeks [19]. Frailty was defined as the presence of at least three and pre-frailty as the presence of one or two of the five attributes. Study participants with none of these attributes were defined as "non-frail".

Nutrition survey

The nutrition data were acquired in the course of a personal interview by a nutritionist with a slightly modified food-frequency-questionnaire taken from the German part of the EPIC study (European Prospective Investigation into Cancer and Nutrition) [20]. The EPIC food-frequency-questionnaire assesses the prevailing consumption of 103 foods and food groups during the last 12 months with standard portion sizes (e.g. 1 cup, 1 piece, 1 teaspoon per month, per week or per day) and includes additional questions about the consumption of fats. The modifications concern the assignment of twelve foods to other groups, in order to improve the survey in regard to the intake of antioxidants and unsaturated fatty acids (e.g. the breakdown of the category "fish" into three categories of fish with different fat contents). In addition, a question about the consumption of wholegrain foods was added.

Assessment of the nutritional quality

The nutritional score calculated here is a modified form of the Healthy Eating Index (HEI) of the U.S. Department of Agriculture [10]. It is based on the nutrition pyramid of the aid infodienst (German food pyramid, GFP) and reflects the dietary recommendations of the German Nutrition Society for nutrition as a recommended number of portions for eight categories of food (◆ Table 1) [21]. For the calculation of the HEI-GFP score, the answers from the food-frequency-questionnaire were summed up and then converted to the standard portion sizes of the aid infodienst into the so-called "actual frequency of consumption" (AFC). Here, with the help of the German Food Key (BLS II.2), the consumption of sweets was expressed in kcal/day. In each category – except for sweets – the ratio of the actual frequency of consumption to the frequency of consumption recommended by the aid infodienst (RFC) was calculated and multiplied by 10 (AFC/RFCx10). Exact compliance with the recommendation therefore always results in 10 points. Consumption below the recommended level accordingly resulted to fewer points. In the categories "beverages", "vegetables" and "fruit", exceeding the recommended level of foods considered to be favourable results in more than 10, up to a maximum of 20 points. In the categories "grains", "milk", "meat" and "fat", which can easily result in an oversupply of energy, consumption greater than the recommended level is calculated with the inverse ratio (RFC/AFCx10), so that exceeding the recommended levels results in a lower score. For "sweets" only this inverse calcula-

Food category	Standard portion sizes (men/women)	RFC (portions/day)
Beverages	150 mL coffee or tea or 280 mL water or 100 ml soft drinks	6
Vegetables	140 g vegetables/leguminous vegetables or 100 mL vegetable juice	3
Fruit	125 g fresh or dried fruit/tinned fruit or 100 mL fruit juice	2
Grains	70/85 g grain/bread or 200/250 g potatoes/noodles/rice	4
Dairy products	250 mL milk or 150 g yogurt or 30 g cheese and other milk products	3
Meat/fish/eggs	200 g meat or poultry or 30 g meat products or 180 g fish or 150 g eggs (= 2–3 per week)	1
Fat	18/20 g butter/margarine/fats or 18/20 g oils	2
Sweets	220/270 kcal chocolate, sweets, ice cream, marmalade, cake, biscuits, salted snacks	1

Tab. 1: **HEI-GFP score [21]: Food categories, standard portion sizes and recommended frequency of consumption (RFC)**

tion (RFC/AFCx10) was used and a maximum of 10 points assigned (= the actual intake of sweets and snacks does not exceed the recommended intake). The scores in the eight food categories are added to a total score, which can have a maximum value of 110 points. A higher score thus reflects better compliance with the recommendations.

Statistical evaluation

For all statistical analyses SPSS 20.0 (IBM) was used. As none of the continuous variables obeys a normal distribution, the proband characteristics were represented in percent and as a median (minimum-maximum). For further analysis, the probands were divided into quartiles of the HEI-GFP score, with the lowest quartile representing the poorest compliance with the dietary recommendations. The risk of frailty (with pre-frailty and non-frail as reference) was calculated by logistic regression analysis in the quartiles of the HEI-GFP (with the lowest quartile as reference) as an odds ratio with 95 % confidence interval. In addition, a test for a linear trend was carried out as a covariant by logistic regression analysis for the quartiles of the HEI-GFP.

As the present sample size of the survey does not allow a fully adjusted model, for the identification of possible confounders a stepwise forward regression analysis of the relationship between frailty and proband characteristics was carried out, in which the proband characteristics were successively added as possible confounders correlating with both frailty and with the HEI-GFP ($p < 0.05$): age, sex, housing situation, educational level, GDS, IADL, number of medicines, and CCI. A confounder was defined as a variable which changed the valuer by at least 10 %, resulting in an adjusted model taking sex, GDS score and IADL score into consideration (Model 2).

As the individual energy intake is not considered in the calculation of the HEI, a further model with adjustment for the energy intake was calculated in order to demonstrate the influence of energy intake on the relationship between the HEI-GFP and frailty (Model 1). The relationship between nutrition and the different frailty criteria (weight loss, low handgrip strength, fatigue, slow walking speed and low physical activity) was calculated on the basis of the odds ratio (OR) for the second, third and fourth quartiles (with reference to the first quartile) of the HEI-GFP score as described above. The significance level was defined as $p < 0.05$.

Results

Random sample characteristics

192 of the original 206 study participants completed the food-frequency-questionnaire (less than three missing items) and were included in the following analysis. The study participants had a mean age of 83 ± 4 years and 64.6 % were female. The mean BMI was 27.5 ± 3.7 kg/m^2.

Characteristic	non-frail (n = 84)	pre-frail (n = 79)	frail (n = 29)
female [%]	56,0	65,0	86,2
age [years][1]	82 (76–91)	84 (76–94)	86 (75–96)
BMI [kg/m²]	26,7 (21,0–35,0)	28,1 (20,9–35,3)	26,4 (18,6–36,1)
living alone [%]	50,6	59,5	79,2
level of education [%][2] *low* *intermediate* *high*	 41,7 23,8 34,5	 39,2 31,6 29,1	 51,7 48,3 0,0
MMSE [points][1]	29 (25–30)	29 (24–30)	29 (25–30)
GDS [points][1]	0 (0–4)	2 (0–5)	3 (0–9)
IADL [points][1]	8 (5–8)	8 (1–8)	7 (2–8)
more than three medicines [%]	35,7	51,9	69,0
CCI [points][1]	0 (0–5)	1 (0–3)	2 (0–4)
goes shopping independently [%]	96,5	87,3	51,7
cooks independently [%]	88,2	82,3	72,4
uses supplements [%]	76,5	68,4	86,2
difficulties with chewing [%]	10,7	26,6	41,4
difficulties with swallowing [%]	2,4	12,7	10,3

Tab. 2: **Study participant characteristics (n = 192)**

[1] Median (minimum–maximum) (for all continuous variables)

[2] „low" = secondary school or did not graduate, "intermediate" = further school, middle school, "high" = school leaving examination or higher qualifications

MMSE = Mini Mental State examination [15], GDS = Geriatric Depression Scale [16], IADL = Instrumental Activities of Daily Living [17], CCI = Charlson Comorbidity Index [18]

41.1 % of the probands were pre-frail and 15.1 % were frail.

The degree of frailty increased with age of the probands ($p < 0.001$) and the percentage of female probands ($p < 0.05$) (◆ Table 2). Frail senior citizens lived more often alone ($p < 0.05$) and had a lower educational level ($p < 0.01$), more frequent depressions ($p < 0.001$) and lower IADL scores ($p < 0.001$) than pre-frail and non-frail probands ($p < 0.05$). The consumption of more than three medicines increased with increasing frailty status ($p < 0.01$), and frail probands had significantly higher scores for the Charlson Comorbidity Index than pre-frail and non-frail probands ($p < 0.05$). Frail probands also had to rely more frequently on assistance with shopping ($p < 0.001$) and more frequently had difficulties with chewing and swallowing ($p < 0.05$) (◆ Table 2).

		1 (n = 48) (≤ 58.91 points)	2 (n = 48) (58.92–65.86 points)	3 (n = 48) (65.87–71.24 points)	4 (n = 48) (≥ 71.25 points)	p for trend[3]
frailty (n = 30)	energy-adjusted	1.00	1.03 (0.38–2.78)	0.58 (0.19–1.78)	0.08 (0.001–0.66)*	0,004*
	confounder-adjusted	1.00	1.48 (0.41–5.41)	0.52 (0.12–2.30)	0.09 (0.01–0.97)*	0,030*
weight loss (n = 16)	energy-adjusted	1.00	0.72 (0.17–3.06)	1.23 (0.34–4.54)	0.14 (0.01–1.40)	0,284
	confounder-adjusted	1.00	0.83 (0.18–3.77)	1.38 (0.31–6.06)	0.22 (0.02–2.22)	0,446
fatigue (n = 42)	energy-adjusted	1.00	0.62 (0.22–1.77)	1.10 (0.43–2.80)	0.60 (0.21–1.74)	0,584
	confounder-adjusted	1.00	0.52 (0.16–1.66)	1.17 (0.40–3.37)	0.68 (0.22–2.13)	0,927
low handgrip strength (n = 75)	energy-adjusted	1.00	0.54 (0.23–1.26)	0.64 (0.27–1.49)	0.42 (0.17–1.05)	0,031*
	confounder-adjusted	1.00	0.64 (0.24–1.73)	0.45 (0.17–1.19)	0.36 (0.14–0.92)*	0,057
slow walking speed (n = 42)	energy-adjusted	1.00	1.02 (0.40–2.59)	0.56 (0.20–1.56)	0.27 (0.07–0.95)*	0,008*
	confounder-adjusted	1.00	2.61 (0.70–9.74)	0.53 (0.11–2.59)	0.47 (0.10–2.14)	0,105
low physical activity (n = 39)	energy-adjusted	1.00	0.77 (0.31–1.91)	0.35 (0.12–1.04)	0.24 (0.07–0.82)*	0,002*
	confounder-adjusted	1.00	1.38 (0.49–3.92)	0.39 (0.12–1.25)	0.24 (0.07–0.83)*	0,010*

Tab. 3: **Risk[1] of frailty[2] and the individual frailty criteria in the quartiles of the HEI-GFP score**

[1]Odds ratio (95 % confidence interval), [2]adjusted for IADL score, sex and GDS, [3]logistic regression
*$p < 0.05$

HEI-GFP nutritional score

The mean HEI-GFP score for the non-frail study probands was 66.5 ± 9.3 points, for the pre-frail study probands 65.1 ± 10.3 points, and 61.0 ± 8.4 points for the frail probands ($p = 0.032$). While the frail probands had a significantly lower HEI-GFP score compared to the non-frail and pre-frail probands, the nutritional score did not differ significantly between non-frail and pre-frail senior citizens (◆ Figure 1). Compared with the probands in the lowest quartile, the probands in the highest quartile had a significantly lower risk of frailty (◆ Table 3) and the linear trend of the ORs was significant as well.

In regard to the individual frailty criteria, the energy-adjusted model showed significantly lower odds ratios and a significant "p for trend" value (logistic regression) for the correlation between "low manual strength", "limited physical activity" and "slow walking speed" and the HEI-GFP, while the "p for trend" values for the confounders IADL score, GDS score and sex were no longer significant with the model including the calculation of the confounders IADL score, GDS score and sex (◆ Table 3).

Discussion

In this convenience sample of senior citizens living at home in the Nuremberg region, the present cross-sectional study shows that probands with strong adherence to the dietary recommendations of the German Nutrition Society have a lower risk of frailty and a lower probability of individual frailty criteria than senior citizens whose nutritional habits comply less with the recommendations. This correlation is independent of the individual energy intake.

The results agree with previous evaluations in the same collective, in which a Mediterranean diet score (MED score) was used to characterise the nutritional quality and investigate the correlation between diet quality and frailty [23]. In the highest quartile of the MED score (diet most oriented to Mediterranean diet) the risk of frailty was significantly reduced compared to the lowest quartile.

Possible influence of diet on frailty via inflammatory processes

A possible explanation for the correlation between health-promoting dietary habits following the DGE recommendations and frailty could be the reduction of inflammation-related tissue damage, oxidative stress and inflammatory processes. A current systematic review of 46 studies on the correlation of dietary habits and inflammation markers found an inverse correlation between low-grade chronic inflammatory condi-

tions – which are typical for older persons ("Inflamm-Aging") [24] – and vegetable- or fruit-based dietary habits, while "western", or meat-based, dietary habits correlated positively with inflammation markers [25]. The HEI-GFP acknowledges a high fruit and vegetable intake, which constitute the main sources of antioxidants such as carotenoids. A further positive effect could relate to the restriction of meat and animal fats. Foods of animal origin, particularly animal fats, are the main source of saturated fatty acids, the intake of which is associated with higher concentrations of proinflammatory markers in the blood [26, 27]. The results of the MED score quoted above for the same collective [23] support this hypothesis, as the two nutritional scores overlap exactly in the requirements for the high consumption of fruits and vegetables and the reduced intake of meat and meat products.

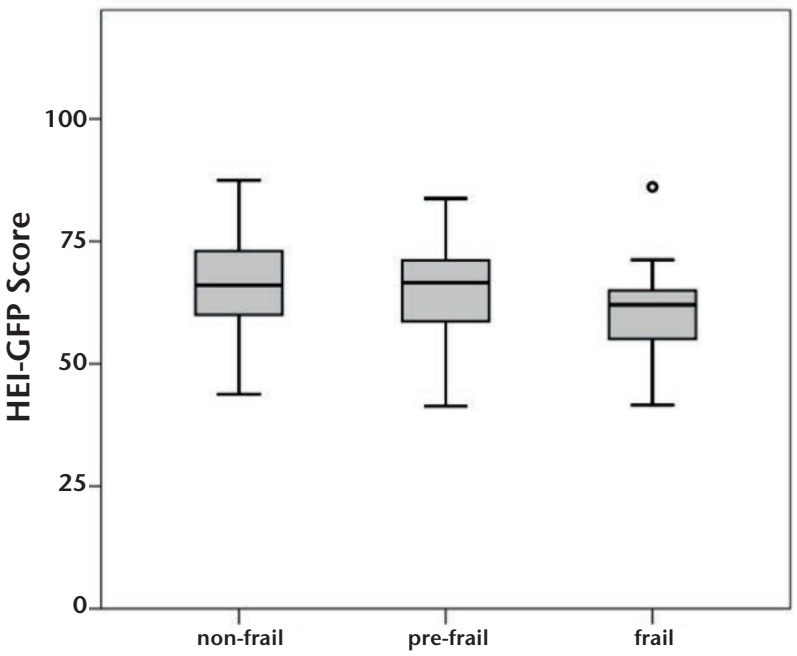

Fig. 1: **Boxplots of the Healthy Eating Index according to Ruesten et al.** (HEI-GFP score, maximum 110 points [21]) for non-frail, pre-frail and frail probands. The wide horizontal lines refer to the median. The boxes border the 25th and 75th percentiles. The whiskers represent the highest and lowest values within an interval of 1.5 inter-quartile ranges. The circles indicate outliers.

Confounding

Confounding due to sex could arise from the fact that women have a better knowledge of nutrition than men [28] and are also more independent with cooking: While only 2.9 % of the female study participants relied on ready prepared food such as convenience products and meals on wheels, this figure rose to 11.4 % among the male study participants. This difference was independent of the participant's age (data not shown). The ability to cook for one's self has an influence on the score of the IADL questionnaire, representing a further confounder. Another question of the IADL is the ability to shop independently. As expected, our data show that senior citizens with increasing frailty status are significantly more frequently dependent on assistance for shopping (◆ Table 2). Thus, the possibility to influence one's own choice of food evidently contributes to the confounding of the correlation between compliance with the dietary recommendations and frailty.

Not only physical but also mental impairments can restrict the room for manoeuvre. Confounding due to depressive moods could be the result of lack of motivation or indifference in regard to nutritional questions. Interestingly, however, none of the probands scored above the a priori limit of six points defined with the GDS for depressions. Nevertheless, our results show that sporadic symptoms for depressive moods can influence frailty (◆ Table 2) and compliance with the dietary recommendations (◆ Table 3). Contrary to the results reported by Ruesten et al. [29], who investigated an association between the HEI and chronic diseases in younger persons, in our study the BMI was no confounder. Although very high and very low BMI values are regarded as a risk factor for frailty [30, 31], this relationship could not be confirmed for the probands in the present study (◆ Table 2). In our analysis, the HEI-GFP did not correlate with the BMI (data not shown). This indicates that, in regard to cardiovascular diseases, diabetes mellitus type 2 and cancer [29], the BMI is a more important parameter than the overall nutritional quality, while our data suggest that anti-inflammatory and antioxidative food constituents influence frailty. In regard to the BMI distribution, however, an error in the selection of our random samples cannot be excluded.

Nutritional evaluation

Compared with other randomised studies in Germany in which an HEI was calculated, our probands achieved a significantly higher score: In an EPIC randomised study with probands over the age of 65 [21] the mean HEI for men was 54.9 points and for women 59.8 points and, for

a younger collective (with a mean age of approximately 50 years) even lower (49.2 points for men and 52.7 points for women) [29], while our male probands achieved a mean score of 61.4 points and our female probands a mean score of 66.8 points. Ruesten et al. developed a classification based on the evaluation of the U.S. Department of Agriculture for the original HEI [21]: > 64 points = "well nourished", 40–64 points = "in need of improvement" and ≤ 40 points = "malnourished".

Ruesten et al. found the majority of their probands over the age of 65 years to be in the "in need of improvement" group (80.0 % of the men and 65.7 % of the women) and only a few to be "malnourished" (3.7 % of the men and 0.8 % of the women). However, in our collective, a larger number of the participants were rated "well nourished", while only 52.9 % of the men and 37.9 % of the women had eating habits "in need of improvement" and no "malnourished" persons were found (data not shown).

In relation to frailty, 61 % of both pre-frail and non-frail probands were "well nourished", but only 35 % of the frail probands. The discrepancy compared with the results of Ruesten et al. [21, 29] may be due to the different age structure. It is just the collective with an age of approximately 50 years [29] which, with profession and family, has entirely different routine eating habits than the – in part – very elderly pensioners of our randomised study, who were probably more interested in health and proper nourishment from the outset. Finally, Ruesten et al. considered the individual energy intake of the probands in the calculation of the HEI. Such data were not available to us, and this could lead to an underestimation or overestimation of the recommended consumption levels.

Strengths and weaknesses of the study

Due to the cross-sectional design it is not possible to reach any conclusions with regard to causal relationships. Nutrition can influence frailty and capability, however it is also plausible that reduced physical capability may influence the choice of foods, for example regarding the associations between frailty and the capacity to shop and cook alone. A further limitation is the small sample size and the relatively small group of frail probands, which limits the statistical reliability of significant associations. Furthermore, the randomised study was comprised of volunteers living in the vicinity of the study centre and is therefore not representative of the elderly population in Germany. For reasons of comparability, the frailty criteria used in this study rely on the original cut-off values of Fried et al. [3] determined in their study of more than 5,000 probands, which have already been used in a number of other studies. The advantages of a standardised procedure were considered more important than possible erroneous classification due to the different age structure and ethnology of the Fried collective compared with the collective investigated in the present study.

However, an advantage of our study is that all food-frequency-questionnaire interviews were conducted in person by a single, suitably trained and experienced nutritionist. Secondly, properly validated instruments were used and professional personnel employed for all data collected. To our knowledge, this is the first investigation examining the correlation between frailty and compliance with health-promoting dietary habits, assessed by the Healthy Eating Index.

Conclusion

The results of the present study indicate a direct relationship between compliance with the dietary recommendations of the German Nutrition Society and a lower risk of frailty at a high age. A preventive effect on the adherence to the dietary recommendations of the DGE on old age frailty must be confirmed with larger data sets and intervention studies.

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Conflict of Interest
The authors declare no conflict of interest according to the guidelines of the International Committee of Medical Journal Editors.

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