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Original Article

Slim larks and overweight owls? A two years dietary intervention in shift workers

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Abstract: Previous studies have shown that shift workers are more prone to non-communicable diseases. The aim of the present crossover study is to investigate whether it is possible to improve the health status of shift workers. Nineteen male shift workers (38.5 years ± 7.4) received every other month a dietary counseling for one year. All subjects kept a seven-day diet diary during a night shift, received bioelectrical impedance analysis, and a laboratory examination was performed at the beginning of the study, after one year and at the end of the study. The laboratory blood test included the main metabolic parameters, melatonin and serotonin. Beside subjects were also motivated to incorporate more physical training into their daily routine. After the intervention period, participants reduced energy intake, mean portion size, table salt, consumption of sugar and saturated fat. C-reactive protein (CRP), mean corpuscular volume (MCV), liver enzymes, triglycerides, and uric acid decreased, while melatonin level increased. Participants lost body weight and reduced waist circumference after the intervention. Lifestyle modification and dietary information could contribute to the health of shift workers. However, further studies are needed to investigate whether this can prevent disease and whether melatonin production can be influenced by diet.

Key words: Chronobiology, Circadian rhythm, Nutrition, Nutritional advice, Bioelectrical impedance analysis, Shift work, Food diary, Physical training

Introduction

Biological rhythms, synchronized by a "master clock", are mainly controlled by photic cues, and melatonin, a hormone based on the amino acid tryptophan. This hormone decreases activity when getting ready to sleep[1)] showed that exogenous as well as endogenous inputs affect the daily routine. Therefore they need to be present in every cell of any tissue in the body, act on circadian, ultradian or infradian rhythms.

Food ingestion and anticipation of food intake increase activity in rodent. Food and fluid intake, as potent exogenous "zeitgeber", are thought to affect circadian rhythmicity as so called food-entrainable oscillators (FEO). Clock mutant mice however did not lack all food anticipatory components, an indication that body clock genes are not

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essential for FEO, and oscillators operate independently of each other. Authors assume the existence of "zeitgeber", located outside the suprachiasmatic nucleus of the hypothalamus, which control food[2].

The daily routine in the world of work generally ignores people's diurnal biological rhythms. For example, school starts at half past seven in the morning, although it is known that young people tend to be late sleepers[3] or shift workers have to work even at night when people normally sleep. Rotating shift work is a special case, by changing the workflow every two or three days, the circadian rhythm is constantly disturbed. The ability to adapt to such changes is affected by several factors such as age, gender, the presence of physical, mental work, indoor or outdoor work, and also the state of health[4]. Nevertheless, the individual circadian rhythm plays a major role in the maintenance of life quality

The scientific literature describes a positive relationship between shift work and cardiovascular disease[5], obesity[6], sleeping disorders[7], genetic changes or specific tumors[8]. If sleep-wake cycle changes, the question arises, to what extent our body is able to adapt to such changes and how long an adaption period endures. Former studies[9] examined this adaptability but concluded in no clear facts, likely because of the lack of homogeneity of subjects and study design.

As humans are diurnal living beings, production of digestive juices, release of several hormones, utilization of nutrients and gastric or intestinal movements mainly occur during daytime[10]. In this regard, night-shift workers frequently complain about indigestion, bloating and constipation[11]. Even the human bacterial flora, the so called microbiome, which in recent research is recognized as a central figure for inflammatory processes and thus involved in ageing and disease, also exhibits a circadian cyclicity[12].

Nutritionists and dieticians agree that the day should start with breakfast, but there is no agreement about the snacks in between. It is often debated whether fruit or vegetable snacks should supplement the need for micronutrients, or the metabolism needs a break when is the optimal time for the last meal and how should it be composed[13]. Studies have showed that: 1. gastric emptying is faster in the morning[14], 2. glucose tolerance is higher in the morning[15], 3. a higher intake of carbohydrates in the morning leads to a lower Body Mass Index[16], 4. food intake in the morning decreases totally calorie intake is[17] 5. more satiating[18], and 6. high daily eating frequency decreases the total energy intake[19].

The lower frequency of meals seems to be effective on weight loss in men, but eating breakfast and earlier intermediate little snacks appear to be more beneficial[20], while a high load at dinner or lunch increases intake of saturated fatty acids and risk of the metabolic syndrome[21].

Ekmekcioglu and Touitou[22] reviewed the connection between circadian variation and obesity based on chronobiological aspects of food intake. They suggest that, among others, more frequent meals are metabolically advantageous. The authors also point out that eating meals earlier and more regularly reduces total energy intake. Recent research recommends, in contrary to these statements a fasting period, especially during the night, as an indispensable synchronizer of the circadian rhythm[19, 23]. Pivovavora *et al*.[24] described a correlation between food composition and central, peripheral clocks as well as inflammatory reactions. Dashti *et al*.[25] also showed that not only time of food intake itself but also the composition of macronutrients can have an impact on diseases.

The present study in shift workers examined whether the time of the day of food intake or the composition of food, regarding their macronutrients content, is 1) able to reduce glycated hemoglobin or low density lipoprotein or 2) influence serum serotonin or melatonin levels, which are involved in our sleep-wake rhythm. Another aim of this study was to improve shift workers health by changing eating habits and improve physical activity[26], without reduction fat free body mass or quality of life.

Subjects and Methods

The study started after approval by the Ethic Commission Innsbruck (AN2015-0271 355/4.20) with recruitment of participants over a period of 4 weeks. The participants were shift workers from a company that generates energy. Shift work was done in three shifts, the early shift from 6:00 am to 2:00 pm, late shift from 2:00 pm to 10:00 pm and night shift from 10:00 pm to 6:00 am. Although the study was presented to almost all shift workers of the company it was difficult to reach the planned number of subjects. The number of participants was limited to 22 male subjects at age of 25 y to 53 y (37.4 y ± 7.5) for organizational and financial reasons. In this crossover study the classification of the subjects into group A and group B was based on the urn model. Group A (age 42.7 y ± 6.6) and group B (age 36 y ± 7.4) were represented by 11 people each. After admission informed consent was obtained from each participant and subjects were briefed about the proceedings. At the beginning of the study both groups wrote a food diary, had a bioelectrical impedance analysis (BIA) and had a laboratory blood test. In the following year only group A received nutritional advice (intervention) for one

Test Plan

Group	Operation	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Phase 1	Recruitment of probands																												
Phase 2	Food diaries																												
	BIA measuring																												
	Blood draw																												
Phase 3	Nutrition advice Group A		i	n	t	e	r	v	e	n	t	i	o	n															
Phase 4	Food diaries																												
	BIA measuring																												
	Blood draw																												
Phase 5	Phase change (Crossover)																												
Phase 6	Nutrition advice Group B														i	n	t	e	r	v	e	n	t	i	o	n			
	Food diaries																												
	BIA measuring																												
	Blood draw																												
Phase 5	Data evaluation																												
Phase 6	Closing operations																												
Phase 7	Presentation of results																												

Fig. 1. The test plan shows the schedule, scope and procedure of the study.

year. One year after the start of the study both groups (A and B) again wrote food diaries, performed BIA measurements and had blood tests again. Then the nutritional counselling for group B started and also lasted for one year. At the end of the study both groups wrote a food diary, had a BIA measurement and had a final blood test. By that time the number of participants had shrunk to 19 persons which could be evaluated (86.4%).

Laboratory

Five ml fasting blood was drawn by an occupational physician after a night shift, between 06:00 and 08:00 respectively, and analyzed in laboratory (Labor Dr. Philadelphy, Innsbruck). Blood parameters analyzed were: erythrocytes, leukocytes, hemoglobin, hematocrit, mean erythrocyte volume (MCV), C-reactive protein (CRP), transaminases, creatinine, glomerular filtration rate, uric acid, triglycerides, cholesterol, low density lipoprotein, postprandial glucose, glycated hemoglobin A1c (HbA1c), serotonin and melatonin.

Nutrition

In order to detect the actual eating situation and as a base for following dietary consultation, participants wrote a diary in form of an estimated food record over seven consecutive days during a night shift. The dietary diary of the Austrian Association of Dieticians (https://www.diaetologen.at/ueber-uns/bestellformular/) served as a template but it was not used by all subjects. Seven participants wrote at least once on a white sheet and two subjects used an app. Nutritional values were calculated with Aconsoft PIU Printex GmbH, Vienna; Acon BKVBLS 2014; database BLS II.2 und BLS II.3. If no nutritional analysis was available, it was queried on the manufacturer homepage or from the website https://fddb.info/db/de/produktgruppen/produkt_verzeichnis/. Not available recipes were acquired from the website www.chefkoch.de, and adapted to describe the portion size.

In order to avoid an additional stress for the participants, portion size of food intake was estimated by the researcher but not actually weighed. In view of the fact that the federal food key ("BLS") calculates with averaged calorie values and considering that over- and underreporting is common in food protocols, weighing was dispensed with. Results of the food diaries were compared with the recommendations of the nutrition societies and served as a basis for the nutritional advice in the following twelve months.

Nutritional information, based on the recommendations of "Deutsche Gesellschaft für Ernährung" (German Nutrition Society), Verband der Diätologen Österreichs (Austrian Association of Dietitians) and "Verband der Ernährungswissenschafter Österreichs" (Association for Nutritional Scientists Austria), took place in one-hour sessions, each meeting concentrating on one topic. These topics were

macronutrients such as carbohydrates (including fiber), fat, protein and micronutrients like vitamins and minerals. Keeping to a strict meal plan starting with breakfast, lunch and dinner was communicated and it was requested that this eating pattern be maintained during the early, late and night shifts. Refraining from eating during night hours was an important topic of communication. If it cannot be avoided, small cut vegetables were recommended. A plate was used as a practical example, half of which should be filled with vegetables and salad, a quarter of the plate should cover the side dish (preferably whole grain products) and the remaining quarter animal foods (maximum three times a week). Two portions of fruit (hand-sized) should be consumed in the first half of the day by noon at the latest, no fruit juice or smoothie. Never buy salty snacks in bulk and sweets should be individually wrapped, was the advice, as well as never eat with a spoon (except for soups), avoid television, computers or newspapers while eating and also do not go shopping when being hungry. The last two meetings focused on food labelling and sensory training on the subject. Nutritional counselling included a theoretical part with nutritional-physiological information and a practical part, where participants estimated the content in food dummies.

The time between the consultations was used to put the information into practice. The aim of the nutritional consultations was to improve the blood metabolic profiles, to beneficially affect serotonin and melatonin levels and increase performance. Melatonin was measured because this hormone controls deep sleep[27], among other things, and can be negatively affected by shift work. Melatonin is formed from serotonin, which is involved in intestinal peristalsis[28] or the feeling of hunger and can improve emotional states[29]. The neurotransmitter is in turn formed from tryptophan, an amino acid found in food[30]. Thus, in this paper it has been investigated whether an evening meal enriched with tryptophan can increase these two hormones.

Body Composition

A bioelectrical impedance analysis (BIA) was performed with the bioelectrical impedance analyzer of the type Nutri Plus Data Input GmbH, Version 5.4.1. at the beginning, after one year and at the end of the study. The measurement was done after a night shift in the fasting state in the supine position with the single channel measurement. The test persons were informed about how the BIA could be influenced so that sources of error could be reduced. The weight and the waist circumference were measured by the subjects the day before. Values were acquired for relative comparisons of the body mass distribution without calibration.

Statistics

The Statistical Package for the Social Sciences IBM SPSS Statistics version 24 was used for statistical analysis. The Mann-Whitney-U-Test for independent samples was disposed to compare the results of groups A and B. The Wilcoxon Test for related samples was used for comparison of the results within the groups before and after intervention. The statistical significance was set at p-value ≤ 0.05.

Results

Nineteen subjects finished the study, ten in Group A and nine in Group B, two participants left the company before and one after it has changed hands.

Laboratory

The results of group A, as delineated in Table 1, showed a decrease of MCV fl (90.9 ± 3.3; 90.0 ± 4.0), CRP mg/dl (0.19 ± 0.15; 0.10 ± 0.07), aspartate transaminase AST U/l (29.3 ± 9.5; 27.5 ± 10.9), alanine transaminase ALT U/l (29.7 ± 11.3; 24.2 ± 5.4) and triglycerides mg/dl (163 ± 64; 153 ± 53) after the diet and lifestyle intervention, while erythrocytes T/l (4.8 ± 0.2; 5.0 ± 0.4), hemoglobin g/dl (15 ± 0.6; 15.5 ± 1.0), hematocrit % (43.7 ± 1.4; 44.6 ± 2.3), cholesterol mg/dl (184 ± 33; 187 ± 37), post meal glucose mg/dl (84 ± 11; 85 ± 9), HbA1c % (5.04 ± 2.5; 4.98 ± 0.2) and melatonin pg/ml (15.2 ± 6; 23.8 ± 11) increased.

The results of group B showed a decrease of MCV fl (89.8 ± 2.8; 88.1 ± 3.0), CRP mg/dl (0.45 ± 0.8; 0.16 ± 0.2), aspartate transaminase AST U/l (23.8 ± 3.9; 22.2 ± 3.2), alanine transaminase ALT U/l (30.1 ± 8.8; 24.1 ± 9.0) and triglycerides mg/dl (141 ± 81; 138 ± 101) after the diet and lifestyle intervention, while erythrocytes T/l (4.9 ± 0.3; 5.2 ± 0.3), hemoglobin g/dl (14.5 ± 0.6; 15.2 ± 0.8), hematocrit % (43.7 ± 1.8; 45.4 ± 2.3), cholesterol mg/dl (216 ± 19; 225 ± 43), post meal glucose mg/dl (85 ± 19; 91 ± 11), HbA1c % (5.24 ± 0.3; 5.33 ± 0.2) and melatonin pg/ml (14 ± 4.5; 22 ± 8.8) increased (Table 1).

Nutrition

The results showed that both groups significantly reduced their medium portion size (group A p=0.005; group B p=0.008) after intervention and reduced their energy up-

Table 1. Laboratory results of group A after intervention (one year after start of the study) and after control period one year later at the end of the study; laboratory results of group B after control period (one year after start of the study) and after one year intervention at the end of the study

Blood Parameters	Group A			Group B		
	start of study	end of intervention	end of study	start of study	end of control period	end of intervention
erythrocyte T/l	4.85	4.97	5.13	4.81	5.02	5.15
leucocyte G/l	6.29	6.91	6.78	6.61	6.51	6.27
hemoglobin g/dl	15.07	15.50	15.87	14.33	15.06	15.17
hematocrit %	44.06	44.65	46.26	43.11	44.11	45.37
MCV fl	90.88	90.00	90.31	89.78	87.98	88.14
CRP mg/dl	0.20	0.10	0.17	0.47	0.17	0.16
serotonin ng/ml	119.64	114.91	119.50	162.25	160.75	139.22
GammaGT U/l	28.27	28.36	34.50	28.5	27.38	27.56
GOTAST U/l	29.00	23.91	27.50	23.5	20.88	22.22
GPTALT U/L	29.18	28.55	29.20	30.88	27.63	24.11
kreatinin mg/dl	1.14	1.11	1.12	0.95	0.93	1.02
GFR ml/min/m²	76.98	79.03	79.76	96.9	99.26	88.46
uricacid mg/dl	6.20	6.21	6.09	6.11	5.7	5.93
triglyceride mg/dl	156.64	148.00	161.70	147.38	188	138.33
cholesterol mg/dl	186.55	187.64	194.80	215.75	221	225.33
LDLcholesterol mg/dl	120.64	118.82	126.00	139.38	144.25	153.89
glukosepp mg/dl	83.82	78.36	87.20	85.88	88.75	90.78
HbA1c %	5.06	4.99	5.13	5.24	5.23	5.33
melatonin pg/ml	14.70	23.28	25.80	14.6	22.18	22.1

MCV = mean corpuscular volume
CRP = C-reactive protein
GT = gamma-glutamyl transferase
GOT (AST) = aspartate aminotransferase
GPT (ALT) = alanine aminotransferase
GFR = glomerular filtration rate
LDL = low density lipoprotein
Glucose pp = blood glucose after meal
HbA1c = glycosylated hemoglobin

take, consumption of disaccharides, table salt and saturated fatty acids but also ascorbic acid, copper and iodine. They increased uptake of complex carbohydrates, tocopherol, phylloquinone, pyridoxine, biotin, potassium, magnesium, phosphor and manganese. So they ate more vegetables and more dietary fiber and they drank less alcohol, as shown in Table 2.

The comparison macro- and micronutrients uptake in groups A and B by using the Mann Whitney U-test at the beginning of the study resulted in two significant values: Group A had significant higher intake of folic acid (p=0.0043) and iodine (p=0.0043). There have not been any significant differences one year after the start of the study, after the intervention of group A and control period of group B. However, at the end of the study, as shown in Table 3, the results of both groups demonstrated significant changes in the uptake of several nutrients. For group A this outcome was one year after the intervention, after the control period and for group B immediately after the intervention (Table 3).

It is noticeable that group A consumed significantly less energy (p=0.043), less carbohydrates (p=0.004) than group B, but also significantly less minerals (p=0.043). Both groups A and B reduced the medium portion size significantly (group A: p=0.005; group B: p=0.008). Almost all participants ate more dietary fibres, but less vegetable and salad.

Bioelectrical impedance analysis

Both groups A and B lost weight after the intervention. There were no significant differences within the two groups from the beginning until the end of the study. However when comparing the two groups A and B with each other, they differed in part significantly. The results of the bio-

Table 2. Major nutritional results of the groups A and B before and after intervention

Parameters	Group A			Group B		
	start of the study	after intervention	end of study / control period	start of the study	start of intervention	after intervention/ end of study
kcal	2,050	1,960	1,790	2,340	2,100	1,790
kilojoule	8,600	8,200	7,500	9,800	8,800	7,500
protein	124.7 g = 24.94 %	111 g = 23.22 %	116.1 g = 26.59 %	105.9 g = 18.55 %	100.6 g = 19.64 %	83.4 g = 19.10 %
fat	44.5 g = 20.19 %	43.4 g = 20.57 %	93.3 g = 20.40 %	52.3 g = 20.78 %	47.4 g = 21.01 %	35.5 g = 18.44 %
carbohydrates	255 g = 51.0 %	255.9 g = 53.53 %	217.4 g = 49.79 %	321.2 g = 56.27 %	290.5 g = 56.72 %	257.3 g = 58.93 %
alcohol	11.3 g = 3.87 %	7.5 g = 2.67 %	8.2 g = 3.22 %	14.7 g = 4.41 %	7.9 g = 2.62 %	9 g = 3.53 %
dietary fibers	18 g	18.8 g	17.2 g	16.7 g	17.3 g	19.2 g

Group A: energy, macronutrients, alcohol and dietary fibers intakes at the start of the study, after the intervention (one year later) and at the end of the study/control period (two years after the start of the study).
Group B: energy, macronutrients, alcohol and dietary fibers intakes at the start of the study, one year later/control period and after intervention at the end of the study (two years after the start of the study).

Table 3. Comparison of macro- and micronutrients, energy and P/S ratio (ratio polyunsaturated fatty acids/versus saturated fatty acids) in group A and B at the end of the study

Nutrients	Group A	Group B
carbohydrates	↓↓	
energy	↓↓	↓↓
monosaccharides	↓↓	
fructose	↓↓	
starch	↓↓	
minerals	↓↓	
sodium	↓↓	↓↓
copper	↓↓	
manganese	↓↓	
chlorine	↓↓	↓↓
total table salt	↓↓	↓↓
biological value	↓↓	
P/S ratio	↑↑	
amino acids	↓	
vitamins	↓	
sugar alcohols	↓	↓
disaccharides	↓	↓
saturated fatty acids	↓	↓
cholesterol	↓	
linoleic acid	↑↑	↑↑

↓= decrease not significant $p>0.05$,
↓↓= significantly decrease $p\leq0.05$,
↑↑= significantly increase $p\leq0.05$

electrical analysis are thereby indicated respectively in Table 4 for group A and in Table 5 for group B.

Comparing Group A and Group B at the start of the study

Group A started with higher weight, body mass index, phase angle and had significantly higher basic metabolic rate ($p=0.035$). They were significantly higher in total body water ($p=0.028$), lean body mass ($p=0.028$) and body cell mass ($p=0.043$) and exhibited more extracellular mass, cellular fraction and body fat than Group B.

Comparing Group A and Group B at the end of the study

The weight loss in Group B was statistically significant ($p=0.043$) as well as the decrease of body fat ($p=0.022$). Group A gained until the end of the study (one year after intervention) more weight and more fat than they had at the start, but also had a higher phase angle, more body cells but less extracellular mass than before the intervention. After intervention Group B had less lean body mass, less extracellular mass, less body fat and cellular fraction. Both groups lost total body water and they increased BMI from the start until the end of the study. In addition, the waist circumference has been slightly reduced by about 3.5% in almost half of the participants.

Discussion

Many previous studies show a link between shift work and metabolic diseases. Although the exact interaction of central and peripheral clocks is not completely understood, it is known that small deviations from the natural circadian rhythm can have massive effects on the metabolism[31]. The present study showed that detailed lifestyle and nutrition information without interdictions or rules can cause shift worker to rethink their nutrition. The participants reduced their energy intake during the night shift and raised their physical activity[32]. This may lead to a better sleep quality[33], a reduction in the risk factors that promote circulatory dis-

Table 4. Results of the bioelectrical analysis showing the most relevant parameters of Group A at the start of the study, after intervention and at the end of the study

Parameters	Group A		
	start of study	after intervention	end of study
weight (kg)	89.8 ± 9.35	88.27 ± 9.91	90.64 ± 9.96
phase angle (°)	7.11 ± 0.79	7.28 ± 0.68	7.16 ± 0.66
lean body mass (kg)	71.43 ± 4.08	69.36 ± 6.46	69.25 ± 5.88
body fat (kg)	19.08 ± 5.52	18.05 ± 5.84	20.83 ± 6.09

Table 5. Results of the bioelectrical analysis showing the most relevant parameters of Group B at the start of the study, start of intervention and at the end of the study

Parameters	Group B		
	start of study	start of intervention	end of study
weight (kg)	81.22 ± 9.44	81.86 ± 9.29	80.49 ± 9.67
phase angle (°)	6.71 ± 0.49	6.73 ± 0.66	6.70 ± 0.54
lean body mass (kg)	65.2 ± 5.70	65.36 ± 5.43	65.06 ± 5.60
body fat (kg)	15.94 ± 4.61	16.41 ± 4.61	15.50 ± 5.38

eases and they reduced factors which favor the development of metabolic syndrome[34]. The increase in erythrocytes and hemoglobin, which normally is only caused by altitude training of competitive athletes, can be explained by the extensive training of some subjects who participated in a marathon[35]. The observed increase of cholesterol and LDL, which are risk factors for cardiovascular disease, has been noticed earlier in weight reduction[36]. Whether this is associated with the reduction of body cell membranes remains a subject of further studies. Blood glucose and long-term average blood sugar levels were minimally higher after the intervention and within the lower limit of the normal range[37].

It is necessary to mention not all participants used the same dietary collection tool. Some subjects used a written diary, others their mobile phone for daily records. But all subjects saw the food log as a burden.

The study showed also that an increase in carbohydrate intake needs not to be accompanied by increasing energy uptake. The highly significant lower carbohydrate intake in the Group A at the end of the study can partly be attributed to the reduction of monosaccharides and starch. Considering post meal responses vary among human people further investigation is needed to determine the causes[38]. Poly-saccharides uptake however also was reduced, which shows that energy reduction entails a reduction of so called "healthy foods" too. The significant reduction of minerals underlines this fact and has to be communicated[39].

A partial success of the study was that the weight gain of four subjects who quitted smoking during the study was minimal, although the averaged weight gain after quitting smoking generally starts with 5%[40]. It was astonishing that all participants declared that they did not feel hungry during the night shift when they ate at regular meal times although they worked physically[41]. In order to achieve a reduction in energy consumption subjects were not willing to abstain from their favorite high-energy dishes, as the food diaries revealed. Subjects in this study gave following reasons for their nightly food intake: a) habit, b) because snacks were available in vending machines on the meeting place during their break or c) to reduce tiredness. Not eating at night could be one of the reasons for energy decrease and weight loss of participants.

Lowden *et al.*[42] show that dietary recommendation for shift workers stands for more than just optimal nutrient intake, so a food alternative must be carefully selected and customized; especially when alcohol is a matter. Noteworthy is that Group B improved food intake even without intervention after one year. Alcohol intake particular in this group was almost reduced by half, while consumption of macronutrients did not change seriously. The reduction of alcohol did not only lower energy intake but also improved aminotransferases and MCV, even significantly in Group B after intervention. Therefore the consumption of alcohol plays a major role when energy uptake should be limited[43].

Protein uptake of subjects, as food diaries showed, was higher than recommended by the nutritional societies. This was not only due to food intake but also to the consumption

of food supplement in some subjects who tried to improve their performance and muscle growth. Since high protein intake was already determined at the beginning of the study and the disease-promoting effect of Branched-Chain Amino Acids (BCAA) is known, protein reduction and abdication of supplements was recommended in the dietary consultations. Serum creatinine and GFR are not only good measuring instruments for their vital function but also for signs of diabetes. There is a need for further studies to investigate if the rise of creatinine as well as reduced glomerular filtration rate is predictors of diabetes development[44].

Melatonin is a hormone that not only regulates the chrono-physiological rhythm of the human body, but can also positively influence its health[30]. A nocturnal decreased level of this hormone is associated with sleep deficit with age, but also with the sleep disturbances of shift work or jet lag.

Melatonin is synthesised from serotonin. This neurotransmitter requires tryptophan, an essential amino acid, which is a building block of proteins. Whether a change in the amino acid pattern in the diet can increase melatonin levels must be investigated in future studies.

In summary, not eating at night was not seen as abstinence. The subjects did not feel hungry at night when they ate a meal regularly. Cravings and snacking only occurred when a meal was skipped. To avoid cravings, it is recommended to eat enough carbohydrates at meals that do not raise blood sugar levels quickly, such as potatoes, brown rice, wholegrain pasta and whole-wheat bread, always combined with vegetables and salad[21]. Vegetables can also be eaten as a snack. It helps to avoid hunger and provides important micronutrients with few calories and above all it tastes well when it is seasonal and regional.

Micronutrients have an effect on blood pressure. Especially dietary salt intake can be linked with hypertension in salt- sensitive people[45]. The addition of table salt when preparing food was not taken into account in this study, because there is table salt with and without added iodine or fluorine on the market. None of the subjects was able to provide information about the type of salt they used, not to mention catering outside home and the industrial processing of salty food. Significant reduction of sodium and chlorine in Group A can therefore be attributed to reduced intake of foods rich in salt. Since salty foods often contain a lot of energy, this might be another explanation for the observed energy reduction after the intervention.

The combination of resistance and endurance training can help to maintain both metabolic and also physical health[46]. As the results of the bioelectrical impedance analysis show it is easier to motivate people to change their eating behaviour than to do more exercise, especially when strength training is taken in account. Although most of the participants had resistance bands at home and knew about their effect, they did not regularly use them. Participants who did not frequently visit a gym or did not have resistance bands were provided with them free of charge. The results show improvements after intervention in both groups. However, when participants were dependent on their own motivation, they forgot to train regularly[47].

Limitations

The voluntary nature of the study addressed information primarily to persons who were prepared to improve their health. When subjects were recruited it was noticed that people, who would benefit most from changes in their life style did not even think about participating in the study or make use of the nutritional consultation offered. These persons would possibly benefit if for example the company would provide a cheap and tasty but healthy midnight snack as an alternative to vending machines or a suitable menu in the canteen at a special price. The author's inquiry showed that the manufacturer was only willing to offer alternatives if sales were secured. Sponsoring a healthy snack or lunch by the company could be the first step to improve the nutrition of employees.

2018 after the end of the first intervention GE Jenbacher was sold to Innio Jenbacher Waukesha Gas Engines. This not only led to uncertainness among employees but also to restructuring in shift work and the loss of test persons.

The composition of meals seems to be different between early (from 06:00 to 14:00), late (from 14:00 to 22:00) or night shift (from 22:00 to 6:00). The present study considered only food diaries during the night shift. If statements about a deficiency or an excess of essential nutrient components would be relevant for the health of the subjects, food protocols of the early shift and the late shift should also be taken into account. However, Lauren *et al*.[48] found no significant difference between food intake during the day and night in terms of calories, macronutrients and fiber.

Nevertheless no statements are made about the real uptake; outcome was evaluated for comparison purposes before and after the intervention. Knowing that food intake changes as soon as dietary records are made, they were primarily used for comparison, not for a statement about the actual uptake, before and after intervention. However, intervention can improve diet and physical activity of shift working people, which may bring a high benefit in terms of

health and life quality.

The bioelectrical impedance analyser measures two physical resistances in humans, from which one can calculate the phase angle and the anatomical body composition. By assessing the nutritional status of the lean mass, formulas are used to calculate the total amount of fat. These formulas are based on statistical principles; therefore statistical errors must be included. The advantage of the BIA measurement is the comparison of the progression, which was used in this study.

Conclusion

The aim of the study was to improve the health of shift workers. Changing eating habits and motivating to integrate more exercise into daily life may be a simple and cost-effective way. The present study has shown that motivation to change lifestyle may help, however impulses must be created again and again so that they do not fall into oblivion. Further studies with possibly higher sample sizes would be needed to confirm our results. This was the first study that worked with the effects of long-term nutritional counselling.

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Disclosure of interest

The authors report no conflict of interest.

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