ABSTRACT

Background: Salt restriction, recommended as the first-line treatment of hypertension, has been proposed to lead to deficiencies in intakes of some other nutrients.

Objective: The aim of this study was to investigate the effects of salt restriction for 20 wk on the intake of other nutrients in free-living subjects with mildly elevated blood pressure.

Design: Thirty-nine subjects (24 men, 15 women) aged 28–65 y with a mean daytime ambulatory diastolic blood pressure of 90–105 mm Hg and a diastolic blood pressure measured in a health care center of 95–115 mm Hg participated in the study. The subjects completed 4-d food records and their salt intake was measured by 24-h urinary sodium excretion. The subjects received both oral and written instructions from a clinical nutritionist on how to reduce their daily sodium chloride intake to <5 g/d but were instructed not to change their diet otherwise. The subjects were provided with low-salt bread during the salt-restriction period.

Results: Few changes were found in nutrient intakes. In men, total energy intake decreased by 1059 kJ/d and alcohol, potassium, and vitamin D intakes decreased, but there were no significant changes in energy-adjusted potassium and vitamin D intakes. In women, total potassium intake increased, but the potassium density of the diet remained unchanged. Total selenium intake and energy-adjusted intake of selenium both decreased significantly in women.

Conclusions: Salt restriction can be undertaken in free-living hypertensive subjects without any untoward changes in the intake of other nutrients.

KEY WORDS  Salt restriction, dietary sodium, sodium, hypertension, blood pressure, diet, humans

INTRODUCTION

Salt restriction is recommended to prevent and to treat hypertension, but concern has been raised regarding the potential deleterious effects of reductions in salt intake. In particular, it has been suggested that a reduced consumption of those foods with a high sodium content could lead to reductions in other nutrients to amounts below recommended intakes (1).

A reduction in salt intake necessitates changes in food patterns: the sodium content of foods and the consumption of foods that contain large amounts of salt should be reduced. Engstrom and Tobelmann (2) showed that a reduction in the intake of high-sodium foods could lead to reduced intakes of calcium, iron, magnesium, and vitamin B-6 from the diet (2). However, changes in the intake of such nutrients resulting from salt restriction seemed to be more apparent in subjects who did not have a goal of maintaining energy intakes similar to those before the salt restriction (3–7).

Because salt restriction is so widely recommended, it is important to determine the nutrient composition of the diet being consumed by individuals implementing a sodium-restricted diet and to examine how the sodium restriction would influence the intakes of other nutrients. The aim of this study was to investigate the effects of salt restriction on the energy and nutrient intakes of free-living subjects with mildly elevated blood pressure.

SUBJECTS AND METHODS

Subjects

Subjects were recruited from previous studies at the Kuopio Research Institute of Exercise Medicine and from local occupational health care services. Thirty-nine subjects (24 men, 15 women) aged 28–65 y with a mean daytime ambulatory diastolic blood pressure of 90–105 mm Hg and a diastolic blood pressure measured in a health care center of 95–115 mm Hg completed the study, which was carried out under free-living conditions in 1993 and 1994. The original study was intended to examine the effects of salt restriction alone or in combination with cilazapril in the treatment of mildly elevated blood pressure (8). This study describes dietary intakes in sex subgroups during a 20-wk salt-restriction period. The 2 treatment groups were combined in the analysis to increase the sample size and the power of the study. On the basis of the pharmacologic properties of cilazapril, it was assumed that cilazapril had no effects on sodium excretion or on total nutrient intakes.

Originally, 99 hypertensive subjects were invited for screening and 59 subjects began the study. However, because of the normalization of blood pressure during the run-in period, 14 subjects

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were excluded. During the 4-wk run-in period, the subjects followed their normal-sodium diet and took one placebo tablet daily, which was given as a control for the cilazapril arm of the study. At week 4, the 45 subjects who still met the inclusion criteria for blood pressure were instructed to consume a low-sodium diet for the next 8 wk and were given placebo tablets. At week 12, the subjects were randomly assigned to 1 of the following 2 groups for the next 12 wk: the low-sodium placebo group or the low-sodium cilazapril group. Subjects were asked to maintain their usual physical activity and their current body weight during the study. Six subjects dropped out during the study phase (between weeks 4 and 24): 3 because they found the diet to be too difficult to follow, 1 because his wife died, 1 because of side effects to cilazapril, and 1 because of elevated blood pressure. Subjects provided their written, informed consent before starting the study, and the study protocol was approved by the Ethics Committee of the University of Kuopio.

Methods

Body weight was measured with a digital scale in subjects wearing light clothing (Seca model 708; Vogel & Halke GmbH & Co, Hamburg, Germany). Blood pressure was measured with a random-zero sphygmomanometer by the same trained nurse while the subjects were in a sitting position (Hawksley & Sons Limited, West Sussex, United Kingdom) between 0800 and 1200 after a 10–15-min rest. The disappearance of Korotkov’s sounds (phase V) was used to determine diastolic blood pressure. Three blood pressure measurements were taken; the mean of the last 2 measurements was used in the analysis. The 24-h ambulatory blood pressure was measured with a Diasys (Novacor SA, Rueil-Malmaison, France) at 20-min intervals between 0600 and 2200 and once an hour during the night. The mean value over the registered time period was used in the analysis.

The 24-h urine collection was carried out under free-living conditions. The urine was collected in plastic containers from 0700 to the next morning at 0700. The completeness of the collection was ascertained from the subjects and was confirmed on the basis of 24-h creatinine excretion (8). Sodium concentrations in urine were determined by using ion-selective electrodes (Kone Microlyte Ion Selective Analyzer; Kone Corporation, Espoo, Finland). Creatinine concentrations in urine were analyzed by using the Jaffe method (Boehringer Mannheim GmbH, Mannheim, Germany).

Diet

At week 4, the patients received oral and written instructions on how to choose and prepare food to reduce their daily sodium chloride intake to 5 g/d. Dietary instructions were given by a clinical nutritionist. The patients were advised to reduce their sodium chloride intakes by 50%, but to otherwise maintain their usual diets. The diets were composed of normal Finnish food items. A low-salt bread (0.5%) was supplied free of charge to the subjects during the entire low-sodium period (from weeks 4 to 24). Subjects were advised to flavor their food with lemon, pepper, herbs, spices, onion, and garlic. Fresh vegetables and fresh fish products were recommended to be eaten instead of salted and pickled vegetables or salted and smoked fish products. The subjects were also asked to eat low-sodium alternatives of meat products, fish products, cereals, and dairy products. Subjects participated once or twice in group meetings, during which they prepared a variety of dishes without the use of salt. Those subjects eating lunch outside of their homes were asked to order a salt-free meal.

Data on food consumption were collected 3 times, once during the normal-sodium diet at week 4 and twice during the salt-restriction period at weeks 12 and 24, by using 4-d food records (3 weekdays and 1 weekend day). The amounts of food consumed were determined by using a portion-size booklet and household measures. Subjects also wrote the recipes of homemade dishes and pastries in the food record. At every visit the subjects met the nutritionist, who advised them on the practical management of the diets and checked the food records for completeness of the data.

Nutrient intakes were analyzed by using the NUTRICa software package (1993; Social Insurance Institution, Helsinki). Daily nutrient intakes were calculated on the basis of Finnish food-composition tables (9). The consumption of different food groups and sodium intake from different food groups were estimated. The food groups included food items used as such and food items present in dishes and pastries, which were first broken down into their component food items by using a recipe file. Salt used in food preparation was included in the group “other food items,” which also contained baker’s yeast and vinegar. The intake of sodium was computed from all food groups. The sodium intake from the group “other food items” represented the sodium intake from salt used in food preparation in the home or by the food industry.

Statistics

Data were analyzed by using SPSS for WINDOWS (versions 6.0 and 8.0; SPSS Inc, Chicago). The normality of the distribution of variables was checked with Shapiro-Wilk’s test before further analyses. Changes in dietary intake, daily urinary sodium excretion, and body weight during the salt-restriction period were analyzed with Friedman’s nonparametric, repeated-measures two-way (case and time) analysis of variance (ANOVA). However, in this analysis, only time was calculated. The Mann-Whitney U test was used to analyze differences in nutrient changes between groups differentiated by changes in dietary and urinary sodium. Spearman correlation coefficients were used to analyze the associations between changes in sodium intake and changes in dietary energy and macronutrient intakes. A P value < 0.05 was considered statistically significant. The results are given as means ± SDs.

RESULTS

Altogether, 39 subjects aged 28–65 y with mildly elevated blood pressure followed the salt-restricted diet for 20 wk (from weeks 4 to 24). During the salt-restriction period, blood pressure (systolic and diastolic, respectively) decreased by 5.9 ± 11.3 (P = 0.013) and 3.8 ± 5.4 (P = 0.28) mm Hg in men and by 3.0 ± 16.4 (NS) and 3.3 ± 6.5 (P = 0.038) mm Hg in women. There was also a small decrease in the body weight of both sexes, but the change was not significant. In women, body weight was 78.1 ± 9.1 kg at week 4, 77.2 ± 8.6 kg at week 12, and 77.0 ± 8.4 kg at week 24. In men, body weight was 88.3 ± 12.0 kg at week 4, 87.4 ± 11.0 kg at week 12, and 87.1 ± 11.2 kg at week 24.

Before the salt-restriction period began (at week 4), 24-h urinary sodium excretion was 220.9 ± 54.5 mmol in men and 162.1 ± 51.3 mmol in women. At the end of the salt-restriction period (week 24), 24-h urinary sodium excretion was 132.8 ± 65.0 mmol in men (P = 0.001) and 79.7 ± 25.5 mmol in women (P = 0.007). The average urinary sodium excretion has been evaluated to be 86% of total sodium intake (10). On that basis, the urinary sodium excretion at the end of the study (week basis 24) corresponded to an average sodium chloride intake of...
9.0 g/d in men and 5.4 g/d in women. At the end of the salt-restriction period, 17% of the men and 33% of the women had achieved the goal of having a salt intake <5 g/d.

The daily sodium intake estimated from diet decreased significantly by 1878 ± 1338 mg in men and by 1374 ± 786 mg in women during the salt-restriction period (P < 0.001 for both sexes; Table 1). The sodium intake at the end of salt-restriction period corresponded to an average salt intake of 5.2 g/d in men and 3.2 g/d in women. The sodium density of the diet decreased significantly (P < 0.001) in both men (437 ± 98 mg/MJ at week 4, 234 ± 84 mg/MJ at week 12, and 253 ± 81 mg/MJ at week 24) and women (410 ± 108 mg/MJ at week 4, 199 ± 82 mg/MJ at week 12, and 193 ± 40 mg/MJ at week 24).

Few changes were found in the intakes of other nutrients during the salt-restriction period (Table 1). In men, total energy intake decreased by 1059 kJ/d; alcohol, potassium, and vitamin D intakes decreased, but there were no significant changes in the intakes of other nutrients. In women, total dietary energy intake decreased by 1059 kJ/d; alcohol, potassium, and vitamin D intakes decreased significantly by the end of the study, but the potassium density in the diet remained unchanged. Both the total selenium intake (P = 0.031) and the selenium density (P = 0.005) of the diet decreased significantly by the end of the study in women.

To study the relations between the changes in dietary and urinary sodium and the changes in other nutrient intakes, the subjects were divided into 2 groups on the basis of the median change in dietary sodium and 24-h urinary sodium excretion. The changes in energy and protein intakes from weeks 4 to 12 were significantly greater in the group with the greater decrease in dietary sodium (Table 2). In the group with a decrease in dietary sodium ≥1529 mg/d, energy intake decreased by 862 ± 1877 kJ/d, whereas energy intake increased by 556 ± 1770 kJ/d in the group with a decrease in dietary sodium >1529 mg/d; protein intake decreased by 1.2 ± 2.9% and increased by 1.3 ± 2.8% in these 2 groups, respectively. There were no other significant differences in the changes in micronutrients between the 2 groups classified by change in dietary sodium from weeks 4 to 12 or from weeks 4 to 24. Changes in energy and macronutrient intakes did not differ significantly on the basis of the change in urinary sodium excretion.

There was a moderate correlation between the changes in energy intake and in dietary sodium intake from weeks 4 to 12 and from weeks 4 to 24 (Figure 1). The changes in 24-h urinary sodium excretion did not correlate with the changes in energy or macronutrient intake. The change in dietary sodium intake from weeks 4 and 24 correlated (r = 0.578, P < 0.001) with the change in fat intake (as a % of energy) and there was an inverse association with the change in carbohydrate (as a % of energy) (r = −0.410, P = 0.009) (data not shown).

Salt restriction was accomplished with minor changes in the consumption of different foods (Table 3). The consumption of...
meat products and eggs decreased significantly during the salt-
restriction period in both men and women. Consequently,
sodium intake from meat products and eggs decreased signifi-
cantly in both sexes ($P < 0.001$ for men, $P = 0.041$ for women; Table 4). The use of beverages, sugars, and sweets decreased in
men ($P = 0.002$) and the consumption of other food items
decreased significantly in both sexes. In men, the sodium
intake from cereals decreased significantly ($P = 0.041$) and in
women the sodium intake from vegetables and fruit decreased
significantly ($P = 0.014$).

![Figure 1](https://academic.oup.com/ajcn/article-abstract/72/2/414/4729454)

**FIGURE 1.** Changes in sodium intake and in 24-h urinary sodium excretion versus the change in energy intake from 4 to 12 wk (A and C) and from 4 to 24 wk (B and D). A: $r = 0.489$, $P = 0.002$; B: $r = 0.448$, $P = 0.004$; C: $r = -0.098$, $P = 0.555$; D: $r = 0.333$, $P = 0.039$. 

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**TABLE 2**

Changes in energy and macronutrient intakes from 4 to 12 wk and from 4 to 24 wk by median reductions in dietary sodium intake and in 24-h urinary sodium excretion.

<table>
<thead>
<tr>
<th></th>
<th>$\Delta$Energy</th>
<th>$\Delta$Fat</th>
<th>$\Delta$Protein</th>
<th>$\Delta$Carbohydrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$kJ$</td>
<td>% of energy</td>
<td>% of energy</td>
<td>% of energy</td>
</tr>
<tr>
<td><strong>Dietary sodium from 4 to 12 wk</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\leq -1529.3$ mg</td>
<td>$-862 \pm 1877$</td>
<td>$-2.1 \pm 7.5$</td>
<td>$-1.2 \pm 2.9$</td>
<td>$3.5 \pm 7.8$</td>
</tr>
<tr>
<td>$&gt; -1529.3$ mg</td>
<td>$556 \pm 1770$</td>
<td>$-0.1 \pm 5.9$</td>
<td>$1.3 \pm 2.8^{3}$</td>
<td>$1.9 \pm 6.1$</td>
</tr>
<tr>
<td><strong>Dietary sodium from 4 to 24 wk</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\leq -1490.3$ mg</td>
<td>$-1399 \pm 1591$</td>
<td>$-3.4 \pm 5.2$</td>
<td>$0.7 \pm 2.5$</td>
<td>$3.6 \pm 6.2$</td>
</tr>
<tr>
<td>$&gt; -1490.3$ mg</td>
<td>$141 \pm 1765$</td>
<td>$3.6 \pm 7.6$</td>
<td>$-0.2 \pm 2.0$</td>
<td>$-0.1 \pm 5.5$</td>
</tr>
<tr>
<td><strong>24-h urinary sodium from 4 to 12 wk</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\leq -84.0$ mmol</td>
<td>$-266 \pm 2109$</td>
<td>$-1.6 \pm 6.0$</td>
<td>$0.3 \pm 2.6$</td>
<td>$3.8 \pm 7.1$</td>
</tr>
<tr>
<td>$&gt; -84.0$ mmol</td>
<td>$-71 \pm 1797$</td>
<td>$-0.6 \pm 7.6$</td>
<td>$-0.3 \pm 3.5$</td>
<td>$1.6 \pm 6.9$</td>
</tr>
<tr>
<td><strong>24-h urinary sodium from 4 to 24 wk</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\leq -82.0$ mmol</td>
<td>$-1122 \pm 1608$</td>
<td>$-0.5 \pm 6.5$</td>
<td>$0.1 \pm 2.4$</td>
<td>$2.6 \pm 5.9$</td>
</tr>
<tr>
<td>$&gt; -82.0$ mmol</td>
<td>$-149 \pm 1957$</td>
<td>$0.5 \pm 8.2$</td>
<td>$0.5 \pm 2.2$</td>
<td>$1.0 \pm 6.3$</td>
</tr>
</tbody>
</table>

1, 2, 3 $\pm$ SD.

2, 3 Significantly different from above value: $^2P = 0.024$, $^3P = 0.008$. 

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**DIETARY EFFECTS OF SALT RESTRICTION**

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TABLE 4
Sodium intake from different food groups¹

<table>
<thead>
<tr>
<th></th>
<th>Men (n = 24)</th>
<th>Women (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Run-in (week 4)</td>
<td>Salt restriction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Week 12</td>
</tr>
<tr>
<td>Cereals</td>
<td>251 ± 95</td>
<td>307 ± 126</td>
</tr>
<tr>
<td>Vegetables and fruit</td>
<td>481 ± 230</td>
<td>475 ± 213</td>
</tr>
<tr>
<td>Fats and oils</td>
<td>39 ± 22</td>
<td>42 ± 30</td>
</tr>
<tr>
<td>Milk products</td>
<td>459 ± 200</td>
<td>520 ± 270</td>
</tr>
<tr>
<td>Meat products and eggs</td>
<td>205 ± 83</td>
<td>177 ± 10</td>
</tr>
<tr>
<td>Fish products</td>
<td>35 ± 27</td>
<td>28 ± 42</td>
</tr>
<tr>
<td>Beverages, sugars, and sweets</td>
<td>1248 ± 395</td>
<td>979 ± 289</td>
</tr>
<tr>
<td>Other food items</td>
<td>6 ± 3</td>
<td>4 ± 2</td>
</tr>
</tbody>
</table>

¹ ± SD. Data based on contents of 4-d food records.
² Significant time effect, P < 0.05 (nonparametric Friedman’s two-way ANOVA).

DISCUSSION

In the present study, the dietary effects of salt restriction were evaluated. During the salt-restricted diet, the sodium intake decreased significantly, but only minor changes were found in the intake of other nutrients.

The only significant reductions observed were in potassium and vitamin D intakes in men and in selenium intake in women. In men, the daily potassium intake (3807 mg) was still at the level recommended for hypertensive persons by the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure in 1997 (11). In general, nutrient intakes were not affected significantly by salt restriction when adjusted for energy intake; however, the selenium density of the diet decreased significantly in women after adjustment for energy intake. Energy-adjusted fiber intake increased in both sexes, although the change was not significant. Improvements in some nutritional components of the diet during the salt-restriction period were described in previous studies (12). During salt restriction, fat and cholesterol intakes decreased in studies by Stamler et al (13, 14) and intakes of potassium, fiber, ascorbic acid, vitamin A, vitamin B-6, vitamin B-12, riboflavin, folic acid, iron, and zinc increased in the study by Wassertheil-Smoller et al (15).

The minor changes in nutrient intakes in this study may have resulted because subjects had been asked to maintain their body weight and because of only moderate compliance with the salt-restricted diet. Despite the marked reductions in sodium intake and excretion, only 1 in 5 men and only 1 in 3 women achieved the goal of having a salt intake < 5 g/d, which was determined on the basis of the subjects’ urinary sodium excretion. The effect of weight maintenance and moderate compliance on the nutritional effects of a salt-restricted diet were observed previously in the Dietary Intervention Study of Hypertension (15, 16) and in the Exeter-Andover Project (17).

It has been suggested that a salt-restricted diet can cause changes in food choices and consequently in nutrient intakes. The changes in nutrient intakes during salt-restriction studies have been attributed to decreased consumption of meats (including poultry and fish), grains, and dairy products (1). A reduction in the consumption of these basic food items has been suggested to lead to decreased intakes of iron, magnesium, calcium, and vitamin B-6. In the present study, the intakes of these nutrients did not change significantly during the salt-restriction period. Decreased consumption of meat products and other food items containing salt used in food preparation in the home and in the food industry were the most marked changes occurring in food consumption during the salt-restriction period. One explanation for the decrease in the use of meat products during the salt-restriction period was the nonavailability of processed low-salt meat products. However, a reduction in the overall consumption of meat products may have beneficial effects on the overall quality of the diet, eg, because saturated fat and energy intakes consequently decrease. The consumption of cereals remained...
unchanged in the present study, likely because low-salt bread was provided free of charge to the patients.

In the present study, the sodium density of the diet decreased, indicating that the patients had eaten foods with a low sodium content and did not reduce their sodium intakes simply by reducing their energy intakes. However, there is evidence that attempts to reduce salt intakes may decrease the total consumption of foods and thus decrease energy intake. In the present study, energy intake did not change in women, but decreased slightly in men; the small decrease in body weight in both sexes during the salt-restriction period may have been due to a reduction in dietary energy intake. The observed correlation between the change in energy intake and the change in dietary sodium and the significantly greater decrease in energy intake from weeks 4 to 12 in the group with the greater decrease in dietary sodium indicates that salt restriction influenced energy intake and vice versa. Note that the reduction in energy intake is a successful way to reduce the intake of sodium. In clinical practice, patients are advised to reduce their body weight because most hypertensive subjects are overweight. Thus, the consequences of consuming a diet low in both energy and sodium should be evaluated.

In most trials, it was difficult to determine the potential effects of salt restriction on the intakes of other nutrients. These difficulties may have been due to the combination of sodium restriction with other dietary interventions, poor compliance with sodium restriction, lack of analysis of changes in patterns of food intake, or interventions that were too short to attain new stable dietary patterns (1). In the present study, the subjects were advised to reduce their salt intake, but to otherwise maintain their usual diet and body weight. The duration of the salt restriction was 20 wk, during which time the average reduced salt intake remained unchanged.

The great difference between the salt intake measured by 24-h urinary sodium excretion (9.0 g in men and 5.4 g in women) and by 4-d food record (5.2 g in men and 3.2 g in women) may be partly explained by the fact that the data used for these estimates were from different time periods. Urinary sodium excretion reflects the sodium intake over 24 h and it varies greatly from day to day. The dietary sodium intake in this study was the average sodium intake over 4 d. The assessment of sodium intake from dietary records is complicated by an underreporting bias and by the variability in sodium sources in the diet, eg, naturally occurring sodium, sodium added during processing, and discretionary salt use. The estimation of dietary sodium intake also depends on the accuracy of the nutrient database used.

In the present study, the goal for daily salt intake was <5 g/d, which is recommended for hypertensive persons as well as the general population (18, 19). Our results showed that it was difficult for the men to achieve the suggested intake of 5 g salt/day because they need more energy than do women and consequently consume more food than do women. For this goal to be achieved by persons consuming a Western diet, the average salt intake should be reduced on average by 50%, the salt content of processed foods should be reduced by 50%, and the preference for the taste of salt among Western people would have to change markedly. Witschi et al (20), in 1985, found that the sodium content of a variety of food products commonly consumed by young persons could be reduced by 51% on average without the foods losing their appeal. Four subjects in the present study withdrew at week 12 because of difficulties in reducing their salt intakes; the subjects who completed the study were well motivated.

Because of the small sample size and the experimental study design of the present study, the results cannot necessarily be generalized to all hypertensive persons being treated clinically.

In conclusion, salt restriction is possible in free-living hypertensive persons without causing untoward changes in the intakes of other nutrients. In a salt-restricted diet, emphasis should be placed on lowering the amount of salt added to foods in addition to eliminating foods rich in salt from the diet. Compliance with salt restriction should be the focus and not concerns about possible detrimental effects on the intake of other nutrients as a result of salt restriction.

We thank the Kuopio Research Institute of Exercise Medicine for the space and measurements provided during the study and Veikko Jokela for his advice about the statistical analyses.

REFERENCES