The influence of South African mineral water on reduction of risk of calcium oxalate kidney stone formation

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Objectives. This study was undertaken to identify a South African mineral water containing relatively high concentrations of calcium and magnesium and to investigate its effect on urinary biochemical and physicochemical risk factors associated with calcium oxalate kidney stone formation.

Design. The study followed a change-over design in which each subject followed a randomised sequence of three water-drinking protocols involving their normal diet, a calcium and magnesium-rich mineral water and a mineral water deficient in these elements.

Setting. University of Cape Town.

Subjects. 54 volunteers without any previous history of stone disease (27 men, 27 women) in the age group 21 - 35 years and 31 with a history of calcium oxalate kidney stones (24 men, 7 women) in the age group 25 - 45 years participated in the study.

Outcome measures. Both mineral waters favourably altered several risk factors. However, the effect of the calcium- and magnesium-rich water was shown to be significantly greater as it altered a larger number of these factors and induced several unique changes that were not achieved by the other water.

Conclusions. The risk of calcium oxalate stone formation can be significantly reduced by consumption of mineral water which is rich in calcium and magnesium.

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In a recent study, the risk of calcium oxalate (CaOx) stone formation was shown to decrease significantly after consumption of a French mineral water.[1] The prophylactic effect of the water was attributed to its high calcium and magnesium content as it has recently been proposed that calcium binds free oxalate in the gut, thereby reducing the amount of the latter which is absorbed; this reduces its concentration in the urine and thus reduces the risk of CaOx urolithiasis.[2] On the other hand, magnesium has been recognised as an inhibitor of CaOx stone formation for many years by virtue of its ability to form soluble magnesium oxalate which is excreted harmlessly in the urine.[3] The present study was undertaken to identify a South African mineral water containing levels of calcium and magnesium similar to those in the French water and to investigate whether it, too, would reduce the risk of CaOx kidney stone formation.

Subjects and methods

Six commercially available South African mineral waters (Baden, Caledon, Ceres, LaVie, Schoonspruit and Valpre) were randomly selected for analysis. The magnesium and calcium concentrations in each water were measured with a Varian 1275 Model flame atomic absorption spectrometer.

Fifty-four subjects with no previous history of stone disease (27 men, 27 women) in the age group 21 - 35 years and 31 with a history of CaOx stone formation (24 men, 7 women) in the age group 25 - 45 years participated in the study. All of the latter had suffered a stone episode in the month prior to participation in the project; confirmation of stone type was achieved by X-ray powder diffraction.

Subjects were required to supply a 24-hour urine sample while on their free unrestricted diets as well as after two drinking protocols involving a mineral water with a high magnesium and calcium content and one containing relatively low concentrations of these two components. In each of the water-drinking protocols, 1.5 litres per day were consumed for a period of 3 days. Urine was collected during the final 24 hours. Glass bottles (2.5 litres), which had been thoroughly washed with 5M hydrochloric acid and rinsed with distilled water, were used for this purpose. No preservative was present. During the collection period the bottle and contents were refrigerated.

Urines were tested for the presence of blood and infection (Combur 10 test strip; Boehringer Mannheim). Samples in which haematuria was detected or which were found to be nitrite-positive were discarded. Thereafter, volume and pH were recorded. Urines were analysed for sodium, potassium, calcium and magnesium content by means of flame atomic absorption spectrometry. Oxalate content was determined with oxalate decarboxylase. For these analyses an ascorbate oxidase spatula was used to remove L-ascorbic acid. Citrate content was determined by citrate lyase conversions to oxalo-acetate. Inorganic phosphorus level was determined with ammonium molybdate; creatinine content was determined with picric acid and uric acid level was determined with uricase. Analytical kits manufactured by Boehringer Mannheim were used for these determinations.

The metastable limit (MSL) of urine is a measure of how readily it supports crystallisation.[4] The method for its determination has been described elsewhere.[5] Briefly, successive aliquots of aqueous sodium oxalate (NaOx) are added in progressively increasing concentrations to the urine, until CaOx crystallisation (as detected by turbidity measurements) is initiated. The concentration of exogenous NaOx required to produce detectable crystallisation is taken as the MSL. It follows that an increase in the MSL (e.g. after administration of a therapeutic protocol) corresponds to a decrease in the likelihood of stone formation.

Several physicochemical quotients, ratios and indices, which have been empirically derived and which have been

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widely used by stone researchers in assessing the efficacy of treatment regimens, were determined prior to and after the water-drinking protocols. Among the most important of these were the CaOx relative supersaturation,[6] the 'risk index'[7] and the standardised activity product.[8] All incorporate urinary component concentrations in mathematical functions, the output of which (in each case) is a number which indicates the potential for stone formation. The higher the relative value of the number, the higher the risk. Risk index and activity product values for all urines were calculated by means of the published equations,[7,8] while relative supersaturation values were determined with the speciation computer program, EQUIL.[6] A summary of the biochemical and physicochemical risk factors which were determined in this study is given in Table I.

Table I. Biochemical and physicochemical risk factors determined in the urine of all subjects in this study

Risk factor	Change indicating reduced risk
Biochemical	
Oxalate excretion[11]	↓
Citrate excretion[12]	↑
Magnesium excretion[3]	↑
Uric acid excretion[13]	↓
Calcium excretion[2]	↑
Phosphate excretion[14]	↑
pH[15]	↑
Volume[16]	↑
Physicochemical	
Calcium oxalate metastable limit[4]	↑
Risk index[7]	↓
Standardised activity product[8]	↓
Relative supersaturation[6]	↓

Statistical design and analysis

The study was statistically planned to follow a Latin square cross-over design[9] in which each subject participated in a randomised sequence of the three protocols (i.e. normal diet, calcium- and magnesium-rich water, calcium- and magnesium-deficient water). The data were analysed by the method of analysis of variance; comparisons between protocols were made with Student's *t*-test to establish which of a multitude of risk factors might change significantly. All analyses were performed with the SAS statistical package.[10]

Results

The concentrations of magnesium and calcium of six randomly selected South African mineral waters are presented in the histogram in Fig. 1. On the basis of these results, Schoonspruit (calcium- and magnesium-rich) and Caledon (calcium- and magnesium-deficient) mineral waters were selected for the trial. Tables II - V give those risk factors for each of the four groups in which a statistically significant change occurred (relative to normal diet values) as a result of either the Schoonspruit or Caledon protocols, or both. In this table a '†' symbol indicates a favourable change (i.e. a shift towards lower stone risk). An asterisk '*' indicates that the effect of one protocol was more significant than that of the other. Risk factors which were measured, but which did not change significantly in any group, were pH and calcium, sodium, potassium, uric acid and phosphate excretions. However, because pH is an important indicator of urine milieu, mean values are included in Tables II - V.

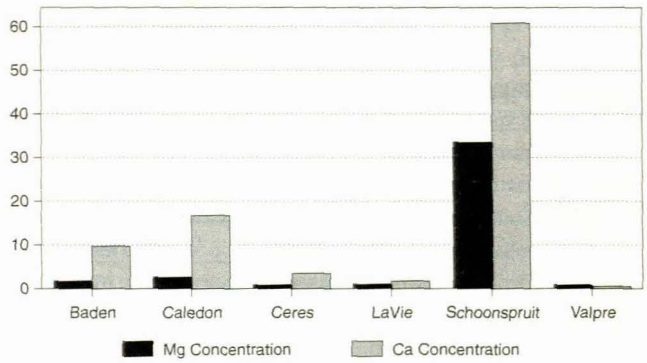

Fig. 1. Mg and Ca concentrations (mg/l) in 6 randomly selected South African mineral waters.

Table II. Male controls (*N* = 27) — mean risk factor values associated with each protocol, standard errors and pairwise *P* comparisons

	Drinking protocol			Pairwise *P*-values		
	Normal (N)	Caledon (C)	Schoonspruit (S)	N v. C	N v. S	C v. S
MSL	0.53 (0.08)	0.69 (0.08)	0.75 (0.08)	0.15	0.04†	0.58
Risk index	318 (30)	284 (29)	174 (30)	0.40	< 0.01†	0.01
CaOx RS	4.96 (0.36)	3.52 (0.34)	2.10 (0.35)	< 0.01†	< 0.01†*	< 0.01
Brush RS	1.35 (0.14)	0.93 (0.14)	1.04 (0.14)	0.04†	0.12	0.57
UA RS	2.11 (0.24)	1.20 (0.24)	1.15 (0.24)	0.01†	0.01†	0.88
Vol (cm^3)	1 537 (116)	2 203 (116)	1 973 (116)	< 0.01†	0.01†	0.16
Cit (mmol/24 h)	2.18 (0.22)	2.83 (0.22)	2.82 (0.22)	0.04†	0.04†	0.97
Ox (mmol/24 h)	0.29 (0.01)	0.30 (0.01)	0.17 (0.01)	0.61	< 0.01†	< 0.01
APS	1.32 (0.10)	1.28 (0.10)	0.78 (0.10)	0.79	< 0.01†	< 0.01
pH	6.00 (0.08)	6.21 (0.08)	6.23 (0.08)	0.07	0.05	0.90

* More significant effect of one protocol relative to the other.
† Favourable change in the risk factor.
MSL = metastable limit (M NaOx); CaOx RS = calcium oxalate relative supersaturation; Brush RS = brushite relative supersaturation; UA RS = uric acid relative supersaturation; APS = standardised CaOx activity product.

Table III. Men with stone formation (*N* = 24) — mean risk factor values associated with each protocol, standard errors and pairwise *P* comparisons

	Drinking protocol			Pairwise *P*-values		
	Normal (N)	Caledon (C)	Schoonspruit (S)	N v. C	N v. S	C v. S
Risk index	405 (32)	269 (32)	229 (32)	< 0.01†	< 0.01†	0.37
CaOx RS	6.26 (0.39)	3.63 (0.38)	3.53 (0.37)	< 0.01†	< 0.01†	0.85
Vol (cm^3)	1 359 (126)	1 877 (126)	1 829 (126)	< 0.01†	0.01†	0.79
Cit (mmol/24 h)	2.11 (0.24)	2.72 (0.24)	2.95 (0.24)	0.07	0.01†	0.51
Ox (mmol/24 h)	0.32 (0.02)	0.26 (0.02)	0.20 (0.02)	< 0.01†	< 0.01†*	0.01
Mg (mmol/24 h)	3.35 (0.31)	4.03 (0.31)	4.38 (0.31)	0.12	0.02†	0.42
APS	1.52 (0.11)	1.33 (0.11)	1.03 (0.11)	0.21	< 0.01†	0.05
pH	5.96 (0.09)	5.96 (0.09)	5.98 (0.09)	0.99	0.91	0.92

* More significant effect of one protocol relative to the other.
† Favourable change in the risk factor.
CaOx RS = calcium oxalate relative supersaturation; APS = standardised CaOx activity product.

Table IV. Female controls (*N* = 27) — mean risk factor values associated with each protocol, standard errors and pairwise *P* comparisons

	Drinking protocol			Pairwise *P*-values		
	Normal (N)	Caledon (C)	Schoonspruit (S)	N v. C	N v. S	C v. S
Risk index	352 (29)	367 (29)	216 (29)	0.72	< 0.01†	< 0.01
CaOx RS	3.49 (0.35)	2.64 (0.34)	1.57 (0.34)	0.08	< 0.01†	0.03
Vol (cm^3)	1 504 (116)	2 342 (114)	2 257 (116)	< 0.01†	< 0.01†	0.60
Cit (mmol/24 h)	2.73 (0.22)	3.32 (0.22)	3.47 (0.22)	0.06	0.02†	0.63
Ox (mmol/24 h)	0.23 (0.01)	0.25 (0.01)	0.15 (0.01)	0.44	< 0.01†	< 0.01
APS	0.91 (0.10)	1.07 (0.10)	0.60 (0.10)	0.25	0.03†	< 0.01
pH	6.20 (0.08)	6.23 (0.08)	6.32 (0.08)	0.77	0.29	0.44

† Indicates a favourable change in the risk factor.
CaOx RS = calcium oxalate relative supersaturation; APS = standardised CaOx activity product.

Table V. Women with stone formation (*N* = 7) — mean risk factor values associated with each protocol, standard errors and pairwise *P* comparisons

	Drinking protocol			Pairwise *P*-values		
	Normal (N)	Caledon (C)	Schoonspruit (S)	N v. C	N v. S	C v. S
Risk index	409 (63)	325 (63)	215 (63)	0.32	0.02†	0.19
CaOx RS	4.62 (0.72)	3.96 (0.72)	2.36 (0.72)	0.50	0.02†	0.10
Ox (mmol/24 h)	0.26 (0.03)	0.24 (0.03)	0.15 (0.03)	0.72	0.01†	0.02
pH	6.20 (0.08)	6.23 (0.08)	6.32 (0.08)	0.77	0.29	0.44

† Indicates a favourable change in the risk factor.
CaOx RS = calcium oxalate relative supersaturation.

Discussion

Both protocols induced several favourable changes in the urinary risk factors. However, the number of factors altered by the Schoonspruit protocol was greater than that affected by the Caledon protocol. Furthermore, when both protocols altered the same risk factor, the effect of Schoonspruit was more significant in two of these — CaOx relative supersaturation (Table II) and oxalate excretion (Table III). It is also noteworthy that Caledon had no effect on the risk factors in women with a history of stone disease, while Schoonspruit altered three of them (Table V).

Three risk factors were favourably altered in all four groups: oxalate excretion, CaOx relative supersaturation and the CaOx 'risk index'. Of these, oxalate excretion is widely regarded as the most crucial determinant in CaOx urolithiasis.[11] The results show that Schoonspruit uniquely achieved a decrease in this risk factor in male controls, female controls and women with a history of stone formation; in men who had experienced stone formation the desired decrease was achieved by both waters, but Schoonspruit was significantly more effective. The CaOx relative supersaturation and the CaOx risk index decreased in the four groups after consumption of Schoonspruit, i.e. favourable shifts occurred in all eight risk factors while a similar effect occurred in only three of these factors after consumption of Caledon. It should be noted that one of the other risk quotients determined in this study — the standardised CaOx activity product — decreased significantly in male and female controls as well as in men who had experienced stone formation, after the Schoonspruit protocol. In women who had had kidney

stones, the decreasing trend was evident but not significant ($P = 0.0708$). The standardised activity product was not affected in any group by the Caledon protocol.

Also worthy of comment is the significant increase in citrate excretion in three groups after mineral water consumption (Tables II - IV) while in the fourth group (women who had experienced stone formation) an increasing (but not significant) trend occurred (normal: 2.08 (0.47); Caledon: 1.99 (0.47); Schoonspruit: 2.74 (0.47)). These observations are of great importance as they provide further evidence in support of the risk-reducing effect of mineral water. However, it is intriguing that the increased citrate excretion was not accompanied by increasing pH values. The mechanism by which this could have occurred is unknown.

The results of this study have demonstrated that both Schoonspruit and Caledon mineral water favourably altered several biochemical and physicochemical risk factors related to CaOx kidney stone formation. However, the effect of Schoonspruit was shown to be significantly greater, as it altered a larger number of risk factors and induced several unique changes in key determinants which were not achieved by the Caledon protocol. Since the two waters differ markedly in respect of their calcium and magnesium content (Fig. 1), it is suggested that these components afford Schoonspruit mineral water its inhibitory capacity in respect of stone formation. This result supports the hypothesis that delivery of a large fluid volume containing relatively high levels of calcium and magnesium reduces the risk of stone development.[1] Therefore, mineral waters such as Schoonspruit, which satisfy this criterion, can be effectively recommended as a therapeutic protocol in CaOx kidney stone disease.

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Do stroke patients realise that a consequence of hypertension is stroke?

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Study objective. The specific objectives of the study were to survey residual disability and handicap following stroke. Information on four risk factors, namely hypertension, age, smoking, and alcohol abuse, was obtained. Enquiry was made into the subjects' insight into the causes of their problems.

Design. Descriptive survey.

Setting. Baragwanath Hospital and Soweto.

Participants. Stroke patients 12 - 14 weeks post-discharge.

Outcome measures. Structured questionnaire.

Results. A total of 361 patients were initially screened. Only 54 fulfilled all inclusion criteria, 38 (70%) over 50 years of age and 16 (30%) under 50 years. Ninety-three of the 361 died within the first 3 months; 71% of all patients knew that they had suffered a stroke. Only 20% of the total group understood that hypertension had probably caused their stroke, although 76% of the older group and 56% of the younger group had been told at some stage that they were hypertensive. Of the older group 32% knew the name of their medication, 21% could not name their medication and 23% claimed they were on no medication. Similarly in the younger group, 19% could name their medication, 25% could not name their medication, and 12% were on no medication. In addition, 16% of the older group and 56% of the younger group admitted to smoking. The abuse of alcohol in both groups was low, but this figure was taken from subjective assessment and may not reflect the true extent of drinking as a risk factor.

Conclusion. Most patients in this study appear well aware of their hypertension and take medication. However, they seem unaware that their hypertension and stroke are causally linked and their hypertension knowledge is suboptimal. It is also apparent that smoking is increasing as a major risk factor for stroke in the black population of South Africa. Patients need more education regarding hypertension and its consequences.

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