Original Article

Effect of yoga exercise therapy on oxidative stress indicators with end-stage renal disease on hemodialysis

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ABSTRACT

Background: Oxidative stress promotes endothelial dysfunction and atherosclerosis in chronic renal disease.

Objectives: This study investigated the impact of *Hatha* yoga on oxidative stress indicators and oxidant status, in patients with end-stage renal disease (ESRD) on hemodialysis.

Design: This prospective randomized study consisted of 33 ESRD patients in the *Hatha* yoga exercise group who were matched with 35 ESRD patients in the control group.

Outcome Measures: The oxidative stress indicators (malondialdehyde - MDA, protein oxidation - POX, phospholipase A2 - PLA2 activity) and the oxidative status (superoxide dismutase (SOD) and catalase activities) were determined in the blood samples taken at the pre-hemodialysis treatment, at baseline (0 months) and after four months.

Results: In patients in the *Hatha* yoga exercise group, lipid peroxidation, as indicated by MDA decreased by 4.0% after four months ($P = 0.096$). There was also a significant reduction in the activity of PLA from 2.68 ± 0.02 IU / L to 2.34 IU / L (− 12.7%; $P = 0.010$) and POX from 2.28 ± 0.02 nmol / mg to 2.22 ± 0.01 nmol / mg (− 22.6%; $P = 0.0001$). The activity of SOD significantly increased from 12.91 ± 0.17 U / L to 13.54 ± 0.15 U / L (4.65%; $P = 0.0001$) and catalase from 79.83 ± 0.63 U / L to 80.54 ± 0.80 U / L (0.90%; $P = 0.0001$). There was a significant correlation between the pre-hemodialysis oxidative stress parameters at the zero month and after four months for the activities of PLA (r = 0.440), catalase (r = 0.872), and SOD (r = 0.775).

Conclusions: These findings suggest that the *Hatha* yoga exercise has therapeutic, preventative, and protective effects in ESRD subjects, by decreasing oxidative stress.

Key words: Antioxidant enzymes; end-stage renal disease; *Hatha* yoga exercise; lipid peroxidation; oxidative stress.

INTRODUCTION

The incidence and prevalence of chronic kidney disease (CKD) are increasing worldwide. According to the 1998−2004 National Health and Nutritional Survey (NHANES), the prevalence of CKD in the US population is 15.3%.[1] The United States Renal Data System (USRDS) reported that the estimated risk for cardiac events, such as myocardial infarction, is 3.5−50 times higher among patients on renal replacement therapy than in the general population.[2] Approximately 50% of the patients with ESRD die from cardiovascular events,[3] which indicate that cardiovascular mortality is 30 times higher in dialysis patients. Chronic kidney disease patients are known to be affected by diabetes mellitus, hypertension, and obesity – which are known traditional cardiovascular disease (CVD) risk factors in the general population.[4] Reports from the Caribbean Renal Registry of six countries identified hypertension, diabetes mellitus, and chronic glomerulonephritis (CGN) as the most common causes of CKD and ESRD. The leading causes of death reported were listed as ischemic heart disease/heart failure, sepsis, and cerebrovascular accident.[5]

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Chronic renal insufficiency *per se* is associated with uremia–specific risk factors, such as, chronic volume expansion, anemia, disturbances of calcium-phosphate metabolism, hyperhomocysteinemia, and a micro-inflammatory state associated with increased oxidant stress.[6] Oxidative stress is defined as tissue damage resulting from an imbalance between the excessive generation of oxidant compounds and insufficient anti-oxidant defense mechanisms.[7] Impaired oxidative balance in CKD is likely to come from a combination of increased reactive oxygen species (ROS) production and reduced clearance, as well as an ineffective antioxidant defense mechanism. Several important antioxidant pathways have been reported to be altered in patients with CKD, including reduced erythrocyte SOD activity,[8] diminished plasma glutathione, and glutathione peroxidase function.[9] Plasma ascorbic acid and lipid-soluble alpha-tocopherol, both potent components of an antioxidant defense system, were found to be significantly reduced after a single hemodialysis session.[10] However, the hemodialysis procedure was also reported to have beneficial effects on the total antioxidant capacity by increasing the plasma thiol content.[11] Concentrations of malondialdehyde (MDA), a by-product of lipid peroxidation, are increased in the plasma and red blood cells of ESRD patients.[12]

Hemodialysis patients are significantly less active than the sedentary age-matched controls and their physical activity declines by about 3.4% each month, after initiation of dialysis.[13] A large research literature documents a variety of potential benefits that ESRD patients may achieve from exercise training.[14] Improvements in reaction time and lower extremity muscle strength, left ventricular systolic function, and psychosocial functioning have been demonstrated in randomized clinical trials.[15] In addition, exercise has beneficial effects on the functional capacity, anemia, cardiovascular risks factors, dyslipidemia, and psychosocial problems.[16]

Yoga has become increasingly popular in Western cultures as a means of exercise and training fitness.[17] It has been used clinically as a therapeutic intervention and its practice includes muscle stretching, breathing exercises, behavioral modification, and dietary control, through mental discipline.[18] A growing number of research studies have shown that *Hatha* yoga can improve strength and flexibility, and may help control physiological variables such as blood pressure, respiration, heart rate, and metabolic rate, to improve the overall exercise capacity.[19] Studies carried out on the medium or long-term effect of yoga exercise on oxidative stress parameters and antioxidant status in end stage renal disease patients are sparse. To date, only one study by Yurtkuran *et al*. has evaluated the effects of a yoga-based exercise program on pain, fatigue, sleep disturbance, and biochemical markers, in hemodialysis patients.[20] This study has investigated the impact of *Hatha* yoga exercise on oxidative stress indicators and the oxidant status in patients with ESRD on hemodialysis.

MATERIALS AND METHODS

Selection of subjects

The study was conducted between January 2009 and April 2009, in accordance with the Declaration of Helsinki. All the participants were recruited from the Hemodialysis Unit at the University Hospital of the West Indies. The inclusion criteria were: End-stage renal disease, between 20 to 70 years old, good psychological condition (in accordance with the psychologist's consideration), non-smoker and non-alcoholic, had no associated serious illness or harmful dependency on toxic habits, and had signed a consent form. There were two groups in the study. The yoga group consisted of patients who participated in 30 minutes of guided *Hatha* Yoga exercise and an additional 30 minutes of instructed and unsupervised home training. The yoga exercises consisted of *pranayama* (breath-control exercises), *asanas* (yogic postures), and supine relaxation in *savasana* (corpse pose). The participants in the control group continued their regular lifestyle practice, without direct intervention from the personnel of this investigation.

Using the Sample Power statistical software, set at type 1 error (alpha) = 0.05 and power of 90%, the minimum number of participants needed to pick up the mean differences from the normal was calculated to be five persons per group of interest. The groups of interest include analysis broken down by four age categories, two gender categories, four body mass index categories, and two overall groupings of cases versus controls. Hence, a minimum of 66 participants (33 cases in the Yoga group and 33 comparison control patients without a guided training program) were needed for this study. Informed consent was obtained, and intervention and control patients were selected using a random sample, from the sample frame of list of patients who attended that Hemodialysis Unit.

On the day of blood collection, the subjects were asked to abstain from *Hatha* yoga or any other form of exercise. Blood (5 mL) was drawn from an antecubital vein at baseline (0 month) and after four months in one sample tube, with a serum separator gel, for oxidative stress indicators and other biochemical investigations in the post absorptive state. The blood was drawn between 7:30 a.m. and 9:00 a.m., without stasis. The serum samples were processed and refrigerated within three hours of blood draw. The serum samples that were not assayed within 24 hours after collection were stored at 2°C to 8°C. Specimens held for longer times were stored at - 70°C.

Measures and biochemical analysis

The determination of the oxidative and anti-oxidative stress biomarkers was done at the Ameijeras Hospital, Havana, Cuba. All samples from both groups were taken and stored in freezers at the Sub-Department of Biochemistry, University of the West Indies, Mona, until they are transported to Cuba. Permission was sought and obtained from the Ministry of Health and Environment in Jamaica, as well as the Ministry of Health in Cuba with regard to the transporting of biological materials.

Serial venous blood samples were collected and assayed for serum levels of urea and electrolytes, albumin, calcium, magnesium, phosphorous, uric acid, urea, and creatinine, utilizing a multi-channel auto analyzer (c8000, Abbott Diagnostics, USA). Serum levels of thyroid-stimulating hormone (TSH) and free thyroxine (FT_4) were measured by radioimmunoassay on an AXSYM System (Abbott Laboratories, Abbott Park, USA) for all subjects.[21] Biochemical assays of lipid profile parameters in the serum samples were performed with a multi-channel *Abbott Spectrum Autoanalyzer (Abbott* Laboratories, *Abbott* Park, USA). Malondialdehyde concentration in the serum was measured spectrophotometrically according to Yagi,[22] and the PLA2 activity in the serum was determined according to the method described by Lobo and Radbani.[23] Protein oxidation was based on the detection of the carbonyl group that appeared as a result of the oxidation of lateral chains of certain amino acids. Plasma carbonyl group levels were evaluated following the 2, 4-dinitrophenylhydrazine (2,4-DNP) assay,[24] and were expressed as nanomoles per milligram of protein. The protein concentration was determined using bovine serum albumin as the standard, according to the Bradford's method.[25] The SOD activity was determined by the inhibition of pyrogallin (formed due to the auto-oxidation of pyrogallol)[26] and the catalase activity was measured by the ultraviolet method, based on the transformation of hydrogen peroxide.[27]

Data analysis

Values for the continuous variables were expressed as mean ± S.E. Comparisons of the biochemical variables of subjects in the control and *Hatha* yoga exercise groups at baseline and after four months were performed using the two-way analysis of variance (ANOVA) with 95% confidence interval, where a level of $P < 0.05$ was considered as statistically significant. This test was also used to investigate the effects of a variable within a group and between groups, and the 'within-subjects' factors and 'between-subjects analyses'. The hypothesis was that *Hatha* yoga had an effect on the biochemical parameters of pre- and post-hemodialysis patients. *Independent* observations were assumed using the *Fisher* exact *test,* and 0.05 was taken to be the cut-off for acceptability of significance levels. The study parameters, which show non-Gaussian distribution, and statistical significance were assessed by the Mann-Whitney U test.[28] A possible correlation between the oxidative stress parameters was assessed using the linear regression analysis. The tested hypothesis was that there was a significant correlation between the oxidative stress parameters in pre- and post-hemodialysis patients, due to intervention with *Hatha* yoga. Statistics were computed using SPSS 11.5 (SPSS Inc., Chicago, Illinois, United States).

RESULTS

The age of the patients in the *Hatha* yoga exercise group was 38.95 ± 2.84 years, while that of the control group was 44.59 ± 2.57 years. The body mass index (BMI) of the patients in the control group was 25.74 ± 0.50 kg/m^2, while that of the *Hatha* yoga exercise group was 25.550 ± 2.21 kg/m^2. The patients in the control group were on hemodialysis for 4.45 ± 0.65 years, while those in the *Hatha* Yoga exercise group were on hemodialysis for 4.86 ± 0.49 years.

In the pre hemodialysis *Hatha* yoga exercise group there was a significant increase in the potassium and calcium concentrations, and a significant decrease in uric acid concentration after four months, compared to the values of these analytes at the zero month [Table 1]. In the post hemodialysis *Hatha* yoga exercise group there was a significant decrease in potassium and urea concentrations, and a significant increase in albumin concentration after four months, compared to the values of these analytes at the zero month [Table 2].

In the pre-hemodialysis control group there was a significant decrease in creatinine, albumin, calcium and phosphorous concentrations after four months compared to the values of these analytes at the zero month [Table 1]. In the post hemodialysis control group there was a significant decrease in creatinine concentration and an increase in sodium concentration after four months compared to the values of these analytes at the zero month [Table 2].

Lipid peroxidation as indicated by MDA decreased in patients in the *Hatha* yoga exercise group by 4.0% after four months, although the difference between the values was not significant. In patients in the pre hemodialysis *Hatha* yoga exercise group, there was a significant reduction in the activity of PLA (12.7% reduction; $P = 0.010$) and POX (22.6% reduction; $P = 0.0001$). There was a significant increase in the activities of SOD (4.65% elevation; $P = 0.0001$) and catalase (0.90% elevation; $P = 0.0001$). In addition, there was a 27.9% significant increase in the FT_4 concentration [Table 3].

Lipid peroxidation activities, as indicated by MDA, of PLA, SOD, and catalase, decreased in patients in

Table 1: Biochemical parameters of pre-hemodialysis patients in the Hatha yoga exercise and control groups at baseline (zero month) and after four months

Biochemical parameters	Mean±S.E. pre HD 0 month	Mean±S.E. pre HD 4 months	*P*-value
Hatha group			
Sodium (mmol/L)	137.30±0.83	137.88±0.92	0.999
Potassium (mmol/L)	4.16±0.16	4.18±0.17	0.016*
Urea (mmol/L)	29.02±1.48	28.46±1.44	0.263
Creatinine (μmol/L)	1349.21±83.68	1199.24±54.71	0.126
Uric acid (mmol/L)	0.49±0.03	0.39±0.03	0.014*
Albumin (g/L)	37.58±0.99	40.09±0.68	0.708
Calcium (mmol/L)	1.99±0.05	2.08±0.05	0.004*
Phosphorous (mmol/L)	1.96±0.13	1.83±0.15	0.052
Control group			
Sodium (mmol/L)	139.31±0.72	132.49±4.06	0.550
Potassium (mmol/L)	4.38±0.14	4.38±0.14	0.113
Urea (mmol/L)	23.76±1.08	25.70±1.07	0.686
Creatinine (μmol/L)	1060.66±50.80	1041.83±54.07	0.0001*
Uric acid (mmol/L)	0.39±0.03	0.39±0.53	0.002*
Albumin (g/L)	40.20±0.96	37.89±0.61	0.001*
Calcium (mmol/L)	2.21±0.03	2.08±0.05	0.001*
Phosphorous (mmol/L)	1.74±0.09	1.62±0.091	0.0001*

*Denotes statistical significance with $P<0.05$ using ANOVA

Table 2: Biochemical parameters of post-hemodialysis patients in the Hatha yoga exercise and control groups at baseline (zero month) and after four months

Biochemical parameters	Mean±S.E. post HD 0 month	Mean±S.E. post HD 4 months	*P*-value
Hatha yoga group			
Sodium (mmol/L)	136.52±0.69	136.12±0.54	0.184
Potassium (mmol/L)	2.62±0.13	2.54±0.11	0.011*
Urea (mmol/L)	12.81±1.40	9.73±1.02	0.002*
Creatinine (μmol/L)	589.88±52.23	409.94±35.63	0.103
Uric acid (mmol/L)	0.18±0.02	0.24±0.04	0.121
Albumin (g/L)	40.64±1.20	43.61±0.87	0.022*
Calcium (mmol/L)	2.12±0.05	2.03±0.48	0.060
Phosphorous (mmol/L)	1.12±0.10	1.00±0.09	0.092
Control group			
Sodium (mmol/L)	136.63±0.83	132.49±4.06	0.022*
Potassium (mmol/L)	2.75±0.11	4.38±0.14	0.805
Urea (mmol/L)	8.50±0.68	25.70±1.07	0.914
Creatinine (μmol/L)	451.69±23.98	1041.83±54.07	0.007*
Uric acid (mmol/L)	0.16±0.02	0.19±0.02	0.121
Albumin (g/L)	41.40±1.04	39.11±1.04	0.095
Calcium (mmol/L)	2.26±0.03	2.17±0.09	0.150
Phosphorous (mmol/L)	0.90±0.08	0.83±0.05	0.813

*Denotes statistical significance with $P<0.05$ using ANOVA

Table 3: Oxidative stress parameters of pre-hemodialysis patients in the Hatha yoga exercise and control groups at baseline (zero month) and after four months

Biochemical parameters	Mean±S.E. pre HD 0 month	Mean±S.E. pre HD 4 month	*P*-value
Hatha yoga group			
MDA (nmol/L)	2.26±0.01	2.17±0.01	0.096
PLA (IU)	2.62±0.13	2.34±0.03	0.010*
POX (nmol/mg)	2.28±0.02	2.22±0.01	0.0001*
SOD (U/L)	12.91±0.17	13.54±0.15	0.0001*
Catalase (U/L)	79.83±0.63	80.54±0.80	0.0001*
TSH (mU/L)	6.71±0.40	6.12±0.27	0.110
FT4 (ng/dL)	0.80±0.07	1.11±0.10	0.0001*
Control group			
MDA (nmol/L)	2.26±0.01	2.25±0.01	0.002*
PLA (IU)	2.69±0.02	2.67±0.02	0.003*
POX (nmol/mg)	2.34±0.02	2.35±0.02	0.0001*
SOD (U/L)	12.70±0.18	12.14±0.14	0.0001*
Catalase (U/L)	80.48±0.49	80.03±0.55	0.0001*
TSH (mU/L)	7.54±0.40	7.46±0.40	0.0001*
FT4 (ng/dL)	0.83±0.07	0.85±0.08	0.009*

*Denotes statistical significance with $P<0.05$ using ANOVA the control group after four months. In patients in the pre-hemodialysis control group the activities of PLA, SOD, and catalase decreased by 0.7% (P = 0.003), 4.4% (P = 0.0001), and 0.6% (P = 0.0001), respectively, while those of POX increased. Furthermore, there was a significant reduction in TSH (P = 0.0001) and increase in FT_4 (P = 0.009); [Table 3].

There was a significant correlation between the pre-hemodialysis oxidative stress parameters in the patients of the *Hatha* yoga exercise group at zero month and after four months for the activities of PLA (r = 0.440; P = 0.010), catalase (r = 0.872; P = 0.001), SOD (r = 0.775; P = 0.001), and POX (r = 0.820; P = 0.0001). In addition, there was a significant correlation for FT_4 (r = 0.802; P = 0.001), [Table 4]. There was a significant correlation between the pre-hemodialysis oxidative stress parameters of control patients at the zero month and after four months for concentrations of MDA (r = 0.503; P = 0.002) and POX (r = 0.608; P = 0.001), and the activities of PLA (r = 0.491; P = 0.003), SOD (r = 0.862; P = 0.0001), and catalase (r = 0.856; P = 0.0001). Furthermore, there was a significant correlation for TSH (r = 0.653; P = 0.0001) and FT_4 (r = 0.433; P = 0.009), [Table 4].

DISCUSSION

Uremia and renal replacement therapies result in markedly enhanced oxidative stress, the production of complement fragments and cytokines, increased adhesion molecules in endothelial cells, and other pro-inflammatory factors. These factors may provide a proper milieu for the development of accelerated atherosclerosis.[29] The present study confirms the positive effects of *Hatha* yoga exercise on oxidative stress and oxidant status in ESRD patients, after four months. Evaluation of the antioxidant status demonstrates a significant increase in SOD and catalase activities, with a concomitant non-significant reduction in MDA in the *Hatha* yoga exercise group, after four months. The improved antioxidant status, due to this exercise regimen, may point to an adaptive response to oxidative stress, reflecting free radical production and increased enzyme biosynthesis.[30]

Patients with chronic renal failure, including those receiving regular long-term hemodialysis have a high incidence of premature cardiovascular disease.[31] Free radicals may cause lipid peroxidation, and damage macromolecules and the cellular structure of the organism, endothelium, and erythrocytes. Oxidative stress generally causes damage to the membrane polyunsaturated fatty acids leading to the generation of MDA, a thiobarbituric acid reacting substance (TBARS). Plasma MDA is the breakdown product of the major chain reactions leading to definite oxidation of polyunsaturated fatty acids, such as linoleic and linolenic acids, and thus, serves as a reliable marker of lipid peroxidation.[32] Plasma MDA is a predictor of cardiovascular disease in patients on hemodialysis, which may underscore the role of oxidative stress as a cardiac risk factor in these patients.[33] Some studies have shown that hemodialysis is connected with increased free radical production.[34] In a study by Marjani *et al.*, examining the possibility of lipid peroxidation and lipid profile variation in hemodialysis patients, there were increased plasma levels of lipid peroxidation and triglycerides in ESRD patients compared to the control subjects. The authors conclude that the changes in the level of plasma lipid peroxidation and triglycerides in hemodialyzed patients, may be related to the patients uremia, dialysis membrane, and the dialysis process.[35] In the present study there was no difference in the baseline MDA concentration of the

Table 4: Correlation of oxidative stress parameters of pre-hemodialysis patients in the Hatha yoga exercise and control groups at baseline (zero month) and after four months

Oxidative stress parameters zero months/four months	MDA	PLA	POX	SOD	Catalase	TSH	FT^4
Hatha yoga group							
MDA	0.295	-	-	-	-	-	-
PLA	-	0.440*	-	-	-	-	-
POX	-	-	0.820*	-	-	-	-
SOD	-	-	-	0.775*	-	-	-
Catalase	-	-	-	-	0.872*	-	-
TSH	-	-	-	-	-	-	0.283
FT^4	-	-	-	-	-	-	0.802*
Control							
MDA	0.503*	-	-	-	-	-	-
PLA	-	0.491*	-	-	-	-	-
POX	-	-	0.608*	-	-	-	-
SOD	-	-	-	0.862*	-	-	-
Catalase	-	-	-	-	0.856*	-	-
TSH	-	-	-	-	-	0.653*	-
FT_4	-	-	-	-	-	-	0.433*

*Denotes statistical significance with P<0.05 using ANOVA patients in both groups. This result differs from other studies, where some researchers[36] have reported that the level of plasma MDA in hemodialysis patients had increased when compared with that of the control group. Furthermore, there was preliminary evidence that regular yoga exercise training reduces oxidative stress markers and fibrinogen levels in non-randomized, controlled, and uncontrolled trials.[37] In our study the decreased concentration of MDA (although not statistically significant) after four months, in ESRD patients in the *Hatha* yoga exercise group, indicated that there was a reduction in lipoperoxidation.

Cellular intracellular enzymes such as SOD and catalase, along with non-enzymatic antioxidants such as glutathione, act as a primary line of defense, to cope with the deleterious effects of the reactive oxygen species.[38] Superoxide dismutase detoxifies the superoxide radicals and converts them to hydrogen peroxide, which is further converted to water by catalase and glutathione peroxidase. Reduced scavenging of free radicals by SOD, decreased glutathione, and decreased activity of catalase are associated with diabetes mellitus and vascular pathology.[39] The activities of SOD and catalase in the ESRD patients in the *Hatha* yoga exercise group were significantly increased after four months, compared to the baseline values. A major benefit of a non-exhaustive exercise, such as yoga, is to induce a mild oxidative stress that stimulates the expression of certain antioxidant enzymes.[40] For example, the gene expression of SOD is enhanced after an acute bout of exercise, preceded by an elevation of NF-kappaB and AP-1 binding. An increase in *de novo* protein synthesis of SOD or catalase usually requires repeated bouts of exercise.[41] This could explain the increase in the activity of SOD in the *Hatha* yoga exercise group after four months.

An oxidative stress due to the overproduction of reactive oxygen species by activated monocytes and impairment in antioxidant defense mechanisms may take place in hemodialysis patients and may contribute to accelerated hemodialysis-induced atherogenesis by oxidatively modified proteins and lipids.[42] Protein oxidation does not have the features of chain reactions and the process has quite a long period. Therefore, the evaluation of POX in plasma is a respected marker of free radical intensity.[43] Reactive oxygen species modify amino acid side chains of proteins such as arginine, lysine, threonine, and proline residues to form protein carbonyls.[44] Carbonyl group formation is considered to be an early and stable marker for POX. The POX significantly increases in the ESRD patients in the *Hatha* yoga group, with a minor increase in the control group. This indicates carbonyl group formation, and thus, evidence of the free radical modification of proteins over the four months.[45]

The functions of T_3 and T_4 include increasing the rate of the metabolism of carbohydrates and fats, as well as the synthesis and degradation of proteins inside the cell. TSH secreted by the pituitary gland regulates the synthesis and the secretion of T_3 and T_4. Thyroid hormones are important regulators of energy metabolism and may influence energy processes during physical exercise.[46] In this study, there has been a significant decrease in TSH level and a significant increase of FT_4, after four months, compared to the baseline. Few studies have investigated the effect of yoga exercises on thyroid function.[47] In a study by Rawal and colleagues, who investigated the effect of one month's yoga and physical training exercise on the thyroid function of subjects, resident at sea level, a greater increase in thyroidal activity was induced by the conventional physical training exercise compared to yoga.[47]

Some studies have reported that exercise improves solute removal due to increased muscle blood flow in the open capillary surface area associated with increased flux of urea from the tissue to the vascular compartment during exercise and increased cell membrane permeability to water-soluble molecules, such as creatinine, due to rising exercise-induced body temperature.[48,49] In our study, there was a significant decrease in serum urea in the post dialysis sample of patients in the *Hatha* yoga exercise group after four months compared to the baseline values. There was also an increase in albumin and calcium, post and pre hemodialysis, respectively, in the *Hatha* yoga exercise group. Yurtkuran *et al*., conducted a single-blind, randomized trial, comparing the effects of yoga with gentle range-of-motion exercises on symptoms related to hemodialysis in 37 renal failure patients. After three months of twice-weekly sessions consisting primarily of standing and seated *asanas* and meditation, the yoga group exhibited significant reduction in the serum levels of urea, creatinine, alkaline phosphatase, total cholesterol, erythrocytes, and hematocrit. These changes were also better than those in the control group.[20]

CONCLUSION

The findings of the study demonstrate the efficacy of *Hatha* yoga exercise on the oxidative stress markers and antioxidant status in patients with ESRD. These findings suggest that *Hatha* yoga exercise in patients with ESRD has therapeutic, preventative, and protective effects in ESRD, by decreasing the oxidative stress. This may have a direct impact on the use of *Hatha* yoga exercise as a safe therapeutic modality in ESRD.

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REFERENCES

1. Whaley-Connell AT, Sowers JR, Stevens LA, McFarlane SI, Shlipak MG, Norris KC, *et al*., CKD in the United States: Kidney Early Evaluation Program (KEEP) and National Health and Nutrition Examination Survey (NHANES) 1999-2004. Am J Kidney Dis 2008;51 (suppl 2):S13-20.
2. Levey AS, Beto JA, Coronado BE, Eknoyan G, Foley RN, Kasiske BL, *et al*.,Controlling the epidemic of cardiovascular disease in chronic renal disease: What do we know? What do we need to learn? Where do we go from here? Am J Kidney Dis 1998;32:853-906.
3. Foley RN, Parfrey PS, Sarnak MJ. Clinical epidemiology of cardiovascular disease in chronic renal disease. Am J Kidney Dis 1998;32:S112-9.
4. Sarnak JM, Levey AS, Schoolwerth AC, Coresh J. American Heart Association Councils on Kidney in Cardiovascular Disease, High Blood Pressure Research, Clinical Cardiology, and Epidemiology and Prevention. Complications in early CKD. Kidney disease as a risk factor for development of cardiovascular disease: A statement from the American Heart Association Councils on kidney in cardiovascular disease, high blood pressure research, clinical cardiology, and epidemiology and prevention. Circulation 2003;108:2154-69.
5. Soyibo AK, Barton EN. Chronic renal failure from the English-speaking Caribbean: 2007 data. West Indian Med J 2009;58:596-600.
6. Zoccali C. Cardiovascular risk in uraemic patients-is it fully explained by classical risk factors? Nephrol Dial Transplant 2000;15:454-7.
7. Sies JH. Oxidants and antioxidants. Exp Physiol 1997;82:291-5.
8. Yilmaz MI, Saglam M, Caglar K, Cakir E, Sonmez A, Ozgurtas T, *et al*., The determinants of endothelial dysfunction in CKD: Oxidative stress and asymmetric dimethylarginine. Am J Kidney Dis 2006;47:42-50.
9. Ceballos-Picot I, Witko-Sarsat V, Witko-Sarsat V. Glutathione antioxidant system as a marker of oxidative stress in chronic renal failure. Free Radic Biol Med 1996;21:845-53.
10. Morena M, Cristol JP, Bosc JY, Tetta C, Forret G, Leger CL, *et al*., Convective and diffusive losses of vitamin C during haemodiafiltration session: A contributive factor to oxidative stress in haemodialysis patients. Nephrol Dial Transplant 2002;17:422-7.
11. Himmelfarb J, McMonagle E, McMenamin E. Plasma protein thiol oxidation and carbonyl formation in chronic renal failure. Kidney Int 2000;58:2571-8.
12. Yukawa S, Hibino A, Maeda T, Mimura K, Yukawa A, Maeda A, *et al*., Effect of ct-tocopherol on *in vitro* and *in vivo* metabolism of low- density lipoproteins in haemodialysis patients. Nephrol Dial Transplant 1995;10:1-3.
13. Johansen KL, Kaysen GA, Young BS, Hung AM, da Silva M, Chertow GM. Longitudinal study of nutritional status, body composition, and physical function in hemodialysis patients. Am J Clin Nutr 2003;77:842-6.
14. Johansen KL. Exercise in the end-stage renal disease population. J Am Soc Nephrol 2007;18:1845-54.
15. Deligiannis A, Kouidi E, Tassoulas E, Gigis P, Tourkantonis A, Coats A. Cardiac effects of exercise rehabilitation in hemodialysis patients. Int J Cardiol 1999;70:253-66.
16. Daul AE, Schafers RF, Daul K, Philipp T. Exercise during hemodialysis. Clin Nephrol 2004;61:26-30.
17. Raub JA. Psychophysiologic effects of hatha yoga on musculoskeletal and cardiopulmonary function. A literature review. J Altern Complement Med 2002;8:797-812.
18. Madanmohan D, Thombre P, Balakumar B, Nambinarayanan TK, Thakur S, Krishnanmurthy N, *et al*. Effects of yogic training on reaction time, respiratory endurance and muscle strength. Indian J Physiol Pharmacol 1993;37:350-2.
19. Ray US, Sinha B, Tomer OS, Pathak A, Dasgupta T, Selvamurthy W. Aerobic capacity and perceived exertion after practice of Hatha yogic exercises. Indian J Med Res 2001;114:215-21.
20. Yurtkuran M, Alp A, Yurtkuran M, Dilek K. A modified yoga-based exercise program in hemodialysis patients: A randomized controlled study. Complement Ther Med 2007;15:164-71.
21. Evered DC. Metabolic and Endocrinologic complications in Beta-Thalassemia. Clinics in Endocr and Metab 1974;3:425-50.
22. Yagi K. Lipid peroxide and human diseases. Chem Phys Lipids 1987;45:337-51.
23. Lobo A, Radbani F. Determination of phospholipase A2 activity by color assay using at pH indicator. Toxicon 1997;25:1181-8.
24. Reznick AZ, Packer L. Oxidative damage to proteins: Spectrophotometric method for carbonyl assay. Methods Enzymol 1994;233:357-63.
25. Bradford MM. A rapid and sensitive method for the quantification of microgram quantities of protein utilizing the principle of protein-dye binding. Anal Biochem 1976;72:248-54.
26. Marklamd S, Marklamd G. Involvement of the superoxide anion radical in autoxidation of piragagoll as a convenient assay for superoxide dismutase. Eur J Biochem 1974;47:469-74.
27. Beer RF, Sezar IW. Spectrophotometric method for measuring the breakdown of H_2O_2 by catalase. J Biol Chem 1952;195:137-40.
28. Feinstein A. Clinical epidemiology, the architecture of clinical research. 1st ed. WB Saunders Co, Orlando FL, USA; 1985.
29. Horl WH, Cohen JJ, Harrington JT, Madias NE, Zusman CJ. Atherosclerosis and uremic retention solutes. Kidney Int 2004;66:1719-31.
30. Lui D, Maulik N, Moraru II, Kreutzer DL, Das DK. Molecular adaptation of vascular endothelial cells to oxidative stress. Am J Physiol 1993;264:715-22.
31. Loughrey CM, Young IS, Lightbody JH, McMadster D, McNamee PT, Trimble ER. Oxidative stress in haemodialysis. Q J Med 1994;87:679-83.
32. Fiorillo C, Oliviero C, Rizzutti G, NedianiPacini CA, Nassi P. Oxidative stress and antioxidant defences in renal patients receiving regular hemodialysis. Clin Chem Lab Med 1998;36:149-53.
33. Boaz M, Matas Z, Biro A, Katzir Z, Green M, Fainaru M, *et al*., Comparison of hemostatic factors and serum malondialdehyde as predictive factors of cardiovascular disease in hemodialysis patients. Am J Kidney Dis 1999;34:438-44.
34. Bast A, Haenen RM, Cees JA. Oxidants and antioxidants: State of the art. Am J Med 1991;91:2S-13S.
35. Marjani A, Moradi A, Veghari G, Ahmadi A. Effect of dialysis on plasma lipid peroxidation and lipid profile in haemodialysis patients. Asian J. Cell Biol. 2007;2:23-8.
36. Ozden M, Maral H, Akaydin D, Cetinalp P, Kalender B. Erythrocyte glutathione peroxidase activity, plasma malondialdehyde and erythrocyte glutathione levels in haemodialysis and CAPD patients. Clin Biochem 2002;35:269-73.
37. Chohan IS, Nayar HS, Thomas P, Geetha NS. Influence of yoga on blood coagulation. Thromb Haemost 1984;51:196-7.
38. Bradley AA, Nathan CF. Glutathione metabolism as a determinant of therapeutic efficiency. Cancer Res 1984;44:4224-32.
39. Baynes JW, Thorpe SR. The role of oxidative stress in diabetic complications. Curr Opin Endocrinol 1996;3:277-84.
40. Reid MB. Redox modulation of skeletal muscle contraction: What we know and what we dont. J Appl Physiol 2001;90:724-31.
41. Jil LL. Exercise-induced modulation of antioxidant defense. Ann N Y Acad Sci 2002;959:82-92.
42. Paul JL, Sall ND, Soni T, Poignet JL, Lindenbaum A, Man NK, *et al*. Lipid peroxidation abnormalities in hemodialysed patients. Nephron 1993;64:106-9.
43. Ramakrishna V, Jailkhani R. Evaluation of oxidative stress in insulin dependent diabetes mellitus (IDDM) patients. Diagn Pathol 2007;2:2.
44. Chevion M, Berenshtein E, Stadtman ER. Human studies related to protein oxidation: Protein carbonyl content as a marker of damage. Free Radical Research 2000;33:99-108.
45. Ahmed N, Babaei-Jadidi R, Howell SK, Thornalley PJ, Beisswenger PJ. Glycated and oxidised protein degradation products are indicators of fasting and postprandial hyperglycaemia in diabetes. Diabetes Care 2005;28:2465-71.
46. Gupta N, Khera S, Vempati RP, Sharma R, Bijlani RL. Effect of yoga based on lifestyle intervention on state and trait anxiety. Indian J Physiol Pharmacol 2006;50:41-7.
47. Rawal SB, Singh MV, Tyagi AK, Selvamurthy W, Chaudhuri BN. Effect of yogic exercises on thyroid function in subjects resident at sea level upon exposure to high altitude. Int J Biometeorol 1994;38:44-7.
48. Parsons TL, Toffelmire EB, King-VanVlack CE. Exercise training during

hemodialysis improves dialysis efficacy and physical performance. Arch Phys Med Rehabil 2006;87:680-7.

49. Kong CH, Tattersall JE, Greenwood RN, Farrington K. The effect of exercise during hemodialysis on solute removal. Nephrol Dial Transplant 1999;14:2927-31.

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