A. R. Siddiqui

IMMEDIATE EFFECTS OF HEAVY EXERCISE ON THE CIRCULATING THYROID HORMONES

A. R. SIDDIQUI, MD, Rebecca B. HINNEFELD, BS,
T. DILLON, BS and W. E. JUDSON, MD*

Departments of Radiology, Division of Nuclear Medicine, and Medicine,
Indiana University School of Medicine, Indianapolis, Indiana*

ABSTRACT

Sera from 20 patients with suspected or known coronary artery disease were measured for thyroxine (T_4), tri-iodothyronine (T_3), tri-iodothyronine uptake ratio (T_3UR), thyroid stimulating hormone (TSH), and reverse tri-iodothyronine (rT_3), before and after maximal or near-maximal exercise. On the average the patients achieved 92% (range 68-108) of the predicted maximum heart rate. There were no statistically significant differences between the pre- and the post-exercise serum levels of thyroid hormones. When five patients who achieved less than 90% of the predicted maximum heart rate were excluded, the results remained unchanged. It appears that the circulating thyroid hormones are not acutely affected after maximal or near-maximal exercise; however, the patient population was highly select.

Key words: Exercise, Thyroid hormones.

INTRODUCTION

Although several reports have been published on the effects of maximal and submaximal physical activity on the thyroid function, the results have not been consistent, in fact, some contradict each other. The circulating T_4 has been reported to increase (Terjung and Tipton, 1971; O'Connell et al, 1979; Refsum and Stromme, 1979; Metivier and Gauthier, 1981) or remain unchanged (Galbo et al, 1977; Sowers et al, 1977; Berchtold et al, 1978; Johannessen et al, 1981) after exercise. Serum T_3 has been shown to increase (Balsam and Leppo, 1975; Refsum and Stromme, 1979; Schmid et al, 1982), decrease (O'Connell et al, 1979), or remain unchanged (Caralis et al, 1977; Galbo et al, 1977; Berchtold et al, 1978; Johannessen et al, 1981; Premchandra et al, 1981). The circulating serum TSH increased (Galbo et al, 1977; Schmid et al, 1982) or was unaffected (Terjung and Tipton, 1971; Terjung and Winder, 1975; Berchtold et al, 1978; Johannessen et al, 1981). Serum rT_3 has been reported to increase (O'Connell et al, 1979), decrease (Schmid et al, 1982),

or not change (Berchtold et al, 1978; Premchandra et al, 1981) after physical stress. We will present our results of the immediate effects of maximal or near-maximal exercise on the circulating thyroid hormones in a select patient population.

MATERIALS AND METHODS

A total of 20 patients (eighteen male and two female) were studied; they ranged in age from 38 to 69 years (mean 53.4). All patients either had known coronary artery disease, or were suspected to have coronary artery disease and referred for cardiovascular stress testing. None of the patients had recently participated in any regular physical conditioning programme.

The stress test consisted of upright bicycle pedalling after an overnight fast. The factors which determined the termination of exercise were: (1) Reaching of the predicted maximal heart rate; (2) Exhaustion; and (3) Development of signs and symptoms referable to cardiovascular system (e.g., chest pain, arrhythmias, etc.). Two venous blood samples were obtained from each patient, one well before the start of the stress test, and another one just as the exercise was terminated (within 1 minute). Both pre- and post-exercise samples were assayed at the same time for total T_4 , total T_3 , tri-iodothyronine uptake ratio (T_3UR), TSH, and rT_3 . Total T_4 was measured by solid phase assay using anti-

For reprints:

Aslam R. Siddiqui, MD,
Division of Nuclear Medicine,
Indiana University Medical Center,
Indianapolis, IN 46223

body-coated test tubes after first treating the sample with 8-anilino naphthalene sulphonic acid and salicylate (Clinical Assays, Cambridge, Massachusetts). Total T_3 was assayed by competitive binding method using antibody-coated resin beads (Bio-Rad Laboratories, Richmond, California). T_3 UR was measured by solid phase assay using antibody-coated test tubes (Clinical Annayn) and serum TSH was measured using progressive saturation method. Reverse T_3 was assayed by competitive binding using polyethylene glycol for separation (Sero Laboratories, Inc., Braintree, Massachusetts).

In our laboratory accuracy and reproducibility of these tests is ensured by a vigorous in-house quality control programme as well as by participation in College of American Pathologists' Basic Ligand Assay quality assurance programme and Wellcome Immunoassay Quality Control Programme.

RESULTS

On average the patients reached 92% (range 68 to 108%) of the target heart rate. The results of pre- and post-exercise peripheral thyroid hormone measurements are given in Table I. The differences between the pre- and post-exercise levels of T_4 , T_3 UR, and rT_3 were not significant statistically ($P > 0.01$ for all three). Although

there appeared to be a slight tendency towards an increase in the serum T_4 and a decrease in the TSH levels following exercise, this was also not significant ($P > 0.05$). The elimination of the five patients who achieved less than 90% of the predicted maximal heart rate did not alter the results.

DISCUSSION

A whole range of thyroid function alterations has been attributed to physical stress. One mechanism that has been postulated suggests that rather than a real change in the thyroid function, exercise-induced haemoconcentration and an increase in serum proteins are responsible for the changes in the circulating thyroid hormones (Caralis et al, 1977; O'Connell et al, 1979; Refsum and Stromme, 1979; Metivier and Gauthier, 1981; Premchandra et al, 1981). The alterations in the peripheral thyroid hormones were considered absolute by Caralis et al (1977), O'Connell et al (1979) and Metivier and Gauthier (1981) and due to haemoconcentration by Terjung and Tipton (1971), Refsum and Stromme (1979) and Premchandra et al (1981). In our study we measured T_3 UR which is an indirect measure of the thyroxine-binding globulin (TBG). In our patients exercise had no effect on it, suggesting that the TBG and, perhaps, other proteins remained unchanged. De Nayer et al (1968) and Schmid et al (1982) also did not

TABLE I

Serum content of thyroid hormones before and after exercise.

Patients	T4, Thyroxine (Radio-Immuno-Assay) (4.5-11.5 µg/dl)		T3, Tri-iodothyronine (Radio-Immuno-Assay) (100-200 ng/dl)		T3UR, Tri-iodothyronine Uptake Ratio (0.86-1.14)		TSH, Thyroid Stimulating Hormone (1-6.5 µIU/ml)		RT3, Reverse Tri-iodothyronine (80-350 pg/ml)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1♀	9.1	9.4	100	103	1.02	1.06	8.3	7.1	361	315
2	10.4	9.4	174	142	1.00	1.03	2.9	2.7	310	306
3	8.8	9.7	148	150	0.95	0.91	2.6	2.2	250	261
4	7.6	8.6	80	108	1.06	1.03	1.9	2.1	220	317
5	6.4	6.2	116	93	1.19	1.16	1.3	1.2	267	242
6	6.8	7.9	104	121	1.17	1.03	1.8	1.7	191	243
7	9.6	9.1	137	153	0.89	0.90	2.1	1.3	234	262
8	10.1	10.3	142	136	1.10	1.03	3.4	3.0	311	371
9	8.7	7.4	147	153	0.92	0.94	3.9	3.8	300	312
10	7.8	8.7	111	128	0.97	0.94	2.3	2.5	311	371
11	6.8	7.2	115	109	0.84	0.81	3.6	3.4	95	114
12	7.0	8.7	100	128	0.88	0.85	2.8	3.3	225	305
13	6.3	7.4	82	97	1.13	1.14	1.9	2.2	248	278
14	6.8	7.1	95	110	1.01	1.04	2.5	2.5	201	142
15	9.2	10.5	152	158	1.04	0.99	3.0	2.1	224	279
16	7.1	6.8	144	124	1.00	1.03	3.1	2.9	139	146
17♀	8.8	9.4	159	186	0.94	0.91	2.8	2.8	191	209
18	6.3	6.1	122	141	0.99	1.00	5.6	4.3	132	77
19	7.5	7.7	98	85	1.06	1.08	2.7	2.9	168	177
20	8.6	9.2	99	130	1.00	0.96	3.0	3.1	311	300

find in any changes in the haematocrit and serum protein after exercise. Since thyroid hormones are mainly protein bound, this could explain why there were no changes in the circulating thyroid hormones.

Ahlborg et al (1974) have compared physical stress to acute starvation; starvation is known to cause thyroid function abnormalities (Vagenakis et al, 1975). Another possible explanation is that the exercise causes increases in circulating catecholamines and those, in turn, affect the thyroid function (Melander et al, 1974; Melander et al, 1975). Our patients did not show any changes in T_4 , T_3 , TSH, rT_3 , and T_3 UR immediately after completion of maximal or sub-maximal exercise. These findings are in agreement with the results of the studies by Berchtold et al (1978) and Premchandra et al (1981).

The reasons for the discrepant results are not clear.

Although we did not measure free T_4 concentrations directly, free T_4 index was obtained by multiplying T_3 UR and total T_4 measurements (Clark and Horn, 1965). This index has been found to be a useful substitute for free T_4 measurements (Rosenfeld, 1974; Bayer and McDougall, 1980). There was no significant change in the free T_4 index following exercise.

We studied our patients immediately upon the conclusion of the stress test. It is possible that it takes some time for the peripheral blood to reflect the changes in the thyroid function. In any case, it appears that the circulating thyroid hormones are not acutely affected by physical stress, however, our patients by no means represent the general population.

REFERENCES

- Ahlborg, G., Felig, P., Hagenfeldt, L., Hendler, R. and Wahren, J., 1974 "Substrate turnover during prolonged exercise in man". *J.Clin.Invest.* 53: 1080-1085.
- Balsam, A. and Leppo, L. E., 1975 "Effect of physical training on the metabolism of thyroid hormones in man". *J.Appl.Physiol.* 38: 212-215.
- Bayer, M. F. and McDougall, I. R., 1980 "Radioimmunoassay of free thyroxine in serum: comparison with clinical findings and results of conventional thyroid function test". *Clin.Chem.* 26: 1186-1192.
- Berchtold, P., Berger, M., Cuppers, H. J., Herrmann, J., Nieschlag, E., Rudroff, K., Zimmerman, H. and Kruskemper, H. L., 1978 "Non-gluco regulatory hormones (T_4 , T_3 , rT_3 , TSH, Testosterone) during physical exercises in juvenile-type diabetics". *Horm.Metab.Res.* 10: 269-273.
- Caralis, D. G., Edwards, L. and Davis, P. J., 1977 "Serum total and free thyroxine and tri-iodothyronine during dynamic muscular exercise in man". *Am.J.Physiol.* 235: E115-E118.
- Clark, F. and Horn, D. B., 1965 "Assessment of thyroid function by the combined use of the serum protein-bound iodine and resin uptake of ^{131} I-tri-iodothyronine". *J.Clin.Endocrinol.Metab.* 25: 39-45.
- De Nayer, P. H., Malvaux, P., Ostyn, M., Van Den Schrieck, H. G., Becker, C. and De Visscher, M., 1968 "Serum free thyroxine and binding-proteins after muscular exercise". *J.Clin.Endocrinol.Metab.* 28: 714-716.
- Galbo, H., Hummer, L., Petersen, I. B., Christensen, N. J. and Bie, N., 1977 "Thyroid and testicular hormone responses to graded and prolonged exercise in man". *Eur.J.Appl.Physiol.* 36: 101-106.
- Johannessen, A., Hagen, C. and Galbo, H., 1981 "Prolactin, growth hormone, thyrotropin, 3, 5, 3'-tri-iodothyronine, and thyroxine responses to exercise after fat- and carbohydrate-enriched diet". *J.Clin.Endocrinol.Metab.* 52: 56-61.
- Melander, A., Ericson, L. E., Ljunggren, J.-G., Norberg, K.-A., Persson, B., Sundler, F., Tibblin, S. and Westgren, U., 1974 "Sympathetic innervation of the normal human thyroid". *J.Clin.Endocrinol.* 39: 713-718.
- Melander, A., Rankler, E., Sundler, F. and Westgren, U., 1975 "Beta₂-adrenergic stimulation of thyroid secretion". *Endocrinology* 97: 332-336.
- Metivier, G. and Gauthier, R., 1981 "The effects of acute exercise on the level of blood serum tri-iodothyronine (T_3), thyroxine (T_4) and free thyroxine index (FTI) in aging male". *J.Sports Med.Phys.Fit.* 21: 371-376.
- O'Connell, M., Robbins, D. S., Horton, E. S., Sims, E. A. H. and Danforth, E., Jr., 1979 "Changes in serum concentrations of 3, 3', 5'-tri-iodothyronine and 3, 5, 3'-tri-iodothyronine during prolonged moderate exercise". *J.Clin.Endocrinol.Metab.* 49: 242-246.

Premchandra, B. N., Winder, W. W., Hickson, R., Lang, S. and Holloszy, J. O., 1981 "Circulating reverse tri-iodothyronine in humans during exercise". *Eur.J.Appl.Physiol.* 47: 281-288.

Refsum, H. W. and Stromme, S. B., 1979 "Serum thyroxine, tri-iodothyronine and thyroid stimulating hormone after prolonged heavy exercise". *Scan.J.Clin.Lab.Invest.* 39: 455-459.

Rosenfeld, L., 1974 "Free thyroxine index": a reliable substitute for "free" thyroxine concentration". *Am.J.Clin.Pathol.* 61: 118-121.

Schmid, P., Wolf, W., Pilger, E., Schwabberger, G., Pessenhofer, H., Pristautz, H. and Leb, G., 1982 "TSH, T₃, rT₃, Ft₄ in maximal and submaximal physical exercise". *Eur.J.Appl.Physiol.* 48: 31-39.

Sowers, J. R., Raj, R. P., Hershman, J. M., Carlson, H. E. and McCallum, R. R., 1977 "The effect of stressful diagnostic studies and surgery on anterior pituitary hormone release in man". *Acta Endocrinol.* 86: 25-32.

Terjung, R. L. and Tipton, C. M., 1971 "Plasma thyroxine and thyroid-stimulating hormone levels during sub-maximal exercise in humans". *Am.J.Physiol.* 220: 1840-1845.

Terjung, R. L. and Winder, W. W., 1975 "Exercise and thyroid function". *Med.Sci.Sports* 7: 20-26.

Vagenakis, A. G., Burger, A., Portnay, G. L., Rudolf, M., O'Brien, J. T., Azizi, F., Arky, R. A., Nicod, P., Ingbar, S. H. and Braverman, L. E., 1975 "Diversion of peripheral thyroxine metabolism from activating to inactivating pathways during complete fasting". *J.Clin.Endocrinol.Metab.* 41: 191-194.

OBITUARY

Dr. John Bodkin Adams, MD, DPH, DA

With the death of Dr. J. B. Adams on July 4th, at the age of 84, there are now only ten founder members of our Association still alive and who are current members. Dr. Adams qualified in Ireland in 1921 and obtained the MD in 1926. He settled in private practice in Eastbourne, and soon became a prominent member of the local Clay Pigeon Shooting Club. In 1952, when the first talks were being held to explore the foundation of a British branch of the International Federation of Sports Medicine, Dr. Adams, by now the Honorary Medical Officer of the Clay Pigeon Shooting Association, supported this idea, and thereby became a founder member of the British Association of Sport and Medicine. He kept in touch with sports medicine affairs, attending both scientific and business meetings of the BASM.

Throughout his adult life he kept a keen interest in his chosen sport, scoring 20 out of 20 just before the Second World War, thereby qualifying for the elite "Skeet 20 Club". At the end of June this year, he was still taking an active interest in shooting, but fell at a gun club meeting and died a few days later, like so many of our deceased members, still "in harness". We are very sorry to record the death of this interesting personality.

H. E. Robson