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RESEARCH

Effects of endurance training on thyroid response in pre- and postmenopausal women

L. Hanke[1] · K. Hofmann[1] · A. L. Krüger[2] · L. Hoewekamp[2] · J. M. Wellberich[1] · B. Koper[1] · P. Diel[1]

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Abstract

Purpose Age-related changes in thyroid function are well-investigated. Likewise, influences of physical activity on the thyroid gland could be determined. Studies that investigated the influence of (endurance) training on thyroid function in postmenopausal women do not exist. Therefore, the aim of this study is to investigate age-related changes in thyroid function during acute endurance training and through an exercise intervention in postmenopausal women and to identify differences to premenopausal women.

Methods 12 pre- and 12 postmenopausal women were included. In all subjects, height, weight, and body composition were assessed. TSH, fT4, and fT3 were assessed at 9:00 am and 9:40 am at rest and after an acute endurance exercise. Subsequently the postmenopausal women conducted a six-week walking intervention and repeated the tests.

Results Weight, BMI, and muscle mass were significantly lower and fat mass significantly higher in postmenopausal women ($p < 0.05$). Fat mass decreased and muscle mass increased ($p < 0.05$) in postmenopausal women after intervention. An elevated TSH response was found significantly in premenopausal women ($p = 0.028$) and non-significantly in postmenopausal women ($p = 0.135$) after acute exercise. There were no changes in fT3 and fT4 in both groups. After intervention, postmenopausal women showed a significant reduction in fT3 response ($p = 0.015$) and a non-significant reduction of TSH response ($p = 0.432$).

Conclusion This study provides evidence that both pre- and postmenopausal women respond with thyroid stimulation to acute endurance training. Furthermore, this study provides preliminary evidence that an endurance training intervention can reduce thyroid response after acute endurance exercise in postmenopausal women.

Keywords Thyroid response · Thyroid hormones · Exercise · Postmenopausal women · Premenopausal women

Introduction

Demographic change and the aging of the population result in an increased demand on the healthcare system. Diseases occur more frequently in old-age thyroid function disorders [1]. The incidence of most thyroid diseases (hypothyroidism, nodular goiter, and cancer) is the highest in postmenopausal and elderly women [1]. In this patient group, the diagnosis of thyroid dysfunction is difficult because symptoms may be nonspecific or co-occur concurrently with menopausal and aging symptoms [1]. In general, many age-specific changes in the thyroid gland and its functionality can be observed.

Histological changes in aging include an increase in interfollicular fibrosis, reduction in follicle size, flattening of glandular epithelial cells [2–4], and a decrease in overall weight of the thyroid gland [1–5]. In addition, neoplastic lesions increase, making the thyroid gland more nodular [1, 5]. Observations conducted in iodine-rich areas have shown that serum thyroid-stimulating hormone (TSH) concentrations increase with age in both men and women. These observations may indicate decreased pituitary sensitivity to thyroxine (T4) in the aging population [6]. In addition, with increasing age, the ability of the thyroid gland to absorb iodine and, as a consequence, the production of thyroid hormones decreases and is 40% lower in people over 80 years of

L. Hanke and K. Hofmann contributed equally to this work.

✉ L. Hanke
lars.h.hanke@gmail.com

1 Institute of Cardiovascular Research and Sport Medicine, German Sports University Cologne, Cologne, Germany

2 Department of Sports Medicine, University of Wuppertal, Wuppertal, Germany

age than in individuals in their 30s [3]. Daily production of T4 decreases by 20 µg, but at the same time, its metabolism slows down due to decreased activity of 5'-deiodinase-I. As a result, T4 half-life increases from 8 to 9.3 days and serum T4 concentration does not change during life [3]. Serum total triiodothyronine (T3) and free triiodothyronine (fT3) levels decrease with age [4, 7] likely due to a decrease in peripheral T4–T3 conversion, which may contribute to decreased T4 depletion [7].

Physical activity could be one way to influence thyroid function in a targeted manner. However, the data on this issue are controversial. Several studies found no effect on blood TSH levels [8, 9], while others found that TSH increases progressively during high-intensity exercise [9–11]. In addition, increases in T4 [8, 10, 12, 13] and T3 [8, 13] as well as decreases in T4 [12, 13] and T3 [10, 14] were observed as a result of higher intensities during endurance training. However, the results are difficult to compare due to some major methodological differences. Furthermore, it should be emphasized that almost only men (< 40 years) were included in the studies examined [8–10, 12, 13]. There was only one study that observed premenopausal women (16 ± 1 years) [14]. In addition, only acute training effects were observed. No training intervention took place in any of the studies. Studies that investigated the influence of (endurance) training on thyroid function in postmenopausal women do not currently exist. Furthermore, thyroid hormones are known to have an influence on resting metabolic rate and consequently on body weight [15]. Basically, the body weight is correlated with the level of the TSH value. Even in healthy individuals with TSH values in the upper normal range, a higher body weight can be observed [16, 17]. In addition, an estrogen-induced change in postmenopausal women could possibly have an influence on the body composition of this group [18].

Therefore, the aim of this study is to investigate age-related changes in thyroid function during acute endurance training and through an exercise intervention in postmenopausal women and to identify differences to premenopausal women. In addition, the extent to which body composition differs between premenopausal and postmenopausal women will be examined.

Methods

The pilot study included 12 untrained pre- and 12 untrained postmenopausal women. It is well known that training-related adaptation effects can be expected more rapidly in untrained individuals [19]. For this reason, only untrained subjects were included. Recruitment was done via gynecologists, fitness studios, personal contacts, and the German Menopause Society. Prior to recruitment start, the positive ethical approval of the ethics committee of the German Sport University Cologne (number 130/2019) was obtained and the study was registered in the German Clinical Trials Register (DRKS-ID: DRKS00020425). The study protocol is in accord with the Declaration of Helsinki. The inclusion and exclusion criteria are shown in Table 1.

The 12 premenopausal women completed 2 examination days at the German Sport University Cologne (trial A, B, and C). The 12 postmenopausal women first completed 3 examination days (trial A, B and C), then completed a 6-week endurance training intervention and finally repeated the examinations (trial D, E, and F). For organizational reasons, trials A and B or D and E were performed on one measuring day.

To exclude menstrual cycle-related influences of premenopausal women on thyroid hormones, examinations were performed in the second half (luteal phase) of the subjects' menstrual cycle. Hormonal contraceptives were excluded. To confirm if the postmenopausal subjects were truly postmenopausal, the hormones estradiol and FSH were determined. If the FSH concentration was above the estradiol level, a postmenopausal status was assumed—together with the absence of menstrual bleeding for one year. Hormone replacement therapy (HRT) was excluded. The time schedule is shown in Fig. 1.

Trials A and D

After informed consent was obtained and signed (only trial A), anthropometric data were collected and body composition was measured by bio-impedance analysis (BodyExplorer, Kommunikation & Service GmbH). For this purpose, the test subjects lay on a bench at rest for 5 min. The device can calculate the body composition based on the measured resistance. The premenopausal women only participated in measurement A.

Trials B and E

Subjects appeared fasting. Two blood samples were taken at 9:00 am (*t*0) and at 9:40 am (*t*1) to identify female sex hormones (Estradiol, FSH) as well as circadian changes in thyroid hormones (TSH, fT4, fT3) without exercise. For the identification of the individual anaerobic threshold, an endurance threshold test was performed on a bicycle ergometer (ergoselect 50, Typ: optibike med K ergoline) according to the WHO scheme (Start at 25 watts and increase by 25 watts after every 2 min until full capacity is reached). Heart rate was monitored via watch with chest belt (Sigma PC 15).

Table 1 Inclusion and exclusion criteria

	Premenopausal women	Postmenopausal women
Inclusion criteria	18–30 years	50–65 years
	Regular menstrual cycle (duration of menstrual cycle between 25 and 35 days)	No menstrual cycle for at least one year
Exclusion criteria	Irregular menstrual cycle ≥ 2 times endurance training per week Unbalanced or radical forms of diet Hormone substitution (incl. oral contraceptives) Hormonal diseases (e.g., thyroid diseases, Cushing syndrome, diabetes) Cardiac arrhythmias requiring treatment Metabolic diseases Heart failure (EF < 55) Performance-limiting pAVK (Fontaine stage ≥ II) Performance-limiting respiratory diseases Performance-limiting degenerative diseases Performance-limiting muscular diseases Performance-limiting renal diseases Performance-limiting neurological diseases Psychiatric and/or addictive diseases Performance-limiting oncological diseases in history (< 5 years) Pregnant/nursing	Regular menstrual cycle ≥ 2 times endurance training per week Unbalanced or radical forms of diet Hormone substitution (incl. oral contraceptives) Hormonal diseases (e.g., thyroid diseases, Cushing syndrome, diabetes) Cardiac arrhythmias requiring treatment Metabolic diseases Heart failure (EF < 55) Performance-limiting pAVK (Fontaine stage ≥ II) Performance-limiting respiratory diseases Performance-limiting degenerative diseases Performance-limiting muscular diseases Performance-limiting renal diseases Performance-limiting neurological diseases Psychiatric and/or addictive diseases Performance-limiting oncological diseases in history (< 5 years) Pregnant/nursing

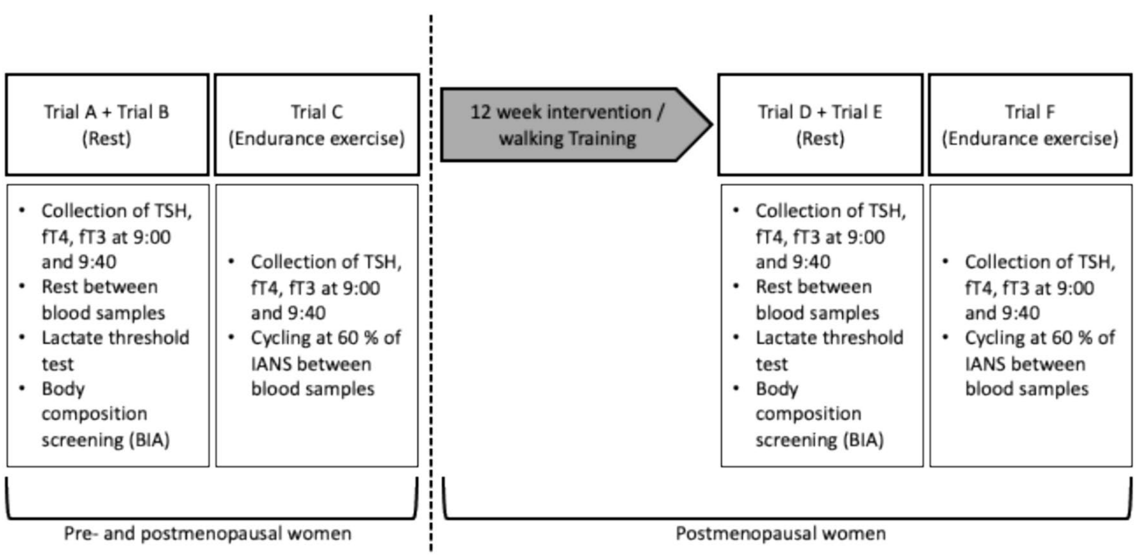

Fig. 1 Time schedule

Table 2 Age and body composition

	Premenopausal baseline	Postmenopausal baseline/ pre-intervention	Postmenopausal post-intervention
Age	24 ± 2.41*1	57 ± 3.47*1	–
BMI	21.45 ± 1.40*1	24.83 ± 3.99*1	24.89 ± 4.14
Weight (kg)	60 ± 5.16*1	70.54 ± 11.38*1	70.67 ± 11.70
Fat mass (kg)	16.32 ± 4.57*1	25.31 ± 7.28*1 *2	25.18 ± 8.11*2
Fat mass (%)	27.61 ± 7.19*1	36.34 ± 5.90*1 *2	34.57 ± 6.67*2
Muscle mass (kg)	21.09 ± 2.26*1	17.96 ± 2.05*1 *2	19.67 ± 3.10*2
Muscle mass (%)	35.90 ± 3.43*1	26.53 ± 3.44*1 *2	27.91 ± 4.41*2

*1 sig. difference ($p < 0.05$) between pre- and postmenopausal women at baseline

*2 sig. difference ($p < 0.05$) between postmenopausal women before and after intervention

Trials C and F

As on the previous day, participants appeared fasting and blood draws were performed at 9:00 am and 9:40 am. Between blood draws (30 min), exercise was performed on a bicycle ergometer at 60–65% of the individual anaerobic threshold. The premenopausal women only participated in measurement C.

Intervention of postmenopausal women

After examinations A–C, the postmenopausal women started into a six-week intervention phase. During the intervention, the subjects exercised three times per week for 45 min. In order to offer a standardized form of training, the subjects conducted a walking training with heart rate monitors. The training was controlled by pulse rate watches and the BORG scale. All training units were performed at pulse values of 55–70% of maxHR and/or with BORG values between 11 and 14. The participants had to record their training sessions in a training diary with date, heart rate, and BORG value. All training units were performed in the form of a continuous load. The intervention was supervised via e-mail and/or telephone contact to ensure a suitable intensity and to be able to react to possible complications.

Data analysis

For statistical analysis, the IBM SPSS Statistics 28 program was used. The Kolmogorov–Smirnov test and the Shapiro–Wilk test were used to determine the normal distribution. In case of different results, the Shapiro–Wilk test was used since it has a higher test strength [20, 21]. If the distribution was normal, the *t*-test was used; if it was not, the Mann–Whitney *U* test or the Wilcoxon test was used. A *p* value of 0.05 was defined as significant.

Results

Body composition: differences of pre- and postmenopausal women

BMI differs significantly between pre- and postmenopausal women. Postmenopausal women showed an average BMI value of 3.39 points higher than premenopausal women.

A highly significant difference was found in terms of skeletal muscle mass in kg and % between pre- and postmenopausal women. Muscle mass was 3.13 kg higher in premenopausal women than in postmenopausal women ($U = 13.00$, $Z = -3.120$, $p = 0.001$), using the exact sampling distribution of U, $r = -0.66$. In premenopausal women, muscle mass was 9.37% higher than in postmenopausal women (95%–CI[6.17,12.57], $t(20) = 6.10$, $p < 0.001$, $d = 2.6$).

Fat mass in kg differs highly significantly between pre- and postmenopausal women. It was higher in postmenopausal women than in premenopausal women by an average of 8.99 kg (95% CI[−14.67,−3.33], $t(20) = -3.31$, $p = 0.003$, $d = -1.4$). Fat mass in % showed a highly significant difference. It was in postmenopausal women by an average of 8.73% higher than in premenopausal women (95%–CI [−14.87,−2.60], $t(20) = -2.97$, $p = 0.008$, $d = -1.3$).

Body composition: differences of postmenopausal women before and after intervention

There was no significant difference in weight ($t(11) = -0.42$, $p = 0.686$, $d = 0.12$) and BMI ($t(11) = -0.58$, $p = 0.571$, $d = 0.17$) of postmenopausal women before and after intervention. There was a significant difference in skeletal muscle mass before and after intervention. Muscle mass was on average 1.71 kg higher ($t(10) = -3.02$, $p = 0.013$, $d = 0.91$) and the percentage of muscle mass was on average 1.38% higher after the intervention ($t(10) = -2.79$, $p = 0.019$, $d = -0.84$). Fat mass also changed significantly through training intervention, decreasing by 0.13 kg ($t(10) = 2.42$,

Table 3 Thyroid hormone concentration

Pre-intervention	TSH rest		TSH stress		fT4 rest		fT4 stress		fT3 rest		fT3 stress	
	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1
Premenopausal women ($n=12$)	2.1 ± 0.85	1.81 ± 0.65	1.65 ± 0.61	1.52 ± 0.53	1.18 ± 0.11	1.18 ± 0.08	1.19 ± 0.10	1.18 ± 0.12	3.42 ± 0.36	3.38 ± 0.36	3.38 ± 0.32	3.3 ± 0.29
Postmenopausal women ($n=12$)	1.92 ± 1.09	1.79 ± 0.87	1.65 ± 0.74	1.65 ± 0.79	1.18 ± 0.11	1.2 ± 0.12	1.18 ± 0.09	1.17 ± 0.11	3.33 ± 0.22	3.29 ± 0.22	3.26 ± 0.26	3.15 ± 0.22
Post-intervention	TSH rest		TSH stress		fT4 rest		fT4 stress		fT3 rest		fT3 stress	
	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1	T0	T1
Postmenopausal women ($n=12$)	1.92 ± 0.91	1.73 ± 0.86	1.95 ± 0.80	1.80 ± 0.73	1.11 ± 0.13	1.14 ± 0.10	1.12 ± 0.11	1.08 ± 0.13	3.15 ± 0.28	3.17 ± 0.26	3.18 ± 0.27	3.1 ± 0.28

Annotation: There were no significant within-group differences and no significant group differences of hormone concentrations ($p > .05$)

$p = 0.036$, $d = 0.73$) or 1.77% ($t(10) = 2.57$, $p = 0.028$, $d = 0.78$) (Table 2).

Thyroid hormone response: pre-intervention

Thyroid hormone response was defined as the difference of hormone concentrations between time point $t1$ and $t0$.

At baseline, the results showed no significant difference between pre- and postmenopausal women for fT4 ($p = 0.736$, 95% CI−0.11,0.09], $t(22)$,−0.17, $p = 0.863$, $d = 0.07$) TSH ($p = 0.145$, 95%–CI−0.74,0.98], $t(22)$,0.29, $p = 0.777$, $d = 0.12$) and fT3 ($U = 68.00$, $Z = -0.234$, $p = 0.830$).

Considering the thyroid response (= difference of TSH, fT4 and fT3 concentration between the second and the first blood sample of an examination day) between the “rest” and “exercise” condition, there was a significant difference in TSH in premenopausal women ($t(11) = 2.53$, $p = 0.028$, $d = 0.73$) and non-significant differences in fT4 ($Z = -0.816$, $p = 0.688$, $r = 0.23$) and fT3 ($Z = -1.046$, $p = 0.313$, $r = 0.30$). In the group of postmenopausal women, there was no significant difference in fT3 ($t(11) = -2.15$, $p = 0.054$, $d = 0.62$), fT4 ($Z = -0.632$, $p = 0.766$, $r = 0.18$) and TSH response ($Z = -1.531$, $p = 0.135$, $r = 0.44$).

There was no significant difference in thyroid response of fT4 ($U = 61.50$, $Z = -0.730$, $p = 0.552$), fT3 ($U = 63.00$, $Z = -0.552$, $p = 0.618$) and TSH ($U = 68.00$, $Z = -0.231$, $p = 0.832$) between pre- and postmenopausal women in the rest condition. There was also no significant difference of the thyroid response between pre- and postmenopausal women in the exercise condition for fT4 ($U = 66.50$, $Z = -0.448$, $p = 0.832$), fT3 ($U = 63.00$, $Z = -0.545$, $p = 0.614$), and TSH ($U = 56.50$, $Z = -0.895$, $p = 0.385$).

Thyroid hormone response: post-intervention

Comparing the “rest” conditions before and after training intervention of the postmenopausal women, no significant differences in thyroid hormone response were found (fT3, $t(11) = 1.59$, $p = 0.139$, $d = 0.46$.; fT4, $Z = -0.541$, $p = 0.781$, $r = 0.16$; TSH, $Z = -1.452$, $p = 0.157$, $r = 0.42$). Likewise, comparing the "exercise" conditions before and after training intervention, no significant differences in thyroid hormone response were found (fT3, $t(11) = 0.48$, $p = 0.638$, $d = 0.14$; fT4, $Z = -1.000$, $p = 0.531$, $r = 0.29$; TSH, $Z = -0.981$, $p = 0.349$, $r = 0.28$.).

On the one hand, there was no significant difference in thyroid hormone response between “rest” and “exercise” in postmenopausal women after intervention of fT4 ($Z = -1.725$, $p = 0.125$, $r = 0.50$). On the other hand, there was a significant difference between rest and exercise in

Table 4 Thyroid hormone response

Pre-intervention	TSH rest Δ	TSH stress Δ	fT4 rest Δ	fT4 stress Δ	fT3 rest Δ	fT3 stress Δ
Premenopausal women (n = 12)	−0.30 ± 0.28*1	−0.13 ± 0.19*1	0.01 ± 0.13	−0.01 ± 0.05	−0.03 ± 0.13	−0.08 ± 0.10
Postmenopausal women (n = 12)	−0.20 ± 0.56	−0.02 ± 0.31	0.02 ± 0.08	0 ± 0.04	−0.03 ± 0.09	−0.1 ± 0.09
Post-intervention	TSH rest Δ	TSH stress Δ	fT4 rest Δ	fT4 stress Δ	fT3 rest Δ	fT3 stress Δ
Postmenopausal women (n = 12)	−0.19 ± 0.17	−0.15 ± 0.1	0.03 ± 0.09	−0.03 ± 0.10	0.02 ± 0.10*2	−0.08 ± 0.13*2

Annotation: Thyroid hormone response was defined as the difference between time point $t1$ and $t0$

*1 Comparison between premenopausal women at rest and after exercise: $p < 0.05$

*2 Comparison between postmenopausal women at rest and after exercise (post-intervention): $p < 0.05$

postmenopausal women after intervention in fT3 response ($t(11) = -2.87$, $p = 0.015$, $d = 0.83$), with fT3 levels decreasing by 0.1 pg/ml after acute exercise. No significant difference was seen between rest and exercise in postmenopausal women in TSH response ($t(11) = 0.82$, $p = 0.432$, $d = 0.23$) (Tables 3, 4 and (Figs. 2, 3).

Discussion

Body composition

It was found that the premenopausal women had lower BMI, lower body weight, more muscle mass, and lower body fat in comparison with the postmenopausal women. These results are consistent with findings from other studies [22–24]. A possible molecular mechanism discussed is an estrogen-related change in the fat metabolism of postmenopausal women [18]. In animal experiments [25, 26] as well as in human intervention studies [27], it could be demonstrated that fat metabolism is directly influenced by 17-beta-estradiol. Although hormone replacement therapy with estradiol can positively influence lean body mass initially (within the first 3 years), the effects are regressive in the long term [28]. Therefore, physical activity is an important measure to reduce the age-related reduction of lean body mass in the long term.

The six-week endurance training greatly improved the body composition of the postmenopausal women through a significant increase in muscle mass and a significant reduction in fat mass. The significant increase in muscle mass due to endurance training is particularly remarkable and can be attributed to the fact that the postmenopausal women were untrained and therefore either did not train at all or did not train regularly. It has already been shown in the literature that untrained elderly subjects can build muscle mass through systematic endurance training [29].

Thyroid hormone response

At baseline, no differences in hormone concentrations of TSH, fT4, and fT3 were detected between premenopausal and postmenopausal women. It is known that TSH concentrations increase with age [30–32], by about 5–10 µIU/ml every decade [30]. However, this was not evident in our study, presumably due to small sample size.

Furthermore, in premenopausal women, a significant elevated TSH response and therefore an increased stimulation of the thyroid gland could be induced by acute endurance training. The postmenopausal women react with a non-significant increased TSH response due to acute endurance exercise. Since changes in TSH are descriptively detectable, it can be assumed that the sample was too small to identify significant changes in TSH in postmenopausal women. In other studies, it has already been shown that endurance training can increase the TSH concentration [10, 11, 13]. Regarding the hormones fT3 and fT4, no changes could be detected in both groups. The data suggest that both pre- and postmenopausal women respond to acute aerobic exercise by increased TSH release due to greater thyroid hormone demand.

Through training intervention, no significant change in TSH response of the postmenopausal women could be detected. Nevertheless, descriptively, a greater decrease in TSH or a weaker TSH response after acute exercise was observed in comparison of pre- and post-intervention measurements. Furthermore, postmenopausal women showed a significantly reduced fT3 response by acute, aerobic exercise after the training intervention compared with the resting condition. The data regarding the response of acute exercise on thyroid hormone concentrations is controversial. Some previous studies assessing thyroid hormones after exercise found increased concentrations of TSH, T4, and T3 [11, 13]. Other studies noted a decrease in thyroid hormones [10, 33]. The biological effects of short-term changes in thyroid hormone concentrations are not fully understood although they may be important in the body's adaptation to stressful or catabolic states [34, 35].

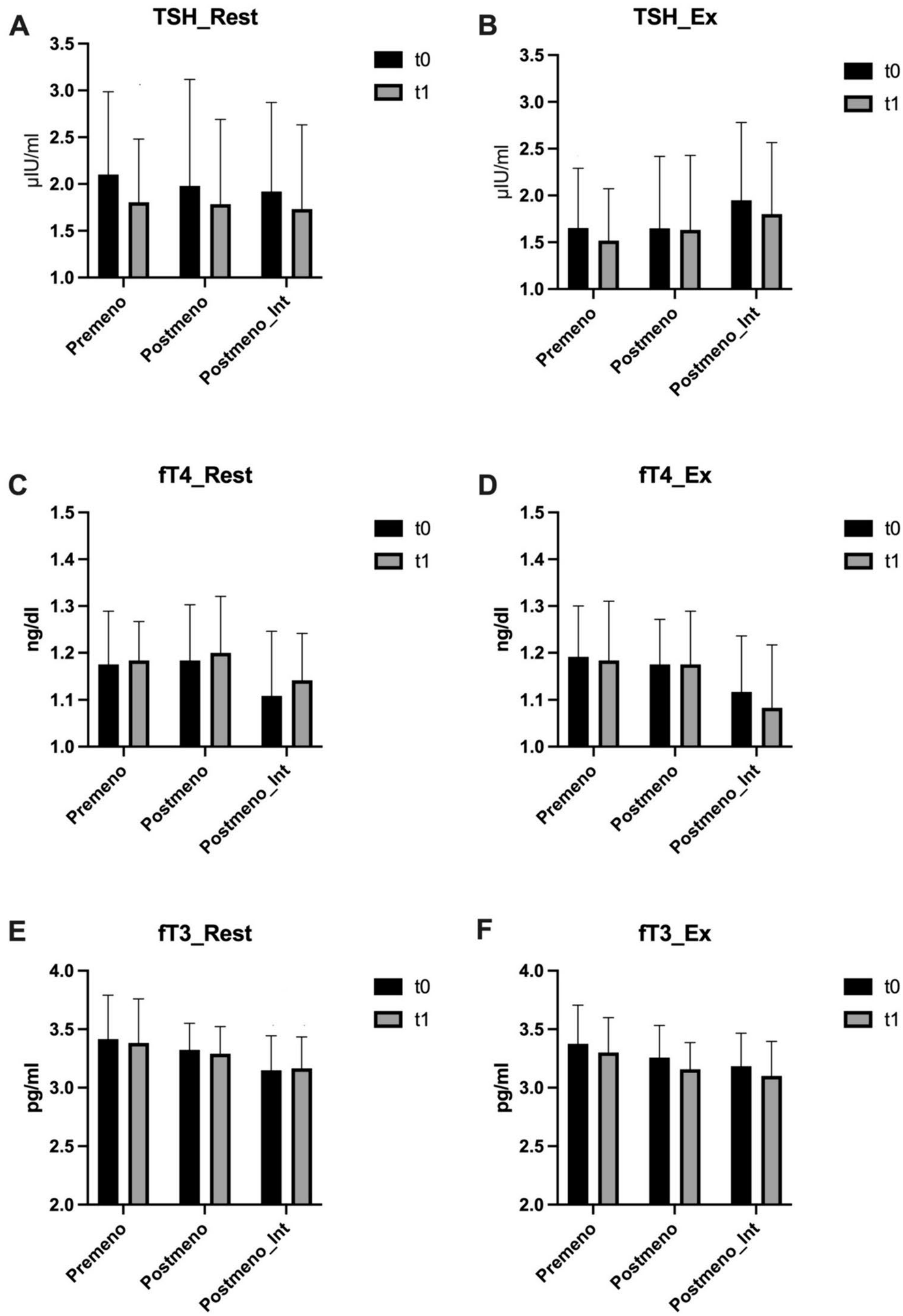

Fig. 2 Thyroid hormone concentration (Rest = no training between 9:00 and 9:40; Ex = acute endurance exercise between 9:00 and 9:40)

However, in this study, it can be assumed that the intervention-induced adaptations of the postmenopausal women resulted in the need for a lower release of thyroid hormones. Indications suggesting a reduced thyroid response in postmenopausal women (post-intervention) are a greater—although not significant—decrease in TSH concentration after acute stress as well as a significantly reduced fT3 release. In animal model, it has already been demonstrated that an endurance training intervention can lead to a greater amount of thyroid hormone receptors [36, 37]. As a result, a lower concentration of thyroid hormones could lead to higher metabolism-increasing effects in target tissues. However, these effects have to be confirmed in humans. In addition, the intervention is likely to improve women's intra- and intermuscular coordination. Therefore, it is expected that acute endurance exercise was experienced as less intense due to increased exercise efficiency and improved muscle activation. As a result, a reduced activation of metabolism

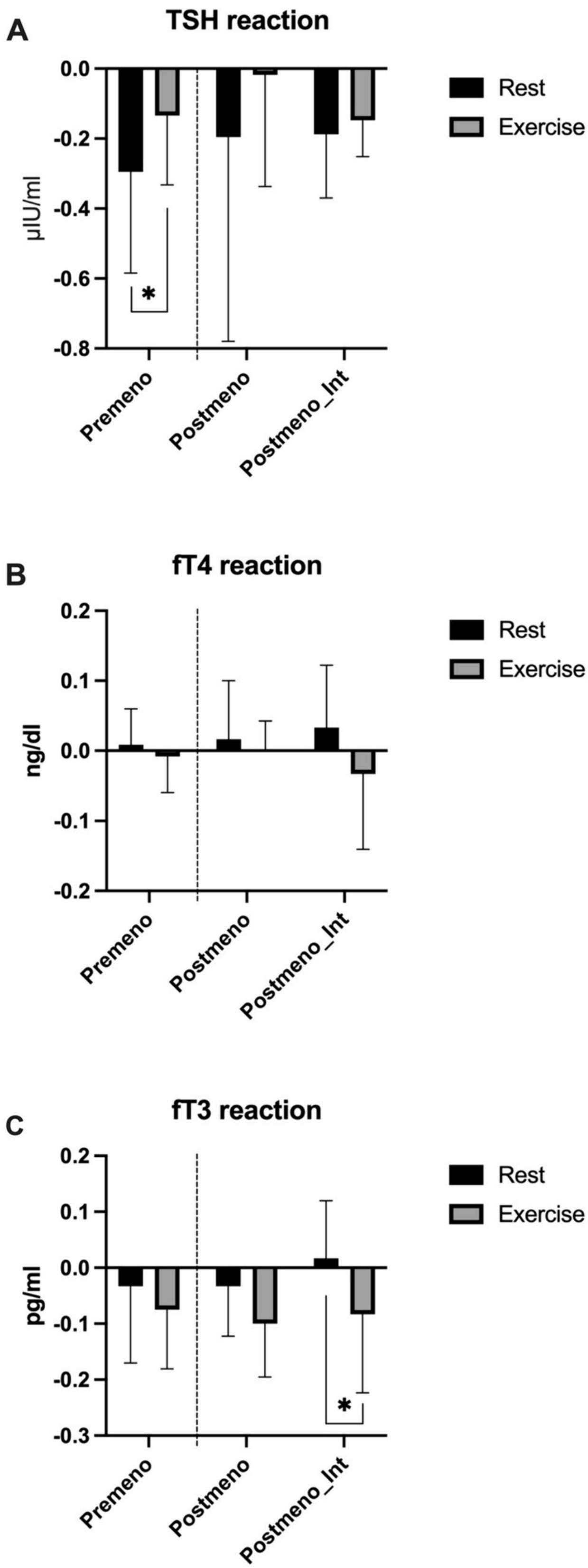

Fig. 3 Thyroid hormone response

is necessary and therefore a reduced release of thyroid hormones.

Limitations

The number of subjects in this study was low, with $n = 12$ per group. For this reason, potential changes may not have become evident. Furthermore, the intervention duration of six weeks may have been too short to make all training-related changes visible. Nevertheless, changes could already be observed after six weeks. Another point to be considered in the interpretation is the determination of the training heart rate for the walking intervention by a load test on the bicycle ergometer. This could result in an underestimation of the subjects' performance. Finally, a further limitation is that the training intervention was not conducted in premenopausal women. For a more detailed comparison of premenopausal and postmenopausal women, it would be necessary to repeat the study with both groups carrying out the intervention.

Conclusion

In summary, a difference in body composition was found between the pre- and postmenopausal women. The premenopausal women showed significantly lower weight, BMI, and body fat as well as significantly higher muscle mass. However, with six weeks of endurance training, the fat mass of the postmenopausal women can be reduced and their muscle mass increased. In addition, both pre- and postmenopausal women respond to acute aerobic exercise with an enhanced thyroid response through an elevated TSH secretion. After a six-week exercise intervention of the postmenopausal women, a non-significantly decreased response of TSH after acute endurance exercise was demonstrated as well as a significantly reduced fT3 response. However, the results must be viewed critically in view of the small sample size.

Therefore, this study provides preliminary evidence that endurance training reduces the thyroid response of postmenopausal women after acute exercise. Whether the reduced need for thyroid hormones after stress is clinically relevant remains to be verified in future studies. However, the results point to the hypothesis that possibly patients with mild, subclinical hypothyroidism might benefit from targeted endurance training in terms of symptom relief or possible reduced doses of thyroxine. Further studies are needed to explore this hypothesis.

Author contributions Lars Hanke, Katharina Hofmann and Patrick Diel created the study design. Lars Hanke, Katharina Hofmann, Anna-Lena Krüger, Lena Hoewekamp, Jean-Michel Wellberich and Ben Koper generated the data. The statistical analysis was provided by

Lars Hanke and Anna-Lena Krüger.Lars Hanke and Katharina Hofmann prepared the manuscript. Patrick Diel reviewed the manuscript and contributed with intellectual ideas. All authors read and agreed to the published version of the manuscript.

Declarations

Conflict of interest The authors have no conflict of interest.

Ethical approval The study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of the German Sports University Cologne (No 130/2019).

Informed consent All participants read and signed the informed consent.

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