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Comparative Effect of Nonlinear and Linear Periodized Resistance Training on Thyroid Function and Quality of Life in Women with Hypothyroidism

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ABSTRACT: Background: Hypothyroidism is a prevalent endocrine condition linked to metabolic impairment, muscular weakness, and diminished quality of life. While pharmacological treatment remains the standard of care, resistance exercise may provide additional therapeutic benefits.

Objective: To compare the effects of non-linear versus linear periodized resistance training on serum thyroid stimulating hormone (TSH), thyroxin (T4), triglyceride-glucose index (TyG), handgrip strength, and quality of life (QoL) in women with hypothyroidism.

Subjects and methods: Seventy-five female subjects diagnosed with hypothyroidism, aged between 35 and 45 years, were randomly allocated into three equal groups (n=25 each): (Group A) non-linear periodized resistance training (NLPRT), (Group B) linear periodized resistance training (LPRT), and (Group C) the control group (CG). The training groups participated in the exercise three times each week for a period of 12 weeks. The results assessed before and after the intervention were blood TSH and T4 levels, triglyceride-glucose index, hand grip strength determined with a hand-held dynamometer, and quality of life evaluated by the SF-12 health survey.

Results: Following the 12-week intervention, the NLPRT group demonstrated significantly higher T4 levels and greater physical and mental quality-of-life scores than the LPRT group, while no significant between-group differences were observed in TSH, blood glucose, triglycerides and triglyceride glucose index (TyG) or handgrip strength. Compared with the CG, both NLPRT and LPRT demonstrated significantly higher T4 levels, hand grip strength, and physical and mental quality of life scores along with significantly lower TyG index values following the intervention, whereas significantly lower TSH, blood glucose, and triglyceride levels were observed only in the NLPRT group.

Conclusion: Both nonlinear and linear periodized resistance training were beneficial in enhancing thyroid function, handgrip strength, and both physical and mental dimensions

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of quality of life. Nonlinear periodization yielded superior advantages, especially with T4 levels and both the physical and psychological dimensions of quality of life.

INTRODUCTION

Hypothyroidism is a prevalent endocrine disorder characterized by inadequate synthesis of thyroid hormones. Hypothyroidism is predominantly identified by biochemical methods owing to the wide range of clinical presentations and the lack of distinct symptoms. Overt or clinical primary hypothyroidism is defined by elevated thyroid-stimulating hormone (TSH) levels and decreased free thyroxine levels (Bianco, 2011). The disease results from inadequate hormone synthesis stemming from primary gland dysfunction or central factors (Wilson, 2011). Primary hypothyroidism constitutes more than 99% of instances, impacting as much as 5% of the overall populace, with an estimated extra 5% remaining untreated. The causes differ by geographical location: iodine shortage is the primary cause globally, whereas Hashimoto's illness is more prevalent in regions with adequate iodine levels (Ametepe et al., 2025). Hypothyroidism is more prevalent in women, with peak incidence between ages 30 and 50 (Chiovato et al., 2019)

Beyond thyroid hormone abnormalities, hypothyroidism is associated with several metabolic disturbances, including impaired glucose–insulin homeostasis, insulin resistance, and dyslipidemia (Cheng et al., 2023). The triglyceride-glucose (TyG) index serves as a surrogate marker of insulin resistance and may offer more understanding of the metabolic changes linked to hypothyroidism (Zhao et al., 2021).

The consequences of hypothyroidism extend beyond metabolic disturbances. Patients may experience fatigue, reduced physical capacity, and psychological difficulties, which can interfere with daily activities and adversely affect both physical and mental aspects of quality of life (Werneck et al., 2018).

Exercise has been demonstrated to affect thyroid function by enhancing thyroid hormone turnover and regulating the pituitary-thyroid axis (Ciloglu et al., 2006). Hypothyroidism diminishes exercise capacity; however, thyroxine therapy can restore it, and regular physical activity may additionally improve thyroid function, mental and physical state, and possibly reduce thyroxine requirements (Bansal et al., 2015).

Periodized resistance training, involving planned manipulation of training variables, may optimize adaptations and prevent overtraining (Vargas-Molina et al., 2025). Nonetheless, the optimal exercise approach for enhancing clinical, functional, and patient-reported results in hypothyroidism has yet to be established (De Lima et al., 2012).

In particular, whether nonlinear periodization provides additional benefits over linear periodization for thyroid function, triglyceride glucose index, hand grip strength, and quality of life has not been sufficiently established. Consequently, the present study was designed to investigate the comparative effects of nonlinear and linear periodized resistance training on thyroid function, triglyceride glucose index, muscle strength, and quality of life in women with hypothyroidism

2- METHODS

The flow of participants throughout the study is illustrated in Figure 1, using the flow diagram format.

Study design

The study is a prospective, parallel-group, randomized controlled trial using a pre- and post-intervention design. The research was carried out from January 2025 until December 2025. Individuals were chosen from the outpatient Endocrine department at Ain Shams University and were enlisted through a reference from an endocrinologist.

Ethical consideration

The Faculty of Physical Therapy's research ethics committee at Cairo University, Egypt, authorized the study, reference number: P.T.REC/ 012/005442. The study was recorded on Clinical Trials.gov under the identifier NCT06757712. A documented informed permission form was acquired from patients for their participation in the current study, along with a verbal elucidation about the significance of the study methods, primary objective, and conceptual framework provided to each patient. Every patient has the right to retract their participation at any moment.

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Sample size calculation

The sample size was determined utilizing the F-test (MANOVA), with repeated measures and within-subject variables, achieving a power of 80% and a type I error rate of 5%. The effect size (0.27) and partial eta squared (0.07) were calculated from the primary outcome (quality of life) in published research (Tozetto et al., 2022) indicating that a sample size of 57 patients was necessary for this investigation. The analysis utilized G* Power version 3.1.9.2 (Franz Faul, University of Kiel, Germany). The number of patients was increased to 75 to avert attrition (Poongothai et al., 2023).

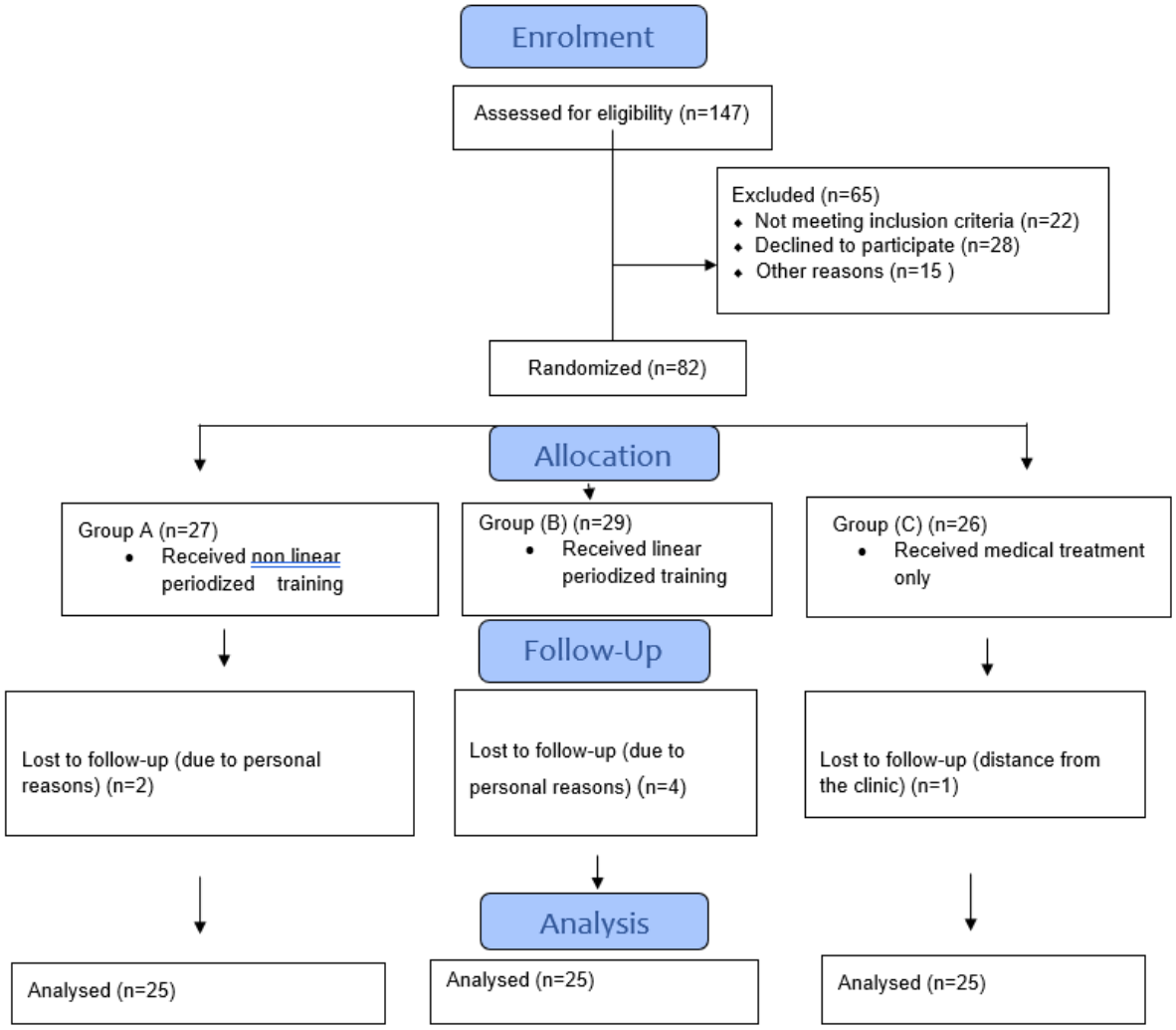


Fig.1 Flow diagram of participants

Randomization:

Randomization was conducted by an investigator uninvolved in the results, utilizing random number creation within an Excel spreadsheet.

The patients were randomly allocated into three equal cohorts, with each group including 25 individuals. Group (A) underwent nonlinear periodization exercise alongside their medical therapy, Group (B) engaged in linear periodization exercise in conjunction with their medical treatment, while Group (C) served as the control group, receiving just their medical treatment.

Seventy-five female patients diagnosed with hypothyroidism were enlisted for this research. The inclusion criteria consisted of: females aged between 35 and 45 years, a body mass index of 30-34.9 kg/m2, controlled hypothyroidism (TSH levels ranging from 0.5 to 4.5 mU/L and free T4 between .7 and 1.8 ng/dl) (Carvalho et al., 2013), and a triglyceride-glucose (TyG) ratio

above 4.5 (Nilofer Sagana et al., 2024). Exclusion criteria included: a history of pulmonary disease, individuals with uncontrolled coronary or cerebrovascular conditions, those who had musculoskeletal surgery in the past year, recent occurrences of lower and upper limb fractures, hip and shoulder dislocations, cognitively impaired individuals, patients with a history of epilepsy, and those engaged in any other exercise regimen.

Outcome measures:

Primary outcome measures

Thyroid function tests: Serum TSH and free T4 concentrations assessed using ELISA kits. (Review biography, incorporated, at EIA KIT, United States). Blood samples were collected in the morning following an overnight fast of 8–12 hours, before the administration of the morning levothyroxine dose.

Health related Quality of life questionnaire (SF-12) (HRQOL):

The SF-12 is a streamlined version of the SF-36, with just 12 questions to evaluate functional health and wellness from the patient's perspective (Busija et al., 2011).

The questionnaire was administered through structured interview, with patients' responses recorded accordingly

Secondary outcome measures

Triglyceride-glucose (TyG) index: The triglyceride-glucose (TyG) index was formulated utilizing a mathematical approach that is contingent only on laboratory evaluations of fasting plasma glucose and triglyceride values. The TyG index was established using the calculation: fasting triglycerides (mg/dL) multiplied by fasting plasma glucose (mg/dL) and thereafter divided by 2 (Araújo et al., 2022).

Hand held dynamometer

Grip strength was assessed using a Baseline Hydraulic Hand Dynamometer (Baseline Evaluation Instrument, NY, USA), while participants were seated in an upright position on a chair, with their knees and hips at 90°, and supported by a backrest. The shoulder on the dominant side was drawn inward toward the chest, the elbow positioned at a 90° angle of flexion, and the wrist kept in a neutral position. Participants were instructed to execute three attempts of handgrip contractions, with the evaluator offering verbal motivation to enhance force during each attempt; the highest force measurement in kilograms obtained from any of the three primary trials was employed for analysis (Lupton-Smith et al., 2022).

Intervention

Both exercise groups (Group A&B) participated in a 12-week resistance-training program, Executed on three non-contiguous days per week. Every training session lasted around 60 minutes and comprised a warm-up, a resistance-training phase, and a cool-down. The preparatory and concluding phases comprised cycling and gentle stretching activities lasting around 10 minutes.

Group C: obtained solely medical intervention. All individuals in the three cohorts received Levothyroxine therapy at a daily dosage between 50 and 200 micrograms, monitored by an endocrinologist.

Prior to commencing the training regimen, the projected one-repetition maximum (1RM) for each resistance exercise was assessed by a submaximal repetition evaluation. The Brzycki formula was employed to calculate 1RM by considering the weight lifted and the repetitions performed: 1RM = weight lifted / (1.0278 - (0.0278 x repetitions) (Moradi et al., 2020).

Training intensity was subsequently prescribed as a percentage of the estimated 1RM and was individually adjusted for each participant. The prescribed intensity was progressively modified according to the assigned periodization model throughout the 12-week intervention.

All exercises performed bilaterally which included: (1) Leg press, (2) Bench press, (3) Leg curl, (4) Hip flexion associated with knee flexion, (5) Hip abduction and adduction, (6) Shoulder flexion, (7) Shoulder abduction, (8) Abdominal exercise, (9) Squatting, (10) Elbow flexion and extension (Frykholm et al., 2019)

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Nonlinear periodized resistance training

The NLPRT group followed a nonlinear periodization program in which training intensity varied across sessions and weeks over the 12-week intervention period (Moradi et al., 2020). Tables 1,2

Table (1) program of (NLPRT)

	Weeks											
	1	2	3	4	5	6	7	8	9	10	11	12
Day 1	L	L	M	VL	M	L	VL	H	H	L	L	VL
Day 2	M	M	H	H	H	M	M	VL	L	H	M	H
Day 3	L	H	L	L	H	H	L	M	M	M	VL	L

VL = very light intensity workout, L = light intensity workout, M = moderate intensity workout. H = heavy intensity workout,

Table (2) program of (NLPRT)

Intensity	Repetitions×Sets	1RM	Rest time
Very light	20×1	40%	1 min
Light	15×2	50%	2 min
Moderate	10×3	65%	2-3 min
Heavy	4×3	85%	2-3 min

linear periodization training

The linear periodized resistance training (LPRT) protocol was developed based on established principles of progressive resistance training (Garber et al., 2011) (Mahmoud et al., 2022)

Throughout the 12-week intervention, training intensity and volume were progressively increased, with rest intervals between sets following the same schedule as that used in the nonlinear periodization group. The protocol was implemented as detailed below Table (3).

Table (3) program of (LPRT)

Weeks	Intensity (protocol-defined)	%1RM	Sets × Repetitions
1–2	Very Ligh to Light	40–50%	1 × 20 / 2 × 15
3–4	Light	50%	2 × 15
5–6	Light to Moderate	50–65%	2 × 15 / 3 × 10
7–8	Moderate	65%	3 × 10
9–10	Moderate to Heavy	65–85%	3 × 10 / 3 × 4
11–12	Heavy	85%	3 × 4

To facilitate comparison with the nonlinear periodization program, the total number of sessions performed at each intensity level, along with the prescribed sets and repetitions, was matched across the two protocols. The main difference between the programs was the temporal distribution of training intensity, which increased progressively in the linear group but varied frequently in the nonlinear group.

Statistical analysis

The statistical assessments were conducted with SPSS software version 22. A comparative analysis of the groups' attributes, including age, weight, height, and BMI, was performed using ANOVA. Furthermore, MANOVA was used to evaluate the outcomes among the three groups. Nevertheless, several comparisons were executed to discern the distinctions among each group, and pairwise analysis were undertaken to uncover the notable changes among the groupings. The Kolmogorov–Smirnov test was employed to evaluate the normality of the data. Furthermore, Levene's test was utilized to evaluate the uniformity of the data. The significance level for all statistical evaluations was set at $P < 0.05$.

RESULTS

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In this research, 75 participants were enlisted and randomly assigned to three groups, with each group including 25 individuals. An analysis of demographic information and initial clinical traits indicated no notable differences among the three cohorts for demographic factors (age, weight, height, and BMI), with P-values beyond 0.05 (Table4).

Table4. Comparison of characteristics and baseline features between groups A, B, C

	Group A (Non Linear) n=25	Group B (Linear) n=25	Group C (Control) n=25	F-value	P-value
	X ± SD	X ± SD	X ± SD		
Age (years)	39.4±2.3	39.3±3	39.36±2.7	0.012	0.988
Weight (Kg)	80.2±5.5	80.4±5.1	81.5±6.7	0.362	0.697
Height (cm)	158.6±5.3	158±4.8	157.7±6.4	0.161	0.851
BMI (kg/m²)	31.9±1	32.2±1.4	32.8±1.5	2.791	0.068

X: Mean, SD: Standard deviation, p-value: Probability value,: significance, n: number of participants*

The research revealed that prior to the intervention, no statistical discrepancies in TSH levels were seen across the three groups; nevertheless, a significant difference emerged post-intervention with a P value of 0.026. Consequently, further analysis indicated a significant difference between groups A and C (P value of 0.023); still, no substantial differences were seen between groups A and B or B and C (P value above 0.05). Furthermore, there were a significant alteration in the TSH level within groups A and B with percentage of the reduction were 36.2% and 26.9%, respectively (Table5).

The investigation showed that no statistical differences regarding T4 level was detected between the three groups before intervention (P value was 0.064) but after intervention, there was a significant variation as P value was less than 0.05. Therefore, later analysis demonstrated a considerable variation between groups A and C, A and B, and B and C (P value was less than 0.05). In addition, there was a conspicuous variation in T4 levels among groups A and B, showing rises of 25.9% and 16.2%, respectively (Table5).

Table5. Comparison between groups regarding Thyroid stimulating hormone (TSH) and T4

	Thyroid-stimulating hormone (TSH) MIU/L					Thyroxine (T4) ng/dl				
	Group A	Group B	Group C	Comparison between group		Group A	Group B	Group C	Comparison between group	
	(Non Linear) n=25	(Linear) n=25	(Control) n=25	F-value	P-value	(NonLinear) n=25	(Linear) n=25	(Control) n=25	F-value	P-value
	X ± SD	X ± SD	X ± SD			X ± SD	X ± SD	X ± SD		
Before Intervention	3.29±0.6	3.15±0.8	2.74±1	2.744	0.071	1.274 ±0.08	1.301 ±0.07	1.369±0.23	2.849	**0.064**
After Intervention	2.1±0.7	2.3±0.9	2.7±0.9	3.862	0.026*	1.604±0.01	1.509±0.07	1.368±0.21	18.680	**P<0.05***
percentage of change	36.2%	26.9%	1.5%			25.9%	16.2%	0.07%		
Comparison within group	P<0.05*	P<0.05*	0.951			P<0.05*	P<0.05*	0.972		
	Post-intervention Multiple Comparisons TSH					**Post-intervention Multiple Comparisons T4**				
	MD		**P-Value**			**MD**		**P-Value**		
Group (A) vs. Group (B)	-0.2		0.927			0.69			**0.049***	
Group (A) vs. Group (C)	-0.6		0.023*			0.236			**P<0.05***	
Group (B) vs. Group (C)	-0.4		0.267			0.140			**0.002***	

X: Mean, SD: Standard deviation, p-value: Probability value,: significance, n: number of participants.*

The research indicated that prior to the intervention, no statistical differences in TG levels were seen across the three groups; nevertheless, a notable difference emerged post-intervention with a P value of 0.013. After the analysis, post-hoc testing demonstrated a noticeable difference between groups A and C (P value of 0.011); in contrast, no significant differences were

found between groups A and B or B and C (P value of 0.05). In addition, groups A and B exhibited a substantial decline in TG levels, with reductions of 13.1% and 8.7%, respectively (Table6).

The inquiry disclosed that before to the intervention, no statistical variances in blood glucose levels were seen across the three groups; but, post-intervention, a significant difference emerged with a P value of 0.001. Consequently, further analysis indicated a significant difference between groups A and C (P value was 0.001); however, no substantial differences were seen between groups A and B or B and C (P-value beyond 0.05). Additionally, there were a significant decrease in the blood glucose level within groups A and B with percentage of the reduction were 9.2% and 5.6%, respectively.

(Table6) Table 6 Comparison between groups regarding triglyceride (TG) and glucose level

	Triglyceride (TG) mg/Dl					**Blood glucose level (mg/dL)**				
	Group A	**Group B**	**Group C**	**Comparison between group**		**Group A**	**Group B**	**Group C**	**Comparison between group**	
	(Non Linear) n=25	**(Linear) n=25**	**(Control) n=25**	**F-value**	**P-value**	**(Non Linear) n=25**	**(Linear) n=25**	**(Control) n=25**	**F-value**	**P-value**
	X ± SD	X ± SD	X ± SD			X ± SD	X ± SD	X ± SD		
Before Intervention	121.3±18.2	121.7±16.9	120.3±19.2	0.037	0.964	86.6±10.3	89.4 ± 11.4	89.8 ±9.2	0.688	**0.506**
After Intervention	105.4±18.7	111.1±16.9	120.4±17.2	4.605	0.013*	78.6±10.1	84.1 ±11.1	89.7±8.5	7.771	**0.001***
percentage of change	13.1%	8.7%	0.08%			9.2%	5.6%	0.1 %		
Comparison within group	P<0.05*	P<0.05*	0.965			P<0.05*	P<0.05*	0.988		
	Post-intervention Multiple Comparisons Triglyceride					**Post-intervention Multiple Comparisons Blood glucose level**				
	MD		**P-Value**			**MD**		**P-Value**		
Group (A) vs. Group (B)	-5.6		0.789			-5.5			**0.168**	
Group (A) vs. Group (C)	-14.9		0.011*			-11.1			**0.001***	
Group (B) vs. Group (C)	-9.3		0.196			-5.6			**0.148**	

*X: Mean, SD: Standard deviation, p-value: Probability value, *: significance, MD: mean difference, n: number of participants*

The analysis indicated that before to the intervention, there were no statistical discrepancies in the TyG index levels among the three groups; but, post-intervention, a significant difference emerged with a P value below 0.05. Furthermore, further analyzes revealed a significant difference between groups A and C, as well as B and C (P value <0.05); however, no substantial difference was seen between groups A and B (P value 0.564). Additionally, a significant decrease in the TyG index was seen in groups A and B, with decreases of 2.8% and 2.2%, respectively (Table7).

Table7. Comparison between groups regarding Triglyceride Glucose index (TyG).

Triglyceride Glucose index (TyG)	**Group A (Non Linear) n=25**	**Group B (Linear) n=25**	**Group C (Control) n=25**	**Comparison between group**	
	X ± SD	X ± SD	X ± SD	**F-value**	**P-value**
Before Intervention	4.6±0.06	4.61±0.05	4.64±0.01	1.255	0.291
After Intervention	4.47±0.09	4.51±0.12	4.63±0.09	17.579	P<0.05*
percentage of change	2.8%	2.2%	0.2%		
Comparison within group	P<0.05*	P<0.05*	0.933		
Post-intervention Multiple Comparisons					
			MD	**P-value**	
Group (A) vs. Group (B)			-0.04	0.564	
Group (A) vs. Group (C)			-0.16	P<0.05*	
Group (B) vs. Group (C)			-0.12	P<0.05*	

*X: Mean, SD: Standard deviation, p-value: Probability value, *: significance, MD: mean difference*

The results of the study indicated that no statistical variations regarding the dynamometer degree observed between the three groups before intervention but after intervention there was a significant variation as P value was less than 0.05. Moreover, follow-up evaluations uncovered a noticeable distinction between groups A and C, along with B and C (P values were <0.05

and 0.003, respectively); nonetheless, no considerable difference was detected between groups A and B (P-value was 0.116). Furthermore, a remarkable surge in the dynamometer values for groups A and B was seen, with percentage increments of 28.7% and 20.9%, respectively (Table8).

Table8. Comparison between groups regarding dynamometer degree.

Dynamometer degree (kg)	Group A (Non Linear) n=25	Group B (Linear) n=25	Group C (Control) n=25	Comparison between group	
	X ± SD	X ± SD	X ± SD	F-value	P-value
Before Intervention	28.9±2.4	28.6±2.8	30.5±5.4	1.728	0.185
After Intervention	37.2±2.6	34.6±2.8	30.4±6.5	15.432	P<0.05*
percentage of change	28.7%	20.9%	0.3%		
Comparison within group	P<0.05*	P<0.05*	0.770		
Post-intervention Multiple Comparisons					
			MD	P-value	
Group (A) vs. Group (B)			2.6	0.116	
Group (A) vs. Group (C)			6.8	P<0.05*	
Group (B) vs. Group (C)			4.2	0.003*	

*X: Mean, SD: Standard deviation, p-value: Probability value, *: significance, MD: mean difference, n: number of participants*

The investigation showed that no statistical differences regarding Quality of life physical score was detected between the three groups before intervention (P value was 0.368) but after intervention, there was a significant variation as P value was less than 0.05. As a result, further analysis revealed a significant difference among groups A and C, A and B, and B and C (P value was under 0.05). Furthermore, a significant alteration was seen in the physical quality of life scores for groups A and B, with enhancements of 18.4% and 11.7%, respectively (Table9).

The study indicated that no statistical differences regarding Quality of life mental score was detected between the three groups before intervention (P value was 0.125) but after intervention, there was a significant variation as P value was less than 0.05. As a result, further analysis indicated a significant disparity between groups A and C, A and B, and B and C (P value was below 0.05). Moreover, a significant alteration was seen in the mental quality of life ratings for groups A and B, reflecting increases of 21.9% and 16.6%, respectively (Table9).

Table 9. Comparison between groups regarding quality of life physical and mental score.

	Quality of life physical score					Quality of life mental score				
	Group A	Group B	Group C	Comparison between group		Group A	Group B	Group C	Comparison between group	
	(Non Linear) n=25	(Linear) n=25	(Control) n=25	F-value	P-value	(Non Linear) n=25	(Linear) n=25	(Control) n=25	F-value	P-value
	X ± SD	X ± SD	X ± SD			X ± SD	X ± SD	X ± SD		
Before Intervention	41.9±2.6	42.9±2.4	42.8±2.8	1.012	0.386	33.2±3.9	31.4±2.8	32.5±2.6	2.138	**0.125**
After Intervention	49.6±2.8	47.9±2.1	42.9±3.7	37.370	P<0.05*	40.5±3	36.6±3	32.6±2.8	44.909	**P<0.05***
percentage of change	18.4%	11.7%	0.2%			21.9%	16.6%	0.3 %		
Comparison within group	P<0.05*	P<0.05*	0.919			P<0.05*	P<0.05*	0.977		
	Post-intervention Multiple Comparisons Quality of life physical score					Post-intervention Multiple Comparisons Quality of life mental score				
	MD		P-Value			MD		P-Value		
Group (A) vs. Group (B)	2		0.049*			3.9			**P<0.05***	
Group (A) vs. Group (C)	7.1		P<0.05*			7.9			**P<0.05***	
Group (B) vs. Group (C)	4.9		P<0.05*			4.1			**P<0.05***	

*X: Mean, SD: Standard deviation, p-value: Probability value, *: significance, MD: mean difference, n: number of participants*

DISCUSSION:

The aim of this research was to assess the effects of nonlinear compared to linear periodized resistance training on thyroid function and quality of life in women suffering from hypothyroidism.

In contrast to the control group, the findings of the study indicated that: group (A) significantly decreased TSH, increased thyroxine T4, decreased triglyceride and blood glucose levels and triglyceride-glucose index, increased dynamometer score, increased score of physical and mental quality of life questionnaire, group (B) participants showed significantly increased thyroxine T4, decreased triglyceride-glucose index, increased dynamometer score , increased score of physical and mental quality of life questionnaire. Group (A) showed significant superiority in increasing thyroxine T4 levels and also significant increase score of physical and mental quality of life, compared to linear periodization (group B).

A statistically significant decrease in TSH levels was observed within both NLPRT and LPRT groups, but not in the CG in addition to the findings regarding Free Thyroxine (T4) showed a statistically significant difference between NLPRT and LPRT favoring NLPRT.

These results align with an earlier investigation that assessed the impact of consistent physical activity, such as sports or jogging, on the thyroid function of treated hypothyroid individuals over a 3-month period of daily 1-hour exercise, revealing that serum T3 and T4 concentrations were markedly elevated in those who exercised regularly compared to their sedentary counterparts, with the exercising cohort exhibiting a significant reduction in TSH upon intergroup analysis, potentially due to enhanced gland perfusion (Bansal et al., 2015). A prior investigation demonstrated a statistically significant elevation in T4 serum concentration (P=0.017) and a reduction in TSH levels (P=0.018) following a sixteen-week progressive intensity resistance exercise program in school-aged children with intellectual disabilities (Zenebe et al., 2020).

Moreover, a comparative study on resistance and aerobic training, which included 50 minutes of exercise, five sessions weekly for three months, revealed a significant reduction in TSH serum concentration among the resistance training cohort of 30 hypothyroid patients aged 30 to 40 years, in contrast to the aerobic training group intervention (Yadav & Verma, 2022). A recent meta-analysis encompassing seven randomized controlled trials corroborates that prolonged exercise functions as an efficacious non-pharmacological strategy for managing hypothyroidism, enhancing thyroid function by reducing TSH and elevating T4 levels when used alongside standard medication(Sundus et al., 2025).The findings of the current investigation are elucidated by a study that assessed the impact of 12 weeks of NLPRT, administered three times weekly, on lipid and hormonal profiles in a breast cancer survivor suffering from lymphedema and hypothyroidism undergoing hormonotherapy, suggesting that the diverse stimuli of NLPRT may beneficially affect thyroid function, as the elevation of T4 levels modulates TSH secretion through negative feedback and TRH mediation, while concurrently boosting the synthesis of its derivative, triiodothyronine (de Jesus Leite et al., 2017).Also the frequent variation in intensity and volume characteristic of NLPRT may effectively reduce the chronic, low-grade stress associated with hypothyroidism and optimize hypothalamic-pituitary-thyroid axis feedback (Kraemer & Ratamess, 2005).

Unlike the findings of the current study, a previous investigation indicated no notable alterations in TSH, T3, or T4 levels following eight weeks of resistance training in young active males, potentially attributable to variations in the frequency of exercise sessions and training methodology (Rahimi et al., 2013). Furthermore, a meta-analysis encompassing data from ten studies conducted on women with hypothyroidism revealed that aerobic and resistance training resulted in a non-significant decrease in TSH levels, concluding that physical exercise did not significantly influence thyroid function, despite potentially yielding secondary benefits for physical and mental health (Duñabeitia et al., 2023).

In the present study the significant reduction in fasting plasma glucose and triglycerides within both exercise groups A, B compared to the baseline with a significant reduction between groups A and C .These findings align with a previous study which evaluated the impact of linear and nonlinear training program for 8 weeks with 3 previous weeks of familiarization, three sessions per week were performed on biochemical parameters(fasting plasma glucose and triglyceride) in older adults and found that both interventions significantly decreased fasting plasma glucose and triglycerides (Vargas-Molina et al., 2025). Furthermore, metabolic challenge is probably provided by the daily or weekly fluctuation in NLPRT, which alternately stresses oxidative and glycolytic pathways. This constant "metabolic switching" may prevent adaptation plateaus and lead to more improvements in glucose uptake and triglyceride metabolism (Foschini et al., 2010).

Both NLPRT and LPRT groups produced significant and comparable decrease in the Triglyceride-Glucose (TyG) Index compared to the control group, with no significant difference between the two training modalities with more percentage improvement for NLPRT 2.8% than LPRT 2.2%. This indicates that both periodization strategies are effective in enhancing systemic insulin sensitivity which is a key factor for hypothyroid patients who are often prone to metabolic syndrome.

Consistent with the current results, prior research investigated the impact of short-term non-periodized, linear periodized, and daily undulating periodized resistance training on insulin resistance in sedentary overweight males over an 8-week duration, revealing a reduction in insulin resistance across all training cohorts, though notable differences were exclusively observed between the daily undulating periodized resistance training and control groups (Ahmadizad et al., 2014).

The present study indicated improvements in quality of life following both resistance training programs, with significant gains recorded in the physical and mental components.in contrast, neither component changed significantly among participants in the control group. The between-group analysis favored Group A, with significantly better physical and mental quality-of-life outcomes than Group B. This is supported by earlier study suggesting that a twelve-week moderate-impact exercise program markedly enhanced physical functioning, overall health, and mental well-being in women with subclinical hypothyroidism (Garces-Arteaga et al., 2013). A recent study indicated significant improvements in both physical and mental health-related quality of life, evaluated by the SF-12, across all forms of exercise (aerobic, strength, and combined aerobic and resistance training) among women with hypothyroidism (Ahmad et al., 2023). The present study uncovered a significant difference in hand grip strength between groups A and C, and B and C, however no substantial differences were detected between groups A and B. These results align with a prior study that assessed strength improvements between LPRT and NLPRT over a 12-week training period, which found comparable strength enhancements in strength-trained males and concluded that both periodization strategies are equally efficacious(Prestes et al., 2009) .In opposition to the results of the current investigation, a prior study assessed LPRT against NLPRT for strength enhancements for12weeks in persons with prior training and discovered that NLPRT was more effective in optimizing strength compared to traditional LPRT (Miranda et al., 2011). Furthermore, an earlier investigation performed a meta-analysis to examine the impact of two periodization frameworks on strength enhancement and determined that NLPRT surpasses conventional periodized training in augmenting maximal strength performance (Caldas et al., 2016).

These findings suggest that periodized resistance training may serve as a useful complement to conventional medical treatment for women with controlled hypothyroidism potentially contributing to favorable changes in thyroid hormone levels, reductions in the triglyceride-glucose (TyG) index, a surrogate marker of insulin resistance, and improvements in health-related quality of life.

CONCLUSION:

The current results suggest that physical activity might beneficially influence thyroid function, triglyceride-glucose levels, muscular strength, and health-related quality of life (HRQoL) in women suffering from hypothyroidism. Both nonlinear (NLPRT) and linear (LPRT) periodized resistance training groups significantly increased T4 levels, muscle strength (dynamometer), HRQoL and decreased TyG index. However, NLPRT resulted in significantly greater improvements in T4 levels and both physical and mental components of HRQoL compared to LPRT. These findings highlight the potential value of tailoring resistance training programs to the individual needs of women with controlled hypothyroidism as part of physiotherapy care.

LIMITATIONS OF THE STUDY

The research possesses many constraints that might affect the understanding of its results. Initially, the limited sample size and the inclusion of only women aged 35–45 years with controlled hypothyroidism might restrict the applicability of the findings. Secondly, the intervention lasted 12 weeks, and the lack of follow-up assessments made it difficult to establish whether the benefits would persist over time. Finally, the mechanisms responsible for the changes in thyroid hormone levels were not directly examined, leaving uncertainty about how the two resistance training approaches may have influenced hormonal responses.

REFERENCES

[1] Ahmad, A. M., Serry, Z. H., Abd Elghaffar, H. A., Ghazi, H. A., & El Gayar, S. L. (2023). Effects of aerobic, resistance, and combined training on thyroid function and quality of life in hypothyroidism. A randomized controlled trial. Complementary Therapies in Clinical Practice, 53(August), 101795. https://doi.org/10.1016/j.ctcp.2023.101795

[2] Ahmadizad, S., Ghorbani, S., Ghasemikaram, M., & Bahmanzadeh, M. (2014). Effects of short-term nonperiodized, linear periodized and daily undulating periodized resistance training on plasma adiponectin, leptin and insulin resistance. Clinical Biochemistry, 47(6), 417–422. https://doi.org/10.1016/j.clinbiochem.2013.12.019

[3] Ametepe, S., Yaw, B., Nyarko, E., Wormekpor, I., Kantah, B., Appiah, M., Kwadzokpui, K., Adejumo, E. N., Obirikorang, C., & Ibrahim, A. (2025). Hypothyroidism phenotypes, clinical characteristics, and factors associated with nodular thyroid disease in patients with hypothyroidism in Southern Ghana: a 6-year retrospective study.

[4] Araújo, S. P., Juvanhol, L. L., Bressan, J., & Hermsdorff, H. H. M. (2022). Triglyceride glucose index: A new biomarker in predicting cardiovascular risk. Preventive Medicine Reports, 29(March), 101941. https://doi.org/10.1016/j.pmedr.2022.101941

[5] Bansal, A., Kaushik, A., Singh, C., Sharma, V., & Singh, H. (2015). The effect of regular physical exercise on the thyroid function of treated hypothyroid patients: An interventional study at a tertiary care center in Bastar region of India. Archives of Medicine and Health Sciences, 3(2), 244. https://doi.org/10.4103/2321-4848.171913

[6] Bianco, A. C. (2011). Hypothyrodisis. Encyclopedia of Clinical Neuropsychology, 390(10101), 1290–1290. https://doi.org/10.1007/978-0-387-79948-3_3710

[7] Busija, L., Pausenberger, E., Haines, T. P., Haymes, S., Buchbinder, R., & Osborne, R. H. (2011). Adult measures of general health and health-related quality of life: Medical Outcomes Study Short Form 36-Item (SF-36) and Short Form 12-Item (SF-12) Health Surveys, Nottingham Health Profile (NHP), Sickness Impact Profile (SIP), Medical Outcomes Study Sh. Arthritis Care and Research, 63(SUPPL. 11). https://doi.org/10.1002/acr.20541

[8] Caldas, L. C., Guimarães-ferreira, L., Duncan, M. J., Leopoldo, A. S., Leopoldo, A. P. L., & Lunz, W. (2016). Traditional vs. Undulating Periodization in the Context of Muscular Strength and Hypertrophy: A Meta-Analysis. 6(6), 219–229. https://doi.org/10.5923/j.sports.20160606.04

[9] Carvalho, G. A. de, Perez, C. L. S., & Ward, L. S. (2013). The clinical use of thyroid function tests. Arquivos Brasileiros de Endocrinologia e Metabologia, 57(3), 193–204. http://www.ncbi.nlm.nih.gov/pubmed/23681265

[10] Cheng, H., Hu, Y., Zhao, H., Zhou, G., Wang, G., Ma, C., & Xu, Y. (2023). Exploring the association between triglyceride-glucose index and thyroid function. European Journal of Medical Research, 28(1), 1–13. https://doi.org/10.1186/s40001-023-01501-z

[11] Chiovato, L., Magri, F., & Carle, A. (2019). Hypothyroidism in Context: Where We ' ve Been and Where We ' re Going. 47–58. https://doi.org/10.1007/s12325-019-01080-8

[12] Ciloglu, F., Peker, I., Pehlivan, A., Karacabey, K., & İlhan, N. (2006). Exercise intensity and its effects on thyroid hormones. (October 2023).

[13] de Jesus Leite, M. A. F., Penha Silva, N., Freire Oliveira, C. J., Mariano, I. M., Sanjuliao Giolo, J., Goncalves Costa, J., & Morais Puga, G. (2017). Effects of Nonlinear Training with Resistance Exercise on Breast Cancer Survivor with Lymphedema and Hypothyroidism during Adjuvant Hormone Therapy: A Case Study. Journal of Womens Health, Issues and Care, 06(03). https://doi.org/10.4172/2325-9795.1000269

[14] De Lima, C., Boullosa, D. A., Frollini, A. B., Donatto, F. F., Leite, R. D., Gonelli, P. R. G., Montebello, M. I. L., Prestes, J., & Cesar, M. C. (2012). Linear and daily undulating resistance training periodizations have differential beneficial effects in young sedentary women. International Journal of Sports Medicine, 33(9), 723–727. https://doi.org/10.1055/s-0032-1306324

[15] Duñabeitia, I., González-Devesa, D., Varela-Martínez, S., Diz-Gómez, J. C., & Ayán-Pérez, C. (2023). Effect of physical exercise in people with hypothyroidism: systematic review and meta-analysis. Scandinavian Journal of Clinical and Laboratory Investigation, 83(8), 523–532. https://doi.org/10.1080/00365513.2023.2286651

[16] Foschini, D., Araújo, R. C., Bacurau, R. F. P., Piano, A. De, Almeida, S. S. De, Carnier, J., Rosa, T. D. S., Mello, M. T. De, Tufik, S., & Dâmaso, A. R. (2010). Treatment of Obese Adolescents: The Influence of Periodization Models and ACE Genotype. 18(4). https://doi.org/10.1038/oby.2009.247

[17] Frykholm, E., Klijn, P., Saey, D., Van Hees, H. W. H., Stål, P., Sandström, T., Sörlin, A., Maltais, F., & Nyberg, A. (2019). Effect and feasibility of non-linear periodized resistance training in people with COPD: Study protocol for a randomized controlled trial. Trials, 20(1), 1–13. https://doi.org/10.1186/s13063-018-3129-y

[18] Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., Nieman, D. C., & Swain, D. P. (2011). Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. Medicine and Science in Sports and Exercise, 43(7), 1334–1359. https://doi.org/10.1249/MSS.0b013e318213fefb

[19] Garces-Arteaga, A., Nieto-Garcia, N., Suarez-Sanchez, F., Triana-Reina, H. R., & Ramírez-Vélez, R. (2013). Influence of a medium-impact exercise program on health-related quality of life and cardiorespiratory fitness in females with subclinical hypothyroidism: An open-label pilot study. Journal of Thyroid Research, 2013. https://doi.org/10.1155/2013/592801

[20] Kraemer, W. J., & Ratamess, N. A. (2005). Hormonal responses and adaptations to resistance exercise and training. Sports Medicine, 35(4), 339–361. https://doi.org/10.2165/00007256-200535040-00004

[21] Lupton-Smith, A., Fourie, K., Mazinyo, A., Mokone, M., Nxaba, S., & Morrow, B. (2022). Measurement of hand grip strength: A cross-sectional study of two dynamometry devices. South African Journal of Physiotherapy, 78(1), 1–5. https://doi.org/10.4102/sajp.v78i1.1768

[22] Mahmoud, N., Mohammadreza, H. A., Abdolhosein, T. K., Mehdi, N., & Arent, S. M. (2022). Serum myokine levels after linear and flexible non-linear periodized resistance training in overweight sedentary women. European Journal of Sport Science, 22(4), 658–668. https://doi.org/10.1080/17461391.2021.1895893

[23] Miranda, F., Simao, R., Rhea, M., Bunker, D., Prestes, J., Diego Leite, R., Miranda, H., Freitas de Salles, B., & Novaes, J. (2011). Effects of Linear vs. Daily Undultory Periodized Resistance Training on Maximal and Submaximal Strength Gains. Journal of Strength & Conditioning Research, 25(7)(1824), 1824–1830.

[24] Moradi, B., Rahmati-Ahmadabad, S., Farzanegi, P., Helalizadeh, M., & Azarbayjani, M. A. (2020). Effects of non-linear resistance training and curcumin supplementation on the liver biochemical markers levels and structure in older women with non-alcoholic fatty liver disease. Journal of Bodywork and Movement Therapies, 24(3), 154–160. https://doi.org/10.1016/j.jbmt.2020.02.021

[25] Nilofer Sagana, M. K., Arul Senghor, K. A., Vinodhini, V. M., & P, R. (2024). Irisin and Triglyceride Glucose Index as Markers of Dyslipidemia in Young Adults. Indian Journal of Clinical Biochemistry, 39(1), 136–141. https://doi.org/10.1007/s12291-022-01083-3

[26] Poongothai, S., Anjana, R. M., Aarthy, R., Unnikrishnan, R., & Narayan, K. M. V. (2023). Strategies for participant retention in long term clinical trials: A participant – centric approaches. 3–9. https://doi.org/10.4103/picr.picr

[27] Prestes, J., Frollini, A. B., de Lima, C., Donatto, F. F., Foschini, D., de Cássia Marqueti, R., Figueira, A., & Fleck, S. J. (2009). Comparison between linear and daily undulating periodized resistance training to increase strength. Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 23(9), 2437–2442. https://doi.org/10.1519/JSC.0b013e3181c03548

[28] Rahimi, E., Zadeh, Y. M., & Boostani, M. A. (2013). The effect of resistance training on thyroid hormones. Pelagia Research Library European Journal of Experimental Biology, 3(2), 443–447. www.pelagiaresearchlibrary.com

[29] Sundus, H., Khan, S. A., Zaidi, S., Chhabra, C., Ahmad, I., & Khan, H. (2025). Effect of long-term exercise-based interventions on thyroid function in hypothyroidism: A systematic review and meta-analysis of randomized controlled trials. Complementary Therapies in Medicine, 92(January), 103196. https://doi.org/10.1016/j.ctim.2025.103196

[30] Tozetto, W. R., Leonel, L. dos S., Turnes, T., & Del Duca, G. F. (2022). Effects of linear periodization of combined training on quality of life of adults with obesity: a blind randomized controlled trial. Scientific Reports, 12(1), 1–15. https://doi.org/10.1038/s41598-022-06461-8

[31] Vargas-Molina, S., García-Sillero, M., Daniel Jiménez-García, J., Carbone, L., Bonilla, D. A., Petro, J. L., Romance, R., & Benítez-Porres, J. (2025). Effects of a Nonlinear Program on Different Health Parameters in the Elderly. Sports Health, 17(2), 419–426. https://doi.org/10.1177/19417381241253267

[32] Werneck, F. Z., Coelho, E. F., Almas, S. P., Garcia, M. M. D. N., Bonfante, H. L. M., de Lima, J. R. P., Vigário, P. D. S., Mainenti, M. R. M., Teixeira, P. de F. dos S., & Vaisman, M. (2018). Exercise training improves quality of life in women with subclinical hypothyroidism: A randomized clinical trial. Archives of Endocrinology and Metabolism , 62(5), 530–536. https://doi.org/10.20945/2359-3997000000073

[33] Wilson, S. A. (2011). Hypothyroidea. Encyclopedia of Clinical Neuropsychology, 1290–1290. https://doi.org/10.1007/978-0-387-79948-3_3711

[34] Yadav, P., & Verma, R. (2022). Impact of Aerobic and Resistance Training on Thyroid- Stimulating Hormone in Hypothyroidism. 13(6), 1751–1762. https://doi.org/10.47750/pnr.2022.13.S06.231

[35] Zenebe, K., Legesse, K., Alemu, K. A., Mondal, S., & Abdulkader, M. (2020). Impacts of resistance exercises intervention on thyroid hormone and thyroid stimulating hormone serum concentration level in school children with intellectual disabilities. 6(2), 68–75. https://doi.org/10.31459/turkjkin.730643

[36] Zhao, Q., Zhang, T., Cheng, Y., Ma, Y., Xu, Y., Yang, J., & Zhou, Y. (2021). Triglyceride-Glucose Index as a Surrogate Marker of Insulin Resistance for Predicting Cardiovascular Outcomes in Nondiabetic Patients with Non-ST-Segment Elevation Acute Coronary Syndrome Undergoing Percutaneous Coronary Intervention. 1175–1194.