Impact of apnoea training on metabolic and cardiovascular health in sedentary adults

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ABSTRACT

Apnoea, an underwater practice that involves the voluntary suspension of breathing, has gained popularity among high-performance athletes and individuals seeking to improve their physical health. We sought to evaluate the effects of a 16-week apnoea training program on body composition and metabolic and cardiovascular biomarkers in university teachers. A pretest-post-test quasi-experimental design was used in a group of nine university teachers. The program included five progressive stages of apnoea training. Measurements were taken before and after the intervention, following the WHO STEPS Surveillance Protocol, evaluating anthropometric, cardiovascular, and metabolic variables. Data were analysed using normality and t-student tests for paired samples. It was found that, although there were no significant changes in participants' body composition, substantial reductions in fasting glucose, total cholesterol, NHDL-C, and haematocrit levels were observed after the intervention. These results suggest improvements in glycaemic regulation and lipid profile, contributing to a reduction in cardiovascular risk. These findings underscore the potential of apnoea as an intervention to improve metabolic and cardiovascular health in sedentary populations.
Keywords: Sport medicine, Apnoea, Cardiovascular risk, Metabolic health, Body composition, Physical training.

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INTRODUCTION

Apnoea is a sport that consists of voluntary suspension of breathing in the water while traveling long distances or descending into it, it is an extreme sport that has begun to gain strength among non-athletes to improve their physical condition or state of health. Despite its growing popularity, few studies evaluate its impact on metabolic and cardiovascular health in untrained populations such as university teachers, who according to other authors, may constitute a group susceptible to developing chronic diseases associated with physical inactivity, sedentary lifestyles, and other lifestyle-related risk factors (Peinado et al., 2017) such as cardiovascular risk (Rojas-Padilla et al. 2022).

Apnoea training induces significant physiological adaptations such as improved oxygen storage capacity and its optimization in muscles (Lamaitre et al., 2015), increased ability to tolerate hypoxia along with better heart rate control (Perini et al.2008), and modulation of the sympathetic nervous system response, contributing to the reduction of resting heart rate (Lugo et al.,2023). These cardiovascular and metabolic changes contribute to maintaining an adequate state of health.

In terms of metabolism, apnoea has been linked to improvements in blood glucose regulation, a crucial aspect for the prevention and control of metabolic diseases such as type 2 diabetes mellitus, since exposure to hypoxia during apnoea can activate metabolic pathways that improve insulin sensitivity and favour glucose utilization by muscles (Andersson & Schagatay, 2008). This suggests that apnoea could be used as a tool not only to improve athletic performance but also to control metabolic risk factors and improve health status in susceptible populations.

On the other hand, the impact of apnoea on the lipid profile has been the subject of research, with results indicating a possible improvement in cholesterol and triglyceride levels, as well as a reduction in the risk of atherosclerosis (Svedenhag & Linnarsson, 1986) because apnoea training can reduce low-density lipoprotein (LDL) levels and increase high-density lipoprotein (HDL), which is a positive marker for cardiovascular health. Complementary to the above, it is necessary to identify additional parameters with utility as predictors of cardiovascular disease, among them: plasma atherogenic index (AI) (Tamarit, 2022), atherogenic coefficient (AC), remnant cholesterol (RC), non-high-density cholesterol (NHDL-C) and atherogenic index of plasma (AIP), which are better predictors of cardiovascular risk (Cao et al., 2020; Varbo et al., 2013).

Most studies on the effects of apnoea have focused on sports populations or highly trained individuals, leaving a gap in understanding how this type of training might impact less physically active populations, such as university faculty. Thus, it is crucial to investigate how they could benefit from apnoea training, given the potential impact on the prevention of metabolic and cardiovascular diseases, in addition to conferring benefits on body composition (Rezaeipour et al., 2021) representing a significant and positive contribution to global public health (Peinado et al., 2017).

The present study aimed to identify the effects of a 16-week apnoea training program on fasting glucose, body composition, anthropometric measures, cardiovascular variables and metabolic biomarkers in a population of university teachers.

METHODS

Study design

This study used a pretest-post-test quasi-experimental design to evaluate the effects of an apnoea training program on body composition, anthropometric variables, and metabolic and cardiovascular biomarkers in a group of university teachers. The study design allowed the observation of changes in the variables of interest before and after the intervention.

Context

The study was conducted in Santiago de Cali, Colombia, which is 995 meters above sea level, at a university institution from August to November 2023. The apnoea training program took place in a semi-Olympic pool and was conducted by a PADI Diving Instructor.

Participants

The sample consisted of nine female university teachers with an average age of 39 years, an average weight of 73.4 kg, and an average height of 1.69 meters. The participants were selected considering inclusion and exclusion criteria.

Inclusion criteria

Women of legal age, linked to the apnoea training program of the university institution; with minimum attendance of 90% to the training sessions and who had submitted signed informed consent and the medical examination report.

Exclusion criteria

Participating in sports training other than apnoea, having a diagnosis of cardiovascular or metabolic diseases, presenting morpho-functional alterations that would limit the training process, missing training sessions or voluntarily withdrawing from the study at any program stage.

Sample size

The sample size was limited to nine participants. Although this number is small, it is adequate to explore initial trends and the feasibility of the apnoea training program in this specific population. Future research with larger sample sizes will be necessary to validate the findings of this study.

Table 1. Operational definition of some variables that make up the physical condition associated with health.

Categories	Variables	Operational definition	Reference values	Measurement Units	Instruments
Body composition	Abdominal circumference	Anthropometric measurement to determine the level of cardiovascular risk in an individual.	≥ 80 M y ≥ 90 H	cm	Lufkin metal tape measure
	% Body fat % Muscular Mass	Bioelectrical impedance technique used to measure body composition based on the body's ability to conduct an electrical current.	> 33,9 > 24,1	%	Electronic scale (OMRON)
	Body Mass Index	Body Mass Index is an index of the relationship between weight and height, generally used to classify underweight, overweight and obesity in adults.	≥ 25	kg/m^2	
Cardiovascular	Systolic blood pressure	When the heart is at rest between beats resulting in a decrease in blood pressure	≥ 130	mmHg	Sphygmomanometer consisting of sphygmomanometer, cuff and stethoscope.
	Diastolic blood pressure	Force exerted by the blood against the walls of the arteries. Each time the heart pumps blood into the arteries	≥ 85		
	Resting Heart Rate	Resting heart rate		Lat/min	
	Peripheral oxygen saturation	Amount of oxygen (in percent) bound to haemoglobin in red blood cells	98%	%	Pulse oximeter
Blood biochemistry	Total cholesterol cHDL cLDL Glucose	Metabolite levels measured in blood by dry chemical methods.	≥ 190 40 - 50 ≥ 130 ≥ 100	mg/dL	vitros 5,1 FS
	Incremental Remaining Cholesterol I Incremental Remaining Cholesterol II Plasma atherogenic index Atherogenic coefficient	Factors that are considered for cardiovascular disease according to serum lipoprotein levels	> 4.5 > 3.0 > 0,24 > 2.8	-	Formulas
	Haematocrit	Ratio of red blood cells	40 - 45 %	%	vitros 5,1 FS

Variables

Anthropometric variables: weight, height, abdominal perimeter, and body mass index (BMI).

Body composition variables: percentage of body fat, percentage of muscle mass, and visceral fat index.

Cardiovascular variables: systolic blood pressure (SBP) and diastolic blood pressure (DBP), resting heart rate (RHR), resting peripheral oxygen saturation (SpO_2), total cholesterol (TC), high-density lipoproteins (HDL), low-density lipoproteins (LDL), atherogenic coefficient (AC), plasma atherogenic index (AIP), remnant cholesterol (CRI), non-HDL cholesterol (NHDL-C) and haematocrit.

Metabolic variable: Fasting glucose.

Aerobic fitness variable: swimming meters using the Cooper 12-minute test.

Data source

Data were collected at two key moments: baseline measurements (pre-intervention) and final measurements (post-intervention). Measurements of cardiovascular, metabolic, anthropometric, and body composition variables were performed following the WHO STEPS Surveillance Protocol, which guarantees the standardization of procedures, and the reliability of the data obtained. Anthropometric variables were evaluated by an ISAK level II certified anthropometrist; muscle mass and body fat measurements were measured with bioimpedance, cardiovascular data, and medical examination were performed at the physical fitness centre of the University Institution and laboratory analysis at a clinical laboratory authorized by the municipal health secretariat (authorization code #7600107211).

Bias

The study implemented several strategies to minimize bias, including standardization of measurement techniques and constant monitoring of training sessions. However, the lack of a control group is a limitation that may introduce bias in the interpretation of the effects of the intervention. In addition, the small sample size may limit the generalizability of the results.

Training

The training was developed in five stages, each designed to progressively increase the intensity and complexity of apnoea training (Table 2).

Table 2. Training description.

Week	Activity	Exercise	Distance (meters)
Week 1 to 3 100% Surface	Warm up	Freestyle swimming	200
	Swimming	Freestyle swimming-breaststroke	600
	Cool-down	Freestyle swimming	200
	Total distance stage		**1000**
Week 4 to 5 80% Surface 20% apnoea	Warm up	Freestyle swimming	400
	Swimming with mask and snorkel		200
	Basic apnoea equipment		200
	Dynamic apnoea 12.5 m	Free kick / dolphin	100
	Dynamic apnoea 20 m		100
	Surface recovery between each dive	Static and dynamic	100
	Cool-down	Freestyle swimming	400
	Total distance stage		**1500**
Week 6 to 8 60% Surface 40% apnoea	Warm up	Freestyle swimming	400
	Basic freediving equipment		300
	Dynamic apnoea - 25 mt	Free kick / dolphin	100
	Dynamic apnoea - Diagonal pool 30 mt.		240
	Dynamic apnoea - 25 mt		100
	Surface recovery between each dive	Static and dynamic	260
	Cool-down	Freestyle swimming	400
	Total distance stage		**1800**

Week 9 to 13 60% Surface 40% apnoea	Warm up	Freestyle swimming	400
	Basic apnoea equipment		200
	Surface hypercapnic apnoea	Crawl. Progressive stroke cycle	300
	Static apnoea. Progressive times	Pool edge-.50 until 120 seg	0
	Hypoxic dynamic apnoea - 20 mt		100
	Dynamic apnoea - 30 mt	Free kick / dolphin	120
	Dynamic apnoea - 40 mt		120
	Surface recovery between each dive	Static and dynamic	160
	Cool-down	Freestyle swimming	200
	Total distance stage		**1600**
Week 14 to 16 50% Surface 50% apnoea	Warm up	Freestyle swimming	400
	Basic freediving equipment		200
	Dynamic apnoea - 20 mt		100
	Dynamic apnoea - 30 mt	Free kick / dolphin	150
	Dynamic apnoea - 40 mt		200
	Static apnoea. Progressive times	Pool edge- 60 until 120 seconds	0
	Dynamic apnoea - 50 mt	Free kick / dolphin	200
	Dynamic apnoea - 75 mt		150
	Surface recovery between each dive	1 minute static	0
	Cool-down	freestyle swimming	200
	Total distance stage		**1600**

*Note. *Dynamic* apnoea *were performed at a depth of approximately 5.5 meters. After each dynamic apnoea, a static or dynamic pause, or a mixture of both, was performed as a strategy to recover oxygenation and ventilation.*

Data analysis
Data analysis was performed using the R Studio program. Univariate analyses were performed to describe the quantitative variables, calculating the mean and standard deviation. The Shapiro-Wilk test was used to verify compliance with the normality criterion for the variables. Subsequently, a test of equality of variances was performed, followed by the t-student test for paired samples, to compare means before and after the intervention. In addition, 95% confidence intervals were calculated for the mean differences, providing an estimate of the range of possible values for the observed differences.

Statement of ethical issues
This study was done considering the Helsinki Declaration and the Resolution 3480 of Health and Social Protection Minister in Colombia. This research was approved by the code 17.133 of the National School of Sports ethics committee in May 2022. Participation was voluntary and accepted by signing an informed consent. The confidentiality was ensuring through file encryption and use of numerical codes.

RESULTS

The participants in this research were nine female university teachers with an average age of 39 years, who did not perform any type of physical exercise other than apnoea, and who lived in Cali, Colombia.

Several variables related to body composition and anthropometry were evaluated, including abdominal perimeter, weight, body fat percentage, muscle mass percentage, visceral fat index, and body mass index (BMI). All these variables, except weight, showed a normal distribution and homogeneity of variances. However, when applying the t-Student test for paired samples, none of these variables showed significant differences between pre-and post-intervention measurements (Table 3).

Table 4 shows the pre-and post-intervention results of the variables evaluated in plasma; among these, only Non-High-Density Lipoprotein Cholesterol (NHDL-C) showed a significant decrease after the intervention (*p*-value = .036), with a reduction in the mean from 160.4 to 146.8 mg/dL. The other atherogenic indices, such as HR-I, HR-II, AIP, and AC, showed no statistically significant changes, indicating that these parameters remained stable throughout the study. Similarly, this table shows the pre-and post-intervention results of the hemodynamic variables and the physical swimming test; within these findings, only diastolic blood pressure presented a significant difference (*p*-value = .003462), reducing from 72.78 mmHg to 64.17 mmHg after the intervention. As for the physical swimming test, although an improvement was observed in the distance swum (from 459.2 m to 491.1 m), this difference did not reach statistical significance (*p*-value = .1028).

Table 3. Body composition variables.

Variables	Media	Standard Deviation	T test (*p*-value)
Abdominal Perimeter (I)	86.22	9.72	.2002
Abdominal Perimeter (II)	85.2	9.86	
Weight kg(I)	73.36	11.7	.7085
Weight kg (II)	73.03	11.56	
% body fat(I)	29.7	7.35	.5499
% body fat (II)	29.47	7.77	
% muscular mass (I)	32.31	5.78	.4379
% muscular mass (II)	32.51	5.99	
Visceral fat index (I)	8.89	3.69	.6811
Visceral fat index (II)	8.78	3.63	
Body mass index (I)	26.19	3.59	.668
Body mass index (II)	26.06	3.34	

*Note. *(I)pre-intervention evaluation; (II)post-intervention evaluation.*

Table 4. Hemodynamic, plasma, and aerobic fitness variables.

Variables	Media	Standard Deviation	T test (*p*-value)
CRI-I (I)	4.644	1.649	.678
CRI – I (II)	4.525	2.09	
CRI-II (I)	2.999	1.143	.682
CRI-II (II)	2.907	1.54	
AIP (I)	0.1551	0.2512	.443
AIP (II)	0.1059	0.312	
AC (I)	3.644	1.649	.678
AC (II)	3.525	2.09	
(NHDL-C (I)	160.4	33.03	.036
(NHDL-C (II)	146.8	44.41	
SpO_2(I)	96	1.06	.8487
SpO_2 (II)	95.94	1.1	
FCR(I)	64.56	10.31	.7727
FCR (II)	63.89	8.6	
SBP(I)	112.83	12.46	.9462
SBP (II)	112.61	4.82	
DBP (I)	72.78	7.16	.0034
DBP (II)	64.17	7.49	
Swimming metres (I)	459.2	157.4	.1028
Swimming metres (II)	491.1	138.3	

*Note. CRI-I: Incremental Remaining Cholesterol; CRI-II: Incremental Remaining Cholesterol; AIP: Atherogenic Index of Plasma; AC: Atherogenic Coefficient; NHDL-C: Non-High Density Lipoprotein Cholesterol; SpO_2: Oxygen saturation percentage; RHR: Resting heart rate; SBP: Systolic blood pressure; DBP: Diastolic blood pressure. *(I)pre-intervention evaluation; (II)post-intervention evaluation.*

Table 5 shows the pre- and post-intervention results for metabolic and haematocrit variables. The analyses revealed significant changes in some of these variables. Fasting glucose showed a *p*-value = .0009775, with a mean difference of 5.33 mg/dL, indicating a decrease in glucose levels after the intervention. Total cholesterol also decreased significantly (*p*-value = .02112), with a reduction in the mean from 210.22 mg/dL to 196.7 mg/dL. Finally, haematocrit showed a significant reduction (*p*-value = .001926).

Table 5. Metabolic variables and haematocrit.

Variables	Media	Standard Deviation	T test (*p*-value)	I.C Medias differences
Glucose (I)	92.67	7.23	.0009775	
Glucose (II)	87.33	5.32		2.90; 7.76
Total cholesterol total (I)	210.22	23.79	.02112	
Total cholesterol (II)	196.7	35.4		2.63; 24.48
Haematocrit (I)	43.8	4.52	.001926	
Haematocrit (II)	46.23	3.83		1.194; 3.672

*Note. *(I)pre-intervention evaluation; (II)post-intervention evaluation.*

DISCUSSION

This study sought to evaluate the effects of a 16-week apnoea training program on body composition and metabolic and cardiovascular biomarkers in university teachers, considering the importance of physical exercise on health parameters (Soto & Vargas, 2024).

The first finding was related to anthropometric and body composition variables, which showed no significant differences after apnoea training. This result could be attributed to the specific nature of apnoea training, which may not exert a significant impact on body composition over a relatively short period of 16 weeks. This finding is consistent with previous studies that have examined the effects of apnoea training on body composition in athletes without representative changes (Herrera et al., 2020; Lemaitre et al., 2015), although it differs from other studies in which training for up to 8 weeks has impacted body composition in obese women (Jaramillo & Giraldo, 2023), in women since performing exercise in situations of intermittent hypoxia, has worked as an effective strategy to decrease body weight and improve fitness (Urdampilleta et al., 2021).

However, when considering biochemical variables such as glucose, significant differences were observed before and after the training program. The changes in these biomarkers suggest that apnoea training may have metabolic and cardiovascular effects on the participants. The significant decrease in post-training glucose levels could indicate an improvement in glycaemic regulation, which is consistent with the positive effects of physical exercise on glucose metabolism (Peinado et al., 2017), similarly, other findings have evidenced positive effects on glycaemic control and HbA1c levels, including increased aerobic fitness, muscle strength, as well as the prevention of pathologies related to and derived from diabetes mellitus (Hidalgo et al., 2024).

As for total cholesterol, its post-training decrease could be related to physiological adaptations to regular exercise, such as increased lipolytic activity and muscle cholesterol synthesis (Sáez-Roca et al., 2019) emphasizing the impact of physical exercise as a crucial intervention to prevent or delay cardiovascular diseases (Insignares et al., 2024).

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On the other hand, the increase in haematocrit levels after training could be attributable to changes in blood viscosity and oxygen-carrying capacity due to repeated exposure to hypoxia during apnoea (Bakovic et al., 2003), consistent with other studies in which a significant increase in haematocrit has been observed with 4-month exercise programs (Pérez et al., 2003), 2003) suggesting that aerobic training improves oxygen delivery to body tissues and The haematocrit level also improves because of tailored exercises that measure the body's proportion of red blood cells (Ribeiro, 2024) and the other effect of apnoea exercises is that they increase the strength of smooth muscles in the respiratory system (Stevens, 2021).

In addition, significant changes in non-high-density lipoprotein (NHDL-C) were observed, which were associated with a decrease in cardiovascular risk. These findings are consistent with previous studies that have demonstrated the beneficial effects of aerobic exercise on cardiovascular health, including reduced NHDL-C (Sato & Fisher, 2018). It is relevant to consider that no changes in blood pressure were seen quite possibly as found in other studies because the dietary diet factor was not controlled for (Ramirez et al., 2024; Salazar et al., 2024) although other studies have found that 16-week exercise programs have generated changes in diastolic and systolic blood pressure in women (Gutierrez et al., 2020).

Heart rate and oxygen saturation did not show significant differences in this study as in the study by Bezruk et al. (2024) in which heart rate and SpO_2 decreased after eight weeks of diving training in athletes and sedentary participants. In the same way, they are considered predictors of peak performance in freedivers (Lee et al. 2024).

Importantly, this study is one of the few to investigate the effects of apnoea training in a population of university teachers, which highlights the importance of continuing to explore this area of research to better understand the benefits and possible risks of this type of intervention in different age groups and health conditions.

CONCLUSIONS

The study demonstrated that apnoea training can have a positive impact on the metabolic and cardiovascular health of university teachers, evidenced by significant decreases in fasting glucose, total cholesterol, and NHDL-C levels, as well as an increase in haematocrit. These changes suggest improvements in glycaemic regulation and lipid profile, which could contribute to reducing the risk of cardiovascular diseases in generally sedentary populations.

Despite the positive effects on metabolic and cardiovascular biomarkers, apnoea training did not induce significant changes in the participants' body composition, including variables such as abdominal perimeter, body fat percentage, and muscle mass. This may indicate that apnoea training, as implemented in this study, may not be sufficient to significantly alter body composition over 16 weeks.

The results highlight the need for further studies with a more robust design, including a control group and a larger sample, to confirm the effects of apnoea training in different populations. Furthermore, it is suggested to extend the duration of the training programs to explore possible long-term changes in body composition, to better understand the physiological mechanisms involved in the response to apnoea training.

Limitations

Despite these promising results, it is important to recognize the limitations of this study, including the lack of a control group and the relatively small sample size. In addition, the duration of the training program may not have been sufficient to induce significant changes in body composition. Further studies with more robust designs and longer duration are needed to confirm these findings and to better understand the effects of apnoea training on health in the group of university teachers.

AUTHOR CONTRIBUTIONS

Conceptualization and methodology: J.G-CH., O.H.J-T., A.C-O; formal analysis, investigation resources, writing—original draft preparation, review, and editing, J.G-CH., O.H.J-T.; A.F-D., A.C-O., and I.C.R.-P. All authors have read and agreed to the published version of the manuscript in JHSE.

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