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Review

Basal metabolism, body composition and physical activity with central obesity in adults: a systematic review

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Abstract: This article aims to systematically review the available evidence concerning the relationship between basal metabolism (BM), body composition (BC), and physical activity (PA) with central obesity. The search strategy was carried out using Web of Science, PubMed, Google Scholar, and SciELO following the PRISMA guidelines. The STROBE checklist and the Jadad scale for quality assessment were also used. A total of 1382 studies were initially identified being 25 publications eligible for systematic data extraction. Individual studies showed that adults with waist circumference (WC) above 88 cm in women and above 102 in men had a higher risk of metabolic alterations related to high absolute energy expenditure and less maximum oxygen consumption (VO2 max). Participants with central obesity presented a high percentage of body fat (BF%) between 30.6% and 41.6%. Most of the PA intervention studies reported reductions in WC between 1.3 and 5.8 cm. In conclusion, there is a direct relationship between the components of BM with central obesity and a direct association between central obesity and BF%. PA is a protective factor that needs to be promoted to reduce WC and control central obesity as a public health problem. PROSPERO ID registration: CRD42021232917.

Keywords: central obesity; waist circumference; physical activity; basal metabolic rate; body composition

1. Introduction

Obesity is a chronic condition that has become a serious public health problem. The World Health Organization (WHO) has quoted this disease as "the epidemic of the 21st century", due to its exponential increase since the beginning of the eighties [1]. The WHO defines obesity as an abnormal or excessive accumulation of fat, which can damage health [2]. In recent years, an increase in obesity has been observed, commonly expressed in an increase in waist circumference (WC) (central obesity) [3]. This accumulation of fat at the level of visceral adipose tissue (VAT) has been linked to metabolic abnormalities contributing to the development of non-communicable diseases (NCDs) such as type 2 diabetes, cardiovascular diseases, hypertension, and various types of cancer [4]. Currently, obesity affects 13.1% of adults globally [5].

The basal metabolic rate (BMR) or basal metabolism (MB) is defined as the minimum amount of energy that the body requires to be alive [6]. It can be determined through predictive equations or indirect calorimetry, the latter being considered the most accurate method [6]. Energy expenditure can be increased because of the energy utilized when practicing physical activity (PA), this being the most fluctuating component of energy expenditure [7]. It has been reported that body size, body composition, age, gender, and other factors such as diet, consumption of energy beverages, and smoking are also BMR modifiers [7–9].

The relationship between muscle mass (MM) and oxygen consumption (VO2) has been extensively studied [7,10–12]; especially, the percentage of body fat (BF%) and MM, which are the tissues most modulated by PA and dietary habits [13]. Although the relationship between metabolic expenditure, physical activity, and abdominal obesity has been described before, it will be important to evaluate it in light of the new findings published in the last decade. The exponential increase in the prevalence of obesity in recent decades together with political and social concern due to the associated impact has influenced the interest of countries in improving the quality of life of their populations and investing in public health interventions to reduce this disease. The objective of the present work was to systematically review the available evidence concerning the relationship between basal metabolism (BM), body composition (BC), and physical activity (PA) with central obesity.

2. Materials and Methods

2.1. Eligibility and identification of studies

The studies considered to be eligible for this review were limited to observational and experimental, controlled, and randomized study designs that investigated the relationships between basal metabolism (BM), body composition (BC), and physical activity (PA) with central obesity in adults of different age groups, ethnicities and genders. The search and selection of the studies were carried out between April and November 2020.

The selection included the screening of titles and abstracts of each article. Studies that met the following criteria were selected: research articles published between 2010 and 2020, with the participation of adult participants of both genders between 18-65 years and with central obesity. We searched for articles using the PubMed, Google Scholar, and SciELO databases by selecting studies published in English between 2010 and 2020.

A combination of the following keywords was used: “basal metabolic rate”, “physical activity”, “body composition”, “abdominal obesity”, “central obesity” and “visceral obesity”. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed. The protocol of this review is available in The International Prospective Register of Systematic Reviews (PROSPERO) as CRD42021232917.

2.2. Data extraction

A digital form was developed using Google Tools to extract the relevant data from each study such as title, year, journal, authors, country, objective, sample, and study design. In addition, information on the interventions, a summary of results, and conclusions were extracted. During data extraction, attention was paid to the possible inclusion of duplicate items. The articles were screened and the information was extracted only for those studies with confirmed eligibility.

2.3. Quality assessment

The quality of the observational studies (cohort, case-control, and cross-sectional study designs) was evaluated through the Strengthening The Reporting of Observational Studies in Epidemiology (STROBE) checklist, which comprises 22 points related to the structure and content of observational studies. The final scores were converted to percent-

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ages [14]. To classify studies according to their methodological quality, three classifications were established considering the 22 points (100%): high (100% -80%), moderate (79% -40%), or low quality (39% or less).

In addition, the Jadad scale also known as the Oxford quality scoring system was used to evaluate the quality of experimental studies. This is a scale composed of 5 questions comprising aspects related to biases, defined by: randomization techniques, masking, and description of losses to follow-up. To classify studies based on their results, those with 5 points were considered "rigorous" and those with less than 3 points of "poor quality", taking into account that each question represented 1 point [15].

3. Results

3.1. Systematic search

1382 articles were initially identified, being 1107 excluded because they were not relevant or duplicated. The remaining 275 articles were screened, excluding 26 duplicates. 25 articles were finally included in the exhaustive review. The rest did not provide an OR with a 95% CI or had low methodological quality. The specific reasons for exclusion and the selection process are summarized in **Figure 1**.

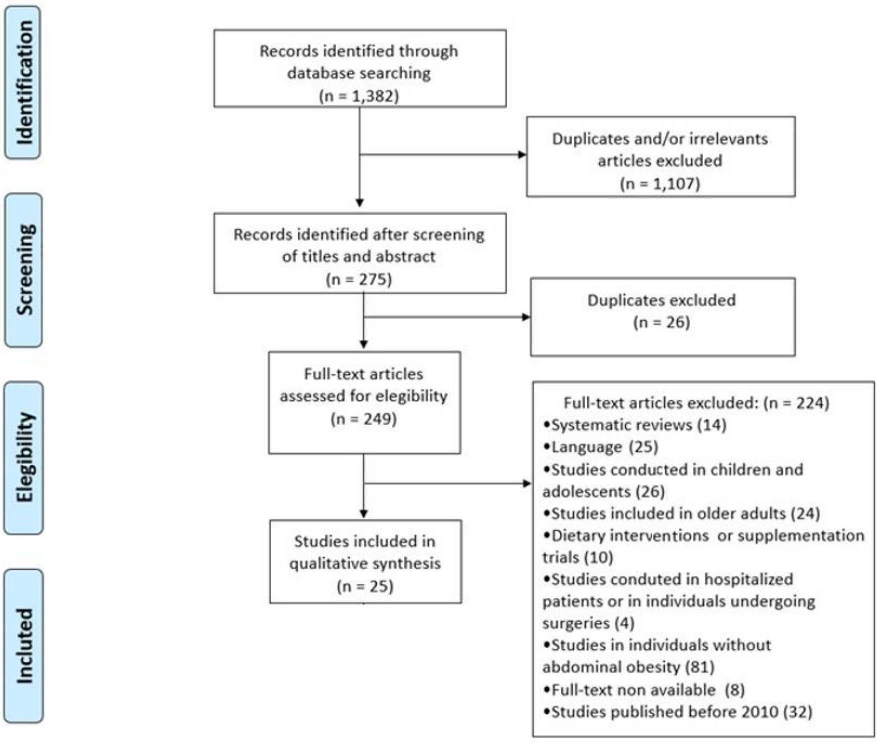

Figure 1. PRISMA flow chart diagram.

3.2. Description of the studies

A summary of the main findings reported in the selected studies is summarized in **Table 1**. Most of the articles had a cross-sectional (n= 11) and experimental (n= 10) study design. Three studies were case-control, and one was a cohort study design. These studies recruited a total of 4073 participants and the majority included individuals of both genders (n= 18). However, six studies were limited to women only and one to men only. Ten of the selected studies included participants with comorbidities associated with central obesity, including hyperglycemia (n= 1), type 1 diabetes mellitus (n= 1), type 2 diabetes mellitus (n= 2), vitamin D deficiency (n= 2), coronary artery disease (n = 1) and metabolic syndrome (n= 2).

3.3. Quality assessment

The methodological quality of the observational studies evaluated through the STROBE checklist ranged between moderate and high quality (58.4% to 83.2%). Most of the studies presented problems in the measures to face possible biases, estimation of the sample sizes, control of independent variables, treatment of missing data, description of participant losses, and specification of study funding. On the other hand, in the experimental studies evaluated through the JADAD scale, the majority presented a low methodological quality with an average of 3 points, presenting problems mainly in the blinding method. Most of the studies had issues in the measures to face biases, control of independent variables, treatment of missing data, and description of the loss of participants.

3.4. Basal metabolism studies

Two studies evaluated the relationship between central obesity and BM. One of these studies found an inverse relationship between central obesity and BM determined by maximal oxygen consumption (VO2 max) [16] while the other indicated a direct relationship between central obesity and BM [17]. The second study divided the sample into two groups: group 1 and group 2. The women in group 1 presented a BM in an average of 1488.6 Kcal and a WC of 96.8 cm, while the women in group 2 showed a BMR of 1194.7 Kcal and a WC of 73.8 cm. A greater risk of metabolic conditions was reported in group 1 related to higher absolute energy expenditure and a WC above 88 cm [17]. To determine VO2 max in individuals with central obesity, another study divided participants into three groups according to the amount of prescribed PA and reported a reduction in WC in all groups compared to the control group. Regarding VO2 max, there were no significant differences between the groups according to the amount and intensity of PA [16].

Study (country)	Study design	General characteristics	Intervention	Metabolic expenditure	Body composition	Physical activity	Quality score
Jyothi et al. 2010 (India)	Case-control	n= 340 obese and non-obese, 18-60 y. 100% women.	-First phase: determine the prevalence of central obesity. -The second phase: compare the risk of obesity between obese and non-obese.			Significant association between PA and central obesity (OR 0.417, 95% CI 0.180-0.968, p= 0.031)	* 47.1%
Karamzad et al. 2019 (Iran)	Case-control	n= 164 adults with central obesity, 18-60 y. 50% women.	-Application of IPAQ to classify into low, moderate, and high-PA. -Evaluation of metabolic syndrome according to Iranian guidelines. -Evaluation of biochemical and anthropometric parameters.			No significance was found between PA levels and the incidence of metabolic syndrome (moderate PA [OR 0.69, 95% CI 0.24-1.97, p>0.05]; high PA [OR 1.25, 95% CI 0.44-3.55, p >0.05])	* 69%
Martínez et al. 2011 (Spain)	Cross-sectional	n= 49, 54.8 ± 4.6 y. 53% women.	-Anthropometric and dietary assessment -Estimation of BMR by Harris-Benedict and FAO/WHO calculation.			39.1% of men and 26.9% of women had central obesity. FA was between light and very light (FA men 1.45 and FA women 1.40)	* 22%
Rahmania et al. 2014 (Iran)	Cross-sectional	n= 161 adults with or without coronary artery disease, 60.5 ± 18.8 y. 48% women.	-Underwent coronary angiography for stable angina. -Bioimpedance analysis was performed to measure adipose tissues and MM.		No significant difference in BMI and weight between groups. The mean levels of WC, waist-to-hip ratio, and MG were significantly		* 47.9%

Study (country)	Study design	General characteristics	Intervention	Metabolic expenditure	Body composition	Physical activity	Quality score
					higher in the group with coronary disease.		
Lopes et al. 2010 (Brazil)	Cross-sectional	n= 40 overweight (Group 1= 36.6 ± 7.7 y) and eutrophic (Group 2= 35 ± 7.5 y), 100% women.	-Anthropometric, dietary, and body composition evaluations were carried out through bioimpedance. -PA was evaluated through an accelerometer and energy metabolism through indirect calorimetry.	Women in G1 had a BMR of 1488.6 Kcal and a WC of 96.8 cm, while the women in G2 had a BMR of 1194.7 kcal and a WC of 73.8 cm.		G1 presented a higher WC ($p<0.05$) compared to G2. 38.5% and 50% of women in G1 and G2 were sedentary. Both groups were classified as sedentary.	* 28.2%
Rocha et al. 2017 (Brazil)	Cross-sectional	n= 106, 18-60 y. 76.4% women.	They were divided into three groups vitamin D deficiency, insufficiency, and sufficiency. Anthropometric and body composition evaluations were done with bioimpedance and biochemical and clinical evaluations.		The vitamin D deficient, insufficient and sufficient groups had 41%, 36%, and 32% BF, respectively.	High WC was observed in those with vitamin D deficiency. The prevalence of a sedentary lifestyle was higher in vitamin D-sufficient individuals with central obesity (36 ± 5) and lower in those with vitamin D deficiency (18 ± 3).	* 58.6%
Momesso et al. 2011 (Brazil)	Case-control	n= 45 adults with DM type 1 and MS or DM type 1, 36 ± 9 y. 100% women.	Body composition and insulin resistance were determined by dual-energy X-ray absorptiometry and eGDR, respectively.		Total body fat and peripheral fat were similar between groups. Central fat was negatively correlated with eGDR.		* 43.2%

Study (country)	Study design	General characteristics	Intervention	Metabolic expenditure	Body composition	Physical activity	Quality score
Álvarez et al. 2019 (Chile)	Experimental	n= 89 hyperglycemic inactive obese / overweight adults, 30-59 y. 100% women.	Randomly assigned to a CT group or a control group. (20 wks. follow-up)			WC decreased significantly (-4.0 cm p <0.001) in the CT group. The prevalence rate of non-response between intervention and control groups for WC was 7.1% and 92.9%, respectively.	† 3
Cruz et al. 2018 (Mexico)	Cross-sectional	n= 50, 19-25 y. 56% women.	Completed a questionnaire to evaluate food intake, and biochemical and body composition parameters were also collected.		Regarding BF%, a high occurrence of overweight (22%) and obesity (38%) was found. Also, visceral fat increased as WC increased.		* 62.2%
Garcia et al. 2020 (Spain)	Experimental	n= 41, 28-58 y. 83.3% women.	Assigned to an intervention group of two weekly sessions of Pilates or a control group.			Intergroup analysis showed significant differences for each of the variables, including WC pre and post-intervention.	† 0
Share et al. 2015 (Australia)	Experimental	n= 62, 18-30 y. 100% women.	Assigned to a PA lifestyle intervention group (2 sessions in progressive circuit and one unsupervised at home), nutrition education, and cognitive-behavioral therapy or a control group. (12 wks. follow-up)	The intervention group had positive results in terms of changes in VO2 max, which increased by 4.7 ml/kg-1min-1 or by		There were significant changes in the intervention group before and after WC (-5.8 cm, -6.4%, p <0.05). The control group also showed improvements in WC before and after (-5 cm, -6 cm) PA was higher after the intervention in the intervention	† 3

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Study (country)	Study design	General characteristics	Intervention	Metabolic expenditure	Body composition	Physical activity	Quality score
				15%. WC decreased by 5.8 cm or 6.4%.		group as opposed to the control group.	
Ross et al. 2015 (Canada)	Experimental	n= 300, 51.4 ± 8.1 y. 65.3% women.	Assigned to a control group or an intervention group with three different programs: - low amount and low-intensity exercise (LALI) -High amount and low-intensity exercise (HALI) -High amount and high-intensity exercise (HAHI) (24 wks. follow-up)			Reductions in WC were greater in the LALI (3.9 cm [95% CI, 5.6 to 2.3 cm]; p < 0.001), HALI (4.6 cm [CI, 6.2 to 3.0 cm]; p < 0.001), and HAHI (4.6 cm [CI, 6.3 to 2.9 cm]; p <0.001) groups than the control group but did not differ among the exercise groups (p > 0.43).	† 3
Sukala et al. 2013 (New Zealand)	Experimental	n= 18, 49 ± 5 y. 72.2% women.	Randomized to resistance training or aerobic training 3 times a week. (16 wks. follow-up)			No association between PA and central obesity.	† 3
Do Nascimento et al. 2015 (Brazil)	Cross-sectional	n= 73, 55.7 ± 11.2 y. 69.8% women.	The prevalence of PAD was assessed using ABI, quality of life was measured using a questionnaire, PA was measured using a modified Baecke questionnaire, and body composition using impedance		Body composition analysis detected an excess of BF, especially in women, but there was no difference between groups.	PA was not different between individuals with PAD and those with normal ABI.	* 80%
Mogre et al. 2012 (Ghana)	Cross-sectional	n= 186, 20-59 y. 35% women.	The dietary pattern was evaluated through food frequency questionnaires and PA was determined using WHO guidelines.			10% of adults performed PA at a high level and 30% at a moderate level, and 60% at a low level.	* 73.1%

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Study (country)	Study design	General characteristics	Intervention	Metabolic expenditure	Body composition	Physical activity	Quality score
Mogre et al. 2014 (Ghana)	Cross-sectional	n= 646, 23.1 ± 2.8 y. 31.1% women.	Anthropometric measurements were taken. The GPAQ questionnaire was applied to measure the level of PA		The prevalence of central obesity was 4.2%, being higher in women with 11.9%, compared to men at 0.7%.	The prevalence of central obesity decreased with PA. Women had a higher risk of central obesity than men. In general, 14.7% performed light PA, 48.8% moderate PA, 36.5% vigorous PA. Of the 27 students with central obesity, 22.2% performed light PA, 44.4% moderate PA, and 33.3% vigorous PA. However, the differences were not significant when stratifying central obesity by the level of PA.	* 81.5%
Gremeaux et al. 2012 (Canada)	Cohort	n= 62, overweight and obese adults, 53.3 ± 9.7 y. 35.5% women.	A program on nutritional counseling, optimized exercise in high-intensity intervals, and resistance training was performed 2-3 times a week. Anthropometric and cardiometabolic measurements were also taken. (9 mo. follow-up)			The prevalence of metabolic syndrome was reduced to 32.5% after finishing the program ($p< 0.05$).	* 73.5%
Martínez et al. 2017 (Colombia)	Cross-sectional	n= 236, 30-60 y. 100% men.	Anthropometric and biochemical body composition data were recorded. To define metabolic syndrome, the criteria of Adult Treatment Panel III		The global prevalence of metabolic syndrome was 20.7%. WC above 102 cm was found in		* 51%

Study (country)	Study design	General characteristics	Intervention	Metabolic expenditure	Body composition	Physical activity	Quality score
			were used. The components of metabolic syndrome were calculated and correlated with the body composition measurements.		11.8%. BMI and% BF correlated well with waist, blood pressure, fasting blood glucose, and triglycerides.		
Marbou et al. 2019 (Cameroon)	Cross-sectional	n= 604, 43.7 ± 17.2 y. 42.6% women.	Interviews and physical, clinical, and biochemical examinations were carried out. The definition of metabolic syndrome from the International Diabetes Federation was used.			Adults with metabolic syndrome were more likely to have high WC compared to normal adults. PA was not related to central obesity	* 89.2%
Shrivastava et al. 2017 (India)	Experimental	n= 267, overweight adults, 22-55 y. 14.2% women.	Overweight (BMI ≥ 23 kg/m2) subjects were recruited from four randomized worksites and two active interventions. The intensive intervention was given at the intervention worksite.			There was a decrease in WC in the intervention group (-1.55 cm). In the intervention group, more individuals switched from a sedentary lifestyle to a more active one, compared to the control group.	† 3
Cowan et al. (Canada)	Experimental	n= 300, 52.8 ± 7.6 y. 60% women.	Adults were divided into four groups: -Control -High amount and low-intensity exercise (HALI) -High amount and high intensity (HAHI)	Regarding VO2, there were no differences between the groups that received a low amount and low intensity of exercise and the		WC was reduced in all exercise groups compared with control ($p<0.008$) but did not differ between exercise groups ($p>0.008$). LALI (-5.1cm), HALI (-6.6cm) and HAHI (-6.2cm)	† 2

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Study (country)	Study design	General characteristics	Intervention	Metabolic expenditure	Body composition	Physical activity	Quality score
			-Low quantity and low intensity (LALI) Activities of daily living were measured with an accelerometer. (24 wks. follow-up)	group that received a low amount and high intensity.			
Stensvold D et al. 2010 (Norway)	Experimental	n= 43, 50.9 ± 10.4 y. 39.5% women.	Assigned to one of these four groups: -Control -Aerobic interval training (AIT) -Strength training (ST) -Combination of aerobic and strength (COM) Each workout was performed 3 times a week. (12 wks. follow-up)			WC was significantly reduced after AIT [95% CI: 2.5 to 0.04, p<0.05], COM (95% CI: 2.11 to 0.63, p<0.05), and ST (95% CI: 2.68 to 0.84, p<0.05), whereas the control group had an increase in WC (95% CI: 0.37–2.9, p= <0.05).	† 4
Cramer et al. 2016 (Australia)	Experimental	n= 60, 18-64 y. 100% women.	Randomized to a yoga intervention or a control group (12 wks. follow-up)			13 participants in the yoga group (32.5%) achieved a relevant decrease in WC of at least 5% (-3.7cm) compared to two participants in the control group (10%).	† 3
Skrypnik et al 2015 (Poland)	Experimental	n= 44, 18-65 y. 50% women.	Randomly assigned to Group A (perform endurance) or Group B (endurance strength training) 3 times a week for 60 min. (3 mo. follow-up)			Both groups resulted in a decrease in WC Group A (-5.26cm), Group B (-7.65cm) without significantly different values between groups (p>0.005).	† 2

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Study (country)	Study design	General characteristics	Intervention	Metabolic expenditure	Body composition	Physical activity	Quality score
Pantovic et al. (Serbia)	Cross-sectional	n= 87, 28-56 y. 60.9% women.	Were divided according to gender and anthropometric, bioimpedance, and biochemical parameters were evaluated. The results were compared according to gender and according to a month of evaluation. (2 mo. follow-up)		Most parameters measured by anthropometry and bioimpedance increased in adults with vitamin D deficiency, including BF% and WC%	%BF and WC increased in those adults with vitamin D deficiency (95% [CI]: -0.206, –0.025, p=0.012)	* 82.2%

Abbreviations: Y, years; Wks, weeks; Mo, months; PA, physical activity; IPAQ, International Physical Activity Questionnaire; BMR, basal metabolic rate; WC, waist circumference; BMI, body mass index; BF, body fat; MM, muscle mass; eGDR, estimated glucose deposition rate; CT, concurrent training; VO2, maximal O2 consumption; PAD, peripheral arterial disease; AAI, ankle-arm index; GPAQ, Global Physical Activity Questionnaire; VO2, peak oxygen uptake; and, BF%, body fat percentage.
* Quality score as a percentage for observational studies.
† Quality score as points for experimental studies.

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3.6. Studies on body composition

A study performed on workers reported that between 11.8% and 43.2% of them had a WC greater than 102 cm. They found the BF% increased concerning WC [18]. Three studies found that a high BF% increased cardiovascular risk [19–21]. Participants with and without coronary disease were studied reporting a directly proportional relationship between WC and BF, presenting higher BF% in the group with coronary disease (30.6%) compared to the group without coronary disease, which presented 21.1% of BF [20].

One study evaluated 45 women diagnosed with type 1 diabetes mellitus being divided into two groups: those with metabolic syndrome and those without. In the group with metabolic syndrome, WC was higher (89 cm) than in the group without metabolic syndrome (79.8 cm). In the same sense, the group with metabolic syndrome had a BF% greater than 38.4%, suggesting that this central fat deposition is a major contribution to the metabolic syndrome [22]. Two investigations evaluated the BC and central obesity through WC measurements in individuals with vitamin D deficiency according to 25(OH) D serum levels (<20 ng/mL or <50 nmol/L) and their findings indicated that there was a direct relationship between this deficiency and the WC which can be explained by the accumulation of vitamin D in adipose tissue [22,23]. The WC was higher (119.93 cm) in the group with vitamin D deficiency, compared to the group with adequate levels (100 cm) [22].

3.7. Studies on physical activity

Three studies reported a significant inverse relationship between PA and the prevalence of central obesity, indicating that non-regular PA represents a higher risk of suffering from central obesity [24–26]. One of these studies in which the association between central obesity and PA was evaluated in 340 obese and non-obese women reported a significant inverse relationship between these two variables with an OR and a 95% CI of 0.417 (0.180- 0.968, p= 0.031) (28). Most of the studies based on interventions of a physical training program regardless of its duration or type of exercise, reported significant improvements in WC [26–35]. Most of these studies reported a WC reduction between -1.3 cm and -5.8 cm. Three studies indicated that regardless of the type of physical activity, level of intensity, or amount, the intervention groups presented similar WC reductions, with no significant differences between groups [16,28,36]. Concerning those studies that evaluated PA through questionnaires or accelerometers, the majority indicated that most of the participants performed a level of PA between light and moderate [25,27,29,37].

In a study in which the participants were divided into three groups according to 25 (OH) D serum level (deficient: <20ng/mL, insufficient: 20-29.9 ng/mL, and sufficient: 30-100 ng/mL), a high prevalence of central obesity was observed in the vitamin D deficient group. However, the highest percentage of sedentary lifestyles was found in the group of individuals with sufficient vitamin D levels [22]. One of the studies, based on comparisons between obese and overweight individuals, carried out an intervention program of nutritional counseling and physical training, specifically of high intensity and resistance, and reported that 51% of the participants presented a reduction in WC after the intervention. Additionally, the prevalence of metabolic syndrome decreased to 32.5% after the intervention [33].

4. Discussion

The findings of this review suggest a significant inverse relationship between BM measured by VO2 max and central obesity (WC >102 cm in men and >88 cm in women) [16,17,26]. The studies reported that PA interventions were directly associated with an increase in VO2 max, decreased WC, and increased overall physical performance [16,26]. This was confirmed by Aspilcueta et al. 2021, reporting an inverse relationship between WC and VO2 max, highlighting the importance of increased PA to improve the components of physical fitness and BM in adults [38].

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In one of the studies where a PA intervention was performed for 12 weeks, it was reported that the intervention group presented an increase in VO2 max, in addition to a decrease in WC [26]. This coincides with other studies performed in periods close to 12 weeks, where high-intensity training in populations with central obesity had a significant impact on the improvement of parameters of physical performance and metabolic health, such as VO2 max [39–41].

The studies analyzed in this systematic review affirm the relationship between BC parameters and central obesity. Studies reported individuals that who underwent a body composition analysis, when presenting a WC above the healthy values, in turn, presented a high BF% [19,21,27]. These findings are similar to those found in postmenopausal women, where it was observed that women with higher WC showed a high BF% and in turn had a 6.9 times higher risk of suffering from metabolic syndrome than those with a lower BF% [42].

The findings reported by the identified studies suggest that in individuals with central obesity and a BF% ≥30%, cardiovascular risk is one of the factors that are increased, compared to those with a healthy BF%. This was observed in three of the studies that evaluated populations with conditions associated with central obesity such as type 2 diabetes mellitus and coronary heart disease [19–21]. These findings are in agreement with those reported by Patino et. al in 2011 to evaluate factors associated with increased cardiovascular risk, where it was found that one of the most detrimental factors was central obesity (52.7%), especially in women ($p < 0.05$) [43]. In the same way, Oviedo et. al (2011) reported a direct association between central obesity and coronary heart disease [44].

Based on the included studies, we highlight the importance of considering the implementation of individual-type interventions detecting populations with higher cardiometabolic risk by measuring WC and body composition at the primary health system level or through community work. In addition, it would be helpful to always consider communication and nutritional education campaigns on the importance of maintaining a healthy WC and promoting better dietary habits as well as having policies such as warning food labeling which would contribute to the development of a healthy food environment and would empower the population towards better food choices.

The findings connecting the relationship between central obesity and body composition with vitamin D deficiency suggest that individuals with this deficiency may have a greater predisposition to elevated WC and higher BF% [22]. The reasons why this association has been found are still a matter of scientific discussion. It is probably that these relations are explained by the role that vitamin D (a fat-soluble vitamin) plays in the adipose tissue since adequate vitamin D status is related to mechanisms of modulation of the inflammatory response, reduction of adipogenesis, and therefore lower secretion of adipocytes [45]. This is consistent with a study where vitamin D levels of postmenopausal women were investigated and were related to body adiposity, reporting that women with central obesity have higher BF% and vitamin D deficiency according to 25 (OH) D serum levels (deficient: ≤20 ng/mL; insufficient: 21-29 ng/mL and sufficient: ≥30 ng/mL) [46]. Based on this, it is important to perform new studies with stronger study designs, preferably case-control, cohort studies, or experimental studies that provide more reliable results and allow a thorough understanding of the relationship between central obesity and vitamin D deficiency. Probably, PA interventions in individuals with vitamin D deficiency and central obesity may be less effective to reduce WC than in individuals with adequate vitamin D status. In this sense, Tamer et al. (2012) found a higher WC and prevalence of central obesity in vitamin D deficient individuals, compared to those without vitamin D deficiency, despite having similar FA regimes [47]. Based on these findings, vitamin D supplementation in conjunction with PA intervention in individuals with hypovitaminosis D and central obesity is suggested as a topic for future research, which would allow to clarify the extend of this deficiency as a factor that negatively makes of PA less efficient on central obesity.

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The analyses on the relationship between central obesity and PA suggest that non-regular PA has a consistent detrimental relationship with central obesity, which coincides with the results of Júdice et al. (2015) who indicated a direct association between a continuous sedentary lifestyle and central obesity, showing increases in WC at higher sedentary episodes [48]. Ramírez & Agredo (2012) also reported a similar association between sedentary behavior and central obesity, being sedentarism a predictor of central obesity in comparison with being physically active [49].

The analyzed studies showed that PA interventions could contribute to a decrease in WC. Consistently, Kay & Fiatarone (2006) reported responses on WC attributable to exercise. They reported significant decreases in WC in 8 of 14 exercise intervention groups, compared to controls, in different experimental studies [50]. The findings reported by the identified studies in the present review suggest that a similar reduction in WC can be achieved, regardless of the type of PA performed. However, Ismail et al. (2012) reported that aerobic exercise, even below the recommendations for obesity management, was considered effective in reducing visceral fat, while resistance exercise alone did not achieve a significant reduction in visceral fat, in comparison with a control group [51]. Park et al. (2003) indicated a greater effect of the combination of aerobic and strength on visceral fat compared to aerobic training alone [52]. However, Stensvold et al. (2010) found that WC reductions have no significant differences between the intervention groups when applying three different training programs: aerobic exercise, resistance exercise, and combined resistance and aerobic exercise [35].

Regarding the intensity and amount of exercise, different studies are inconsistent concerning its relationship with central obesity. Ismail et al. (2012) did not find a relationship between intensity or amount of exercise and decreases in abdominal fat [51]. In this sense, Slentz et. al (2005) did not find a dose-response relationship between exercise intensity and the reduction of WC, but did find a relationship between the amount of exercise and the reduction of WC, showing a significantly greater decrease in abdominal fat in the exercise group with the high amount and vigorous-intensity of PA, compared to other groups of exercise intervention (low amount and moderate intensity, low amount and vigorous intensity) [53]. Ekelund et al. (2011) also suggest a linear dose-response association between the level of PA and change in WC, such that higher PA generates a greater impact on abdominal adiposity [54].

New studies are needed to further understand the relationship between the level of PA and central obesity. It would be ideal to study how each type, duration, and frequency of PA influence abdominal fat, which would allow us to know better how to reduce the risk of central obesity. Our results indicate a positive influence of FA on central obesity, which is consistent with the results of a systematic review where it was reported that FA of all types was capable to reduce WC [55].

It is well-known that central obesity is widely related to metabolic syndrome, a major cardiometabolic risk factor [56–58]. The present review showed a reduction in WC and a reduction in the prevalence of metabolic syndrome through PA. Consistently, Zajac et. al (2017) reported that women with a higher level of PA had an almost 4 times lower risk of suffering from metabolic syndrome compared to less active women [59]. Therefore, it is important to raise awareness and ideally educate the population through campaigns about the importance of PA and the negative consequences of a sedentary lifestyle on health. Additionally, due to the complex relationship between AF, body composition, BM, and even nutrients like vitamin D with central obesity, is important to highlight that together with the implementation of health programs and policies at the population level, the participation of a multidisciplinary team of doctors, nutritionists, and exercise physiologists is ideal for successful improvements and treatment of this condition.

Figure 2 shows a summary diagram of the main findings provided by the different studies included and analyzed in this review. A negative association of central obesity with the components of BM was found, suggesting an increased risk of metabolic alterations. However, PA interventions demonstrated an improvement in these components. PA was shown to reduce the prevalence of central obesity and with it the risk of metabolic syndrome. Central obesity is associated with a higher fat percentage suggesting an increased risk of chronic non-communicable diseases. However, PA generated positive changes in WC in participants with central obesity. In individuals with the additional condition of vitamin D deficiency, the predisposition to present a high-fat percentage seems to be greater and the effect of PA on obesity seems to be less efficient. PA seems to be an important factor in the treatment and prevention of central obesity. It is necessary to establish policies that promote PA and the development of a healthy eating environment through frontal labeling, nutritional education campaigns, and the prevention of a sedentary lifestyle. It is also advisable to measure body composition as a preventive measure.

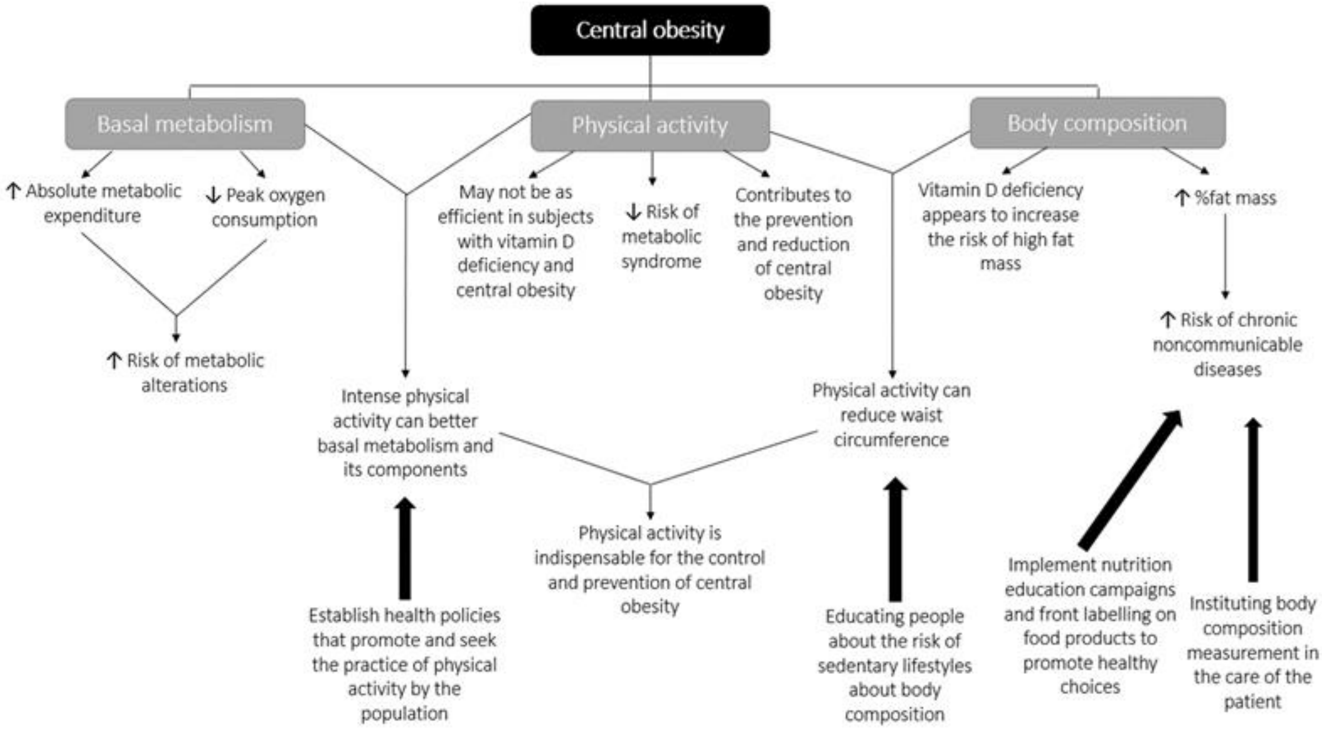

Figure 2. Summary diagram.

One of the strengths of this review lies in the extraction of recent data. This review offer a critical, comprehensive, novel, and relevant view of central obesity and its relationship with PA, BM, and body composition. It also highlights relevant research questions, for example regarding the relationship between abdominal adiposity and vitamin D deficiency. Among some limitations, we acknowledge the inclusion of a limited study sample. Also, different countries and ethnicities of the participants can be considered as limitations of the study, in addition to age and associated comorbidities. Additionally, the age range was wide, including various age groups such as young adults and older adults, which could generate bias in the results of the study, due to the well-known influence of age on body composition. In addition, there were a variety of conditions or diseases associated with central obesity, which could also influence the results of body composition. The few studies that have reported data on BM can be also considered a limitation for the present review.

5. Conclusions

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In conclusion, a relationship between the components of BM with central obesity has been proposed. In addition, a direct association was found between central obesity and BF%. FA contributes to the reduction of WC and the prevalence of central obesity. Vitamin D deficiency was found to be a risk factor for central obesity. These findings are useful for the design of policies and programs for the control and prevention of obesity in the adult population.

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