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The Independent Effect of Age Groups on the Effectiveness of Lifestyle Intervention

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Abstract The impact of age on anthropometric measures, body composition, and metabolic risk factors following a lifestyle intervention is usually evaluated after adjustment for age at baseline; however, this strategy does not provide a clear clinical message other than age is a predictor of the responses. The objective of this review was to evaluate the independent effect of age groups on anthropometric measures, body composition, and metabolic risk factors following a lifestyle modification (exercise, diet, or combined intervention) in studies that included at least two different adult age groups. Eighty-five percent of studies reviewed reported significant differences among evaluated age groups on at least one studied outcome. In general, when a difference was observed among age groups, the advantage was to the oldest group studied, especially in the reduction of body weight, blood pressure, and type 2 diabetes risk. This is of crucial importance to health care providers because the impact of lifestyle modification interventions may be different among age groups. It is thus essential in future studies to stratify results by age group in order to provide a clear message on the impact of the intervention in different age groups, instead of merely adjusting results according to age.

Keywords Aging · Physical activity · Diet · Obesity · Lifestyle

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Introduction

Lifestyle is defined as a style of living that reflects the attitudes and values of a person or group of people. Lifestyle comprises several sub-categories including physical activity, diet, sleeping, alcohol consumption, and smoking [1]. This review article focuses on the effect of age groups on outcomes related to the modification of diet and physical activity.

Most industrialized countries report an important percentage of overweight or obese people among their populations and the World Health Organization has declared obesity as an epidemic [2]. Obesity significantly increases the risk of developing various serious health problems including type 2 diabetes, coronary heart disease [3], osteoarthritis [4], hypertension [5], Alzheimer's disease [6], sleep apnea [7], and dyslipidemia [8]. All these chronic conditions have in turn an impact on an individual’s quality of life regardless of their age. Furthermore, health expenses related to obesity are increasing. For example, health costs increased by 40 % in Canada between 1997 and 2004 [9] and it has been reported that an obese individual will cost the health system $1486 more annually than a lean counterpart [10]. Lifestyle modification is one of the strategies to address the obesity epidemic and other chronic conditions

[11]. However, it is still unclear whether lifestyle modification is sustainable and effective in all age groups.

Despite the fact that age is usually considered as a potential confounder and taken into consideration by the use of regression analysis, most do not report the results stratified by age group [12–16]. Nonetheless, modifications in diet and physical activity levels have shown positive impact in young [17], middle-aged [18], and older adults [19–22]. These findings demonstrate the importance of age on the response to a lifestyle intervention, but without direct comparison they cannot provide clinically useful information on the differences that should be expected among young, middle-aged, or older adults following the same lifestyle intervention. The optimal strategy to improve anthropometric measures, body composition, and metabolic risk factors following a lifestyle intervention could vary according to age groups for several reasons. Those reasons include body composition modification observed with aging [23, 24], obesity duration that can potentially be longer in older adults [25, 26] and different personal goals during the intervention [27].

Weight loss benefits in older adults have been challenged in the last decade especially because of the risk of losing fat-free mass and increasing mortality rate [28–32]. However, several studies have argued the contrary by showing weight-loss benefits in different age groups including older adults [33–35]. For example, one study including individuals over 35 years of age reported that an attempt at weight loss was in fact associated with lower all-cause mortality, and that a higher mortality rate occurred only in those reporting unintentional weight loss [34]. A joint position statement has supported that weight-loss therapy improves physical function, quality of life, and reduces medical complications associated with obesity in older adults, and that bone and muscle mass can be preserved [35]. Furthermore, ideal weight and weight discrepancies are weakly associated with age and extra body weight is a concern in every age group [36]. The real question may not be whether or not we should promote weight loss in older adults, but whether we should promote weight loss in all age groups using the same approach?

Methods

There are at least two ways to explore the impact of age group on outcomes of lifestyle modification. First, it is possible to compare two studies that used a similar intervention with two different age samples (e.g., a lifestyle intervention study with adults aged 65 and older vs. a similar lifestyle intervention study with adults aged 18–45 years) and make assumptions on the independent impact of age. Second, it is possible to perform studies formally exploring whether different age groups respond differently to the same intervention. This review article highlights available studies that formally tested the benefits of lifestyle intervention including diet, physical activity or a combination of both strategies *in different age groups*. The studied outcomes were regrouped into three categories: anthropometric characteristics, body composition, and metabolic risk factor improvement.

To identify the independent role of a specific age group in response to the same lifestyle intervention, electronic searches of MEDLINE (until February 2011) were performed using individual or a combination of different terms. Search keywords were: lifestyle and age, exercise and age, diet and age, intervention and age, weight loss and age, age group, age effect, aging, and obesity and age. Only English language articles were screened. The inclusion criteria were: 1- formally tested the benefits of the same lifestyle intervention in adults (≥ 18 years old) including diet, physical activity or both *in two or more age groups*; - 2- reported change in anthropometric characteristics, body composition, or metabolic risk factors. A total of 312 articles were identified by reading abstracts as potential articles to be included in this review. The articles were then screened by one of the authors (DRB) to identify articles reporting results by two or more age groups. Most articles were rejected because results were not stratified by age in secondary analyses. The remaining articles were rejected because the studied outcomes did not include anthropometric measures, body composition, or metabolic profile.

As a result, a total of 13 studies were identified. Table 1 gives a summary of the outcomes reported in those studies and specifies whether the oldest age group for each outcome had greater, lower, or equal benefits compared to younger age groups. Some articles reported one of more outcomes while others only reported one outcome. Table 2 reports the selected studies in detail.

Anthropometric Measures

Body Weight

At any age, one of the main objectives of lifestyle modification is to reduce body weight to treat or prevent obesity related co-morbidities. The magnitude of change in body weight observed after a lifestyle intervention depends mostly on the duration and the intensity of the intervention. As presented in Table 1, body weight change following a lifestyle intervention was the outcome most frequently evaluated among identified studies. Seven studies have formally investigated the effect of age group on body weight reduction following the same lifestyle intervention [37–43]. In general, these studies suggest that lifestyle intervention is

Table 1 Summary of studies that formally compared age group following a lifestyle intervention

Outcome	Older age group *vs*. younger age group						
Anthropometric characteristics							
Body weight	⇔[37]	⇑[38]	⇔[39]	⇓[40]	⇔[41]	⇑[42]	⇑[43]
Waist circumference	⇔[37]	⇑[38]	⇔[39]	⇔[47]			
BMI	⇔[37]	⇔[39]	⇔[47]				
Body composition							
Fat mass	⇔[39]	⇓[40]					
Fat-free mass	⇓[39]						
Bone density	⇔[53]						
Metabolic profile							
Glycemia	⇑[38]	⇑[39]	⇑[63]				
Blood pressure	⇑[39]	⇑[41]	⇑⇔[47]	⇑[70]	⇔[72]		
Blood lipids	⇔⇑[39]	⇓[47]	⇔[76]				

⇑ Greater benefits as compared to younger age group

⇓ Lower benefits as compared to younger age group

⇔ Equal benefits as compared to younger age group

associated with a significant decrease in body weight for all age groups. However, four out of seven studies [39, 41–43] reported a significant difference among age groups, while the others did not [37, 38, 40]. Interestingly, three of the four studies reporting a difference among age groups showed the greatest benefit in the oldest group compared with the younger age groups. The greater body weight loss observed in the oldest group could be influenced by the fact that older adults are less likely to be employed, have fewer social responsibilities, and therefore have more time to devote to the intervention and follow advices given by the research group [38]. Moreover, older adults may be more aware of disease vulnerability having previously lost a loved one or having already suffered from a worrisome event. More recently, a 10-year follow-up from the Diabetes Prevention Program (DPP) showed that differences among age groups observed after the three years intervention [38] persisted in long term follow-up [44••]. The authors also reported in their long term follow-up study that body weight loss *was less* sustained in participants younger than 45 years than those aged 45 years and older at baseline [44••]. This latest result suggests that age groups may respond differently not only to initial bodyweight reduction, but also to long-term weight loss maintenance. Altogether, these results confirm that older adults are able to modify their lifestyle habits in order to lose weight despite a general assumption that they have an encrypted lifestyle [45, 46].

Waist Circumference and Body Mass Index

Three out of the four studies that have investigated age group waist circumference (WC) and body mass index (BMI) response to a lifestyle intervention [37, 39, 47], have reported a significant reduction in WC and BMI following an intervention, but did not report any significant difference among age groups. In contrast to this finding, in one study [38] with a threefold longer follow up, the authors reported a greater decrease in WC in the oldest group ($P \leq 0.05$), but did not report information with regard to BMI. Notably, this study included a higher physical activity volume during the initial intervention compared to the other three interventions. In fact, the objective of the DPP study [38] was to reach a minimum of 150 min/week while two of the abovementioned studies [37, 39] recommended exercising twice a week without specifying duration. However, it is likely that those two interventions did not include 75 minutes per session. This result suggests that compared with younger adults, older participants may respond better to a lifestyle intervention recommending higher durations of physical activity to achieve a significant reduction of WC. This is in line with studies that reported a decrease in WC during interventions comprising a similar volume of physical activity (~150 minutes per week) with or without weight loss [13, 48].

In summary, four out of the seven studies that formally tested the influence of age group on anthropometric measures in response to lifestyle interventions found differences among age groups with the greatest benefits in the oldest group. Thus, modifications in lifestyle might induce greater anthropometric improvement in older adults compared to younger adults.

Body Composition Following a Lifestyle Intervention

In older adults who experience inevitable loss of muscle mass and bone mass [49], another important aim of lifestyle intervention is to preserve fat-free mass and bone mass while significantly reducing fat mass. However, reductions in fat-free mass (FFM) [50] and bone mass [51] are almost inevitable with any weight loss program, especially if weight loss is achieved using caloric restriction as the sole

Table 2 Description of studies reporting age groups difference after lifestyle interventions

Study	Extractable outcomes	Intervention	Duration	Group characteristics	Subject characteristics	Main results
Berg 2008 [37]	Anthropometry	Diet: Food guide	12 months	N=454 Intervention	75 % women	All age groups decreased significantly their mean body weight (−6.3, -6.3, -7.0 kg), BMI (−2.2, -2.2,-2.5) and WC (−6.2, 7.5,-8.5) $P<0.001$.
		Physical activity: 1–2 X/week		Age groups:	Mean BMI: 36 kg /m^2	No difference was observed among age groups.
				18–44	Classes 1 and 2 obese	
				45–59	Mean age: 49	
				>60	Age range: 30–70	
Crandall 2006 [38]	T2D	Diet : Food guide	3.2 years	N=879 Intervention	68 % women	All age groups improved significantly (body weight, WC, T2D incidence) in lifestyle intervention compared to control group; all $P\leq.05$.
		Physical activity: ≥150min/ week		N=1082 Control	Mean BMI : 31 kg /m^2	T2D incidence rate cases/100 person per year in intervention groups: 6.3 in 25–44 yrs old, 4.9 in 45–59 yrs old, and 3.3 in 60–85 yrs old; P to trend ≤.01.
		aerobic training		Age groups:	Impaired glucose + elevated fasting plasma glucose	
				25–44	Mean age: 66	
				45–59	Age range: 60–85	
				60–85		
Deibert 2007 [39]	Anthropometry	Diet: low fat intake + meal replacement + 1500 daily kcal	12 months	N=72 Intervention	100 % women	Mean weight (pre 6.4 vs 6.3 kg), BMI (2.4 vs.2.6 kg/m^2) waist (−6.2 vs.5.0 cm), hip circumference (−6.3 vs.4.8 cm), and FM (5.0 vs. 6.3kg) decrease significantly in both groups but no difference between groups.
	Blood pressure	Physical activity: 60 min/ 2 X per week		Age groups:	Mean BMI: 32 kg /m^2	Only premenopausal women decreased FFM.
	Blood lipids			18–54	Overweight and obese class 1	Only postmenopausal women decrease significantly: Blood pressure, TG, fasting glucose and improved HDL (all $P<0.05$).
				51–75	Mean age : 53	Both groups decreased cholesterol, LDL levels without any difference between groups
					Age range: 18–75	

Table 2 (continued)

Study	Extractable outcomes	Intervention	Duration	Group characteristics	Subject characteristics	Main results
Irwin 2003 [40]	Body weight	Diet: none	12 months	N=87 Intervention	100 % women	Mean body weight only decreased significantly in the youngest age group (50–59) vs. control.
	Body fat	Physical activity : 5X/week aerobic + 2X/week resistance training		N=86 Control	Mean BMI: 31 kg /m^2	Mean FM (−1.1 and −1.1 kg; P<.01) and mean subcutaneous fat decrease significantly in the two youngest age groups (−22.2 and −39.4 g/cm^3 both P≤.05).
				Age groups:	Post-menopausal women	Mean intra abdominal fat only decreased in the middle age group (23.5 g/cm^3; P=.007).
				50–59	Mean age: 61	
				60–69	Age range 50–75	
				70–75		
Svetkey 2005 [41]	Blood Pressure	Diet: Food guide or Food guide +DASH diet	6 months	N=540 Intervention	62 % women	Significant weight loss with both interventions in each age group vs control (−4.6, -5.8 vs.1.3 kg in ≥50) and (−5.2, -5.5 vs. 0.9 kg in <50).
	Body weight	Physical activity: ≥ 180 min/week		N=270 Control	Mean BMI: 29 kg /m^2	Food guide + DASH effective to reduce systolic blood pressure vs. Control (−6.4 mmHg) and Food guide (−2.9 mmHg) only in the oldest group.
				Age groups:	Hypertensive participants	
				<50	Mean age : 50	
				≥50	Age range: 40–65	
Van der Mark 2009 [42]	Body weight	Diet: Energy intake reduction	6 months	N=4440 Intervention	46 % women	18–33,34–44,45–83
		Physical activity: Increased energy expenditure		Age groups (2 different classifications)	Mean BMI:30 kg /m^2	Mean weight loss % was different among age groups in both women [5.4 for 18–33,5.9 for 34–44 and 6.0 for 45–83 (P=.003)] and men [6.7 for 18–33,7.7 for 34–44, 6.6 for 45–83 (P=.011)]
		Internet based behavioral program		1. 18–33	General population	45–64 and 65–83
				34–44	Mean age:41	No difference was observed between the two oldest age groups in both women (P=.06) and men (P=.09).
				45–83	Age range : 18–85	
				2. 45–64		

Table 2 (continued)

Study	Extractable outcomes	Intervention	Duration	Group characteristics	Subject characteristics	Main results
				65–83		
Wadden 2009 [43]	Body weight	Diet: Meal replacement, caloric restriction (1200–1800 kcal /day)	1 year	N=2570 Intervention	59 % women	The oldest age group lost more body weight 9.4±6.3 % compared to both the 45–54 age group 7.9±7.2 % and the middle age group 8.5±7.0 %.
		Physical activity: >175 min/week		N=2575 Control	Mean BMI : 36 kg /m^2	
				Age groups:	Diabetic patients	
				45–54	Mean age: 59	
				55–64	Age range: 45–74	
				65–74		
Maniar 2009 [47]	Anthropometry	Diet: Education	3 months	N=685 Intervention	29 % women	With the exception of diastolic blood pressure in the oldest group and HDL in both age groups which did not improve significantly BMI, WC, systolic blood pressure and TG improved in both groups.
	Metabolic risk factors	Physical activity: Aerobic training 2–3X/week		Age groups:	Mean BMI : 30 kg /m^2	The improvement was significantly greater in the youngest group for mean total cholesterol (−26.5 vs. 14.4 mg/dL; P<.01) and mean LDL-cholesterol (−22.7 vs. 15.5mg/dL; P=.03).
				<65	Cardiac patients	
				≥65	Mean age : 63	
					Age range: NA	
Lin 2003 [53]	Bone density	Diet: DASH or Western diet	3 months	N=91 Intervention	59 % women	DASH diet = reduced serum OC by 8–11 % and CTX by 16–18 % (both P<0.001) two indicators of bone turnover.
		Physical activity: none		N=95 Control	Mean BMI: 29 kg /m^2	No difference between age groups.
				Age groups:	Hypertensive	
				<50	Mean age: 50	
				≥50	Age range: 23–76	
Lindstrom 2008 [63]	T2D	Diet : Food guide	4 years	N=265 Intervention	67 % women	The two oldest intervention groups 51–61 (0.49:0.26–0.93) >61 (0.36:0.17–0.80) decreased their T2D risk (both P<0.05) compared

Table 2 (continued)

Study	Extractable outcomes	Intervention	Duration	Group characteristics	Subject characteristics	Main results
						to the youngest age group (40–64 yrs old)
		Physical activity: 240 min/week aerobic training		N=257 Control	Mean BMI :31 kg /m^2	T2D Incidence rate (cases/100 persons-year) in the intervention groups were: 6.0 (3.9–9.2) in <51 yrs old, 4.0 (2.3–6.7) in 51–61 yrs old, 2.4 (1.3–4.7) in >61 yrs old P=0.04.
				Age groups:	Impaired glucose	
				<51	Mean age: 55	
				51–61	Age range: 40–64	
				>61		
Short 2003 [76]	Metabolic risk factors	Diet: none	4 months	N=65 Intervention	50 % women	TG decrease significantly vs. control by 23 % without age group differences.
		Physical activity: 4X/week		N=37 Control	Mean BMI : 26 kg /m^2	No change in fasting glucose in any group.
		40 min each at 80 % of maximal heart rate		Age groups:	Healthy adults	
				20–39	Mean age: NA	
				40–59	Age range: 21–87	
				≥ 60		
Vollmer 2001 [70]	Blood Pressure	Diet: DASH or Western	12-week	N=208 Intervention	57 % women	Significant reduction in both systolic and diastolic blood pressures in both age groups vs. Control.
		Physical activity: none		N=204 Control	Mean BMI:	More effective in the oldest group (systolic-11.6 mmHg vs. -5.6mmHg; P<0.01 and diastolic-5.5mmHg vs. -3.3 mmHg; P<0.05).
				Age groups:	29 kg /m^2	
				≥45	Hypertensive participants	
				<45	Mean age : 48	
					Age range: 28–58	
Neter 2003 [72]	Blood Pressure	Diet physical activity or both (depending on the study)	8 weeks to	N=4874 in 25 different studies	82 % women	Significant decreases in both age groups of systolic blood pressure −4.74 (≤45) vs −4.80 (>45) and diastolic blood

Table 2 (continued)

Study	Extractable outcomes	Intervention	Duration	Group characteristics	Subject characteristics	Main results
						pressure −3.69 (≤45) vs −3.43 (>45).
		Meta-analysis	5 years	Age groups: ≤45 >45	Mean BMI: 31 kg /m^2 With or without hypertension Mean age: 46 Age range 37–66	No significant difference was reported between age groups.

T2D: type 2 Diabetes; OC: osteocalcin; DASH: Dietary Approaches to Stop Hypertension; CTX: carboxy-terminal collagen crosslink; NA: Not available; WC: Waist circumference; TG: triglycerides; HDL: High density lipoprotein; LDL: Low density lipoprotein

strategy. By combining resistance training with caloric restriction, some authors have demonstrated the possibility of maintaining FFM even in older adults [19, 52]. However, another study by Brochu et al. [20] reported a significant decrease in FFM despite the fact that caloric restriction was combined with a resistance training program in postmenopausal women. Surprisingly, only a few studies have specifically reported the independent influence of age on changes in body composition following a lifestyle intervention [39, 40, 53].

Fat Mass

Only two studies were identified in which the authors formally tested the changes in fat mass (FM) after a lifestyle intervention in different age groups [39, 40]. First, one study has reported significant FM decreases in both age groups of pre- and post-menopausal women (both $P<0.01$), but no difference was observed in the magnitude of change between groups [39]. In contrast, another study has demonstrated that FM was significantly decreased in groups aged between 50–59 and 60–69 years, but not in the oldest group aged between 70 and 75 years following a 12-month physical activity intervention [40]. The difference between the two studies might be explained by the fact that subjects in the oldest age group in the last study were aged 73 yrs old in average [40] while the mean age in the oldest age group for the first study was 58 yrs old [39]. Moreover, the first study combined both physical activity and diet [39] while the second [40] relied solely on physical activity to decrease FM. This result implies that it is possible to reduce FM in all age groups but FM reduction might not be observed in the elderly (≥70 years old) especially when only exercise is part of the intervention. More studies using the same stratification of age and including men are needed to confirm this observation.

Similar to total FM, abdominal and visceral fat distributions have been identified as conferring important health risks [54, 55]. However, to our knowledge, only one study examined changes in intra-abdominal and subcutaneous fat deposits after a lifestyle intervention in two or more age groups [40]. This study reported that only the middle age group (60–69 yrs old) showed a decrease in both intra-abdominal (−23.5 g/cm^2; P=0.007) and subcutaneous FM (−39.4 g/cm^2; $P\leq0.05$) after a 12-month physical activity intervention. The youngest age group (50–59 yrs old) only decreased subcutaneous fat content (−22.2 g/cm^2; P=0.03) while no such decrease was observed in the oldest group (70–75 yrs old). As observed in most studies that report age group comparisons, the oldest age group had a small sample which can affect the statistical power to detect any change in this subgroup.

Fat-Free Mass

One of the reasons why controversy exists in promoting weight loss in older adults is the risk of fat-free mass (FFM) loss [35, 56]. To our knowledge, only one study has formally tested FFM modification in two or more age groups after the same lifestyle intervention [39]. However, Hunter et al. [52] reported that it is possible to maintain FFM if a caloric restriction induced by diet is associated to resistance exercise training in middle age women while Brochu et al. [20], reported the inverse in older women. Those two studies support that the effect of a similar intervention might induce different results based on age group. The study that formally tested FFM modification in two or more age groups after a lifestyle intervention reported that FFM decreased to a lower extent in postmenopausal women compared with premenopausal women (-3 % of total weight loss vs. -21 %, $P<0.01$) after a 12-month intervention including both physical activity and diet. This result is quite interesting since total weight reduction was similar between groups. Therefore, based on this unique study, it might be proposed that preservation of FFM is feasible in postmenopausal women that combine caloric restriction and physical activity in order to improve obesity-related conditions.

Bone Mass

Another important concern of lifestyle interventions inducing weight loss, especially in older adults, is the loss of bone mass [35]. Reduction in bone mass is almost inevitable with any weight loss program [51], especially if weight loss is achieved solely by caloric intake restriction [51]. However, progressive weight loss associated with exercise also reduces bone-mass loss [33], although it is still not clear which type of exercise is preferable to preserve bone-mass. Weight bearing activities and resistance training are usually beneficial in the prevention and treatment of osteoporosis [57]; but during a weight loss program, studies have demonstrated that the tendency to reduce bone mass remains even when caloric restriction is combined with resistance training and weight bearing exercise [58, 59]. Nonetheless, even if an unfavorable, accelerated bone turnover is observed during weight loss, the potential negative consequences do not outweigh the numerous other health benefits of weight loss [60]. Only one study was identified in which the independent effect of age was reported after a lifestyle intervention [53]. This study included 186 participants and was conducted in a broad age sample (23–76 yrs old). The primary objective of the intervention was to decrease salt consumption by adopting the dietary approaches to stop hypertension (DASH) diet, although it also aimed at adopting a healthy overall diet [53]. The DASH diet was originally developed as an eating style to help lower blood pressure, but it has been found to have many additional advantages. The DASH diet is rich in fruits, vegetables, whole grains, and low-fat dairy foods, and is limited in sugar-sweetened foods and beverages, red meat, and added fats. In a study by Lin et al. [53], participants were divided into two age groups (< 50 *vs.* ≥ 50 yrs) and data was collected following a 12-week intervention. The authors demonstrated that the DASH diet, without any exercise intervention, significantly reduced serum osteocalcin and carboxy-terminal collagen crosslinks, two indicators confirming that the DASH diet increases bone mineral status. However, no significant difference in bone mass was observed between age groups. The absence of differential effect of age on bone mineral density after a lifestyle intervention reported in humans was also observed in animal models following a 12-week physical activity intervention [61].

Metabolic Outcomes

At any age, obesity increases the risk of developing a wide range of co-morbidities including type 2 diabetes and cardiovascular diseases [62]. Besides improving anthropometric characteristics and body composition, lifestyle interventions also focus on preventing and treating these conditions.

Glycemia and Type 2 Diabetes (T2D)

Although a large number of published studies are available in the current scientific literature regarding the impact of lifestyle modification on the control of glycemia, only three studies were identified in which the authors formally tested the independent effect among age groups [38, 39, 63]. The three studies combined physical activity with caloric restriction in a total of more than 2500 participants. All studies reported a beneficial impact of the intervention in the oldest age groups [38, 39, 63]. However, only two out of the three studies reported a beneficial impact in the youngest age groups studied [38, 39].

Besides a beneficial impact of the intervention in the oldest age group, one study reported that the oldest group presented with a significantly lower incidence rate of T2D compared to both younger age groups studied: 6.3 (25–44 yrs old), 4.9 (45–59 yrs old) and 3.3 (60–85 yrs old) cases per 100 person-years ($P<0.01$) [38, 39]. After a 10-year follow-up of this study, the lowest T2D incidence in the oldest age group remained significant [44••]. Similar findings were reported in a Finnish study [63], in which the oldest group presented the lowest incidence rate after a median follow-up of four years: 2.4 (>61 yrs), 4.0 (51–61 yrs) and 6.0 (< 51 yrs) cases per 100 person-years

(P_{trend}=0.0039). Based on the strong study's methodology, it may be concluded that individuals over 60 years of age pull greater benefits from a lifestyle intervention combining physical activity and caloric restriction compared to younger adults to prevent T2D.

Blood Pressure

High blood pressure is a highly prevalent chronic condition in our modern society [64], and the fact that more than half of the population is either overweight or obese is contributing to this high prevalence [65]. A major strategy to treat hypertension is diet modification (weight loss and/or reduced salt intake) and physical activity [39, 41, 47, 66–71]. We have found four studies [39, 41, 47, 70] and a meta-analysis [72] that formally tested the influence of two or more age groups on blood pressure response following a lifestyle intervention. Svetkey et al.[41] has demonstrated that both age groups of hypertensive participants (< 50 and ≥50 yrs old) significantly decreased their blood pressure compared to the control group (P<0.01), without difference among age groups. However, when the intervention included the established recommendations plus DASH diet, the oldest age group decreased their systolic blood pressure significantly compared with the youngest age group. This response might be the result of a higher baseline value in older adults as it is well established that blood pressure increases with age [73] and that this higher initial value is associated with greater overall improvement [74]. Similar findings were reported with a shorter intervention [70] by dividing the results into two age groups (≥45 yrs and <45 yrs). The authors of this study reported that all subgroup participants lowered their blood pressure but the DASH diet produced the greatest effect in the older age group in decreasing systolic (−11.6 *vs*.-5.6) and diastolic (−5.5 *vs*.-3.3) blood pressure, compared to the younger age group (both P<.05). Finally, Deibert et al. [39] also reported a greater blood pressure decrease in the older age group after a 24-week lifestyle intervention including diet and physical activity [39]. In contrast to findings by the three studies above, one study [47] did not report any differences among age groups in terms of systolic blood pressure and a greater decrease for diastolic blood pressure in the younger age group. The inverse result observed in the later study was confirmed in a meta-analysis summarizing the impact of weight-loss interventions on blood pressure in a total of 4874 participants [72]. Note that no study integrated in this meta-analysis was included in our review. In fact, the meta-analysis did not report age group differences in each study, but only compiled results of all studies and compared the general result for all studies included in the meta-analysis for two age groups (≥ 45 yrs and <45 yrs). The meta-analysis concluded that both age groups showed a decrease in blood pressure values following a lifestyle intervention without any difference between age groups. The conclusion of this meta-analysis is thus discordant to the findings of three of the four clinical trials reported above, which concluded that age may affect the impact of lifestyle intervention on blood pressure with an advantage to the older age group. This might be explained in part by the fact that the studies included in the meta-analysis were not all hypertensive while all participants included in the clinical trials were. So, based on the most robust evidence available, hypertensive older age groups respond more positively than younger ones to a lifestyle intervention to decrease blood pressure.

Lipid Profile

Most weight loss studies including lifestyle modification also aim to improve lipid profiles, including triglycerides (TG) and cholesterol (total, LDL-chol and HDL-chol). According to a recent systematic review, weight loss produces a modest change in lipid profile in adults aged between 18 and 65 years, with a greater difference observed if weight loss is maintained over a period of two years or more [75]. Nonetheless, many studies have shown that age is associated with altered lipid profile, and that higher initial values are associated with a greater positive effect following lifestyle modification [74]. However, studies that have verified the independent impact of lifestyle modification on lipid profile by age group are scarce. Only three studies were identified in which the influence of age on lipid profile changes was formally tested and all three reported different findings depending on the specific outcome and the studied population. First, Deibert et al. [39] showed that a 12-month intervention combining physical activity and diet induced a significant reduction in total cholesterol and LDL-chol in both the older and the younger age groups. However, no difference was observed between the different age groups. HDL-chol levels increased significantly and TG levels decreased significantly only in the oldest age group. Second, with the use of aerobic exercise as the sole intervention, one study reported no TG difference between age groups (20–39, 40–59 and >60 yrs old) [76]. Third, a study in a cardiac rehabilitation program including diet education and aerobic physical activity reported no improvement in both age groups for HDL-chol while similar improvement was reported between age groups for TG [47]. Finally, only the youngest group significantly decreased total and LDL-chol after the intervention. These studies show that lipid profile response may differ among age groups according to the intervention, the population, and the lipid marker studied.

Limitations

In all reviewed studies, most were not specifically designed to verify the impact of age or the outcomes of interest for this review were not studied. Consequently, the identification of selected articles was usually impossible by only keyword searches of the titles or abstracts but searching in articles themselves increased the number of studies that could be included in this review. Thus, some studies having reported secondary results by age group might not be included in this review. Another limitation is that some age groups were relatively small and may be statistically underpowered to report differential impacts of lifestyle modification. Moreover, interventions of the studies assessed in this review included various combinations of physical activity, diet quality or caloric restriction intervention that may explain different responses among age groups.

Conclusion

Even though age is known to be an important factor associated with many outcomes following a lifestyle intervention, this review demonstrates that few studies have formally tested the independent effect of age groups on the beneficial effects of lifestyle interventions. In general, our results show that the oldest age groups experience equal or greater benefits, at least in regard to body weight, blood pressure, and type 2 diabetes prevention. This result is of crucial importance to health care providers because they can expect different responses to lifestyle modification interventions based on the initial age groups of their clients. Furthermore, our results suggest that health benefits might outweigh risks of modifying lifestyles in older age groups.

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•• Of major importance

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