The relationship between physical activity, appetite and energy intake in older adults: A systematic review

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Abstract

Ageing often causes a reduction in appetite and energy intake in older adults which can result in malnutrition. Current guidelines for older adults suggest increasing physical activity to enhance appetite. However, it is unclear if there is evidence to support this advice. This aim of this review is to assess if appetite and energy intake is changed in older adults that undertake acute or regular physical activity (measured from cross sectional and intervention studies). Databases SPORTDiscus, CINAHL, MEDLINE were searched for studies between 1970 and 2017 using search terms related to ageing, physical activity (including exercise), energy and appetite. Studies included contained adults over 60 years, including acute, cross-sectional and intervention (longitudinal) studies. Of 34 full-text articles assessed, 8 were included. The Cochrane Collaboration's tool was used for assessing risk of bias. No acute studies were found. Of the cross-sectional studies, one study suggested that individuals who undertake habitual physical activity had an increased energy intake and none of the studies found differences in appetite ratings. Energy intakes increased in the intervention studies, though not always sufficiently to maintain energy balance. One study showed that ability to correctly compensate for previous energy intake was better in those that undertake habitual physical activity. The limited number of studies, wide range of data collection methodologies, time-scales and interventions mean that definitive outcomes are difficult to identify. At this stage advice to increase acute or habitual physical activity as a mean to increase appetite is not supported by sufficient evidence.

PROSPERO database (registration number CRD42017058355)

Keywords: Physical activity; appetite; older adults; energy intake; ageing

Introduction

Age related loss of appetite can be due to numerous factors, including reduced physical activity and lower metabolic rate. If this reduction in appetite is not compensated for in the long term, it can lead to weight loss and malnutrition. [1]. Middle age is often associated with an increase in body weight and increased rates of obesity and being overweight [2]. However as people age further, both lean body mass and percentage body fat decrease as shown in both cross sectional [3; 4] and longitudinal studies [5; 6]. This is due to a linear decrease in energy intake across the lifespan caused by a lack of appetite and desire to eat [7; 8]. Insufficient energy intake is an important issue and one of the main reasons for malnutrition in older adults [9] who currently fail to meet the estimated average requirements for energy intake [10].

Reduced appetite in older individuals has been documented across a number of satiety studies. Clarkston et al [11] reported that after an overnight fast, older adults tended to be less hungry than their younger counterparts and after a standard meal, older adults reported a greater degree of satiation than younger adults. Rolls et al [12] found that healthy older adults ingested less energy than younger men over a single meal, and older men were subjectively less hungry and more full at the start of lunch. One potential mechanism causing decreases in appetite is a delayed gastric emptying (GE) often seen with advancing years. Most but not all studies suggest that the rate of GE and gastrointestinal transit slows in older compared with younger adults [13; 14; 15]. The rate of GE will affect both the gastric distension signalling fullness via the vagus nerve [16] and the delivery of nutrients initiating satiety via release of satiety hormones [17], indicating that slower GE would result in the stomach remaining distended for a longer period of time and satiety being maintained. It has also been shown in younger and older adults that GE is accelerated in those that undertake habitual physical activity [18; 19]. Hence it seems appropriate that increasing physical activity may be a potential non-invasive opportunity by which appetite could be increased or maintained in older adults possibly through increasing rates of GE.

In a recent systematic review it has been proposed that habitual physical activity improves appetite control in younger adults but the effect in older individuals is less clear [20]. Current guidelines being produced by organisations such as the NHS and Age UK for older adults who are concerned about a reduction in their appetite, recommend increasing their physical activity levels [21; 22]. Although physical activity is recommended to increase appetite, the type and quantity of physical activity and whether there is evidence available to support this guidance is not clear. The benefit of physical activity in older adults cannot be understated. It has been shown to reduce risk of all-cause mortality, chronic disease, and premature death [23]. However, evidence for increasing appetite with acute or habitual physical activity in older adults appears to be unclear.

Therefore, the aim of this review is to assess if there is evidence to support advice to undertake physical activity as a means of increasing appetite in older adults, where physical activity is defined here as "any bodily movement produced by skeletal muscles that requires energy expenditure" [24; 25]. Specifically, the objectives are to examine if

(i) regular, habitual physical activity (from cross sectional studied) can influence appetite and energy intake and endocrine measures linked to appetite,

(ii) either acute or long term physical activity interventions can change energy intake and appetite or alter endocrine measures linked to appetite in older individuals.

Materials and methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [26] and is registered in the PROSPERO database (registration number CRD42017058355).

Search strategy

The databases SPORTDiscus, CINAHL, MEDLINE were searched for studies between January 1970 and December 2017 comprising of all human participants using the strategy (physical activity AND ageing AND (appetite AND (energy intake OR endocrine measures))). Previous systematic reviews were screened to identify relevant subject headings and key words to include within each subject category. The specific key words used for the search are listed in Table 1.

Inclusion and exclusion criteria

Limits were set to include articles published in the English language and studies conducted in human adults aged 60+ years. Studies were included if they examined the relationship between either appetite or appetite control or energy intake and being physically active or inactive. This includes acute studies looking at single physical activity sessions and appetite, longitudinal studies assessing appetite control before and after a physical activity based intervention in previously inactive individuals and cross sectional studies looking at the relationship between physical activity levels and appetite. Given the limited data on the topic, the decision was taken to include studies involving both residential and community-based individuals.

Data screening and extraction

Two independent investigators (MC and AG) reviewed studies using a systematic hierarchy of exclusion criteria (Figure 1). Records were initially screened for duplicates and these were removed. Record titles were then screened and titles that did not contain reference to energy intake, appetite or physical activity were removed. Record titles that clearly indicated it was a review paper or indicated that it was in an animal, children adolescents or young adults were excluded at this stage.

One author extracted the following information into a spreadsheet: authors, date of publication, sample size, participant characteristics (age, sex, body mass index [BMI], any physical activity details), study setting, physical activity measure, appetite outcome measures and results.

Quality checks

The Cochrane Collaboration's tool for assessing risk of bias was used to assess selection bias, performance bias, detection bias, attrition bias, reporting bias as well as other bias that may exist in the selected studies [27]. Study inclusion was not influenced by the results of the risk of bias assessment.

Results

The database search yielded 261 articles and a further 5 were identified from reference lists. Of these, 31 were eliminated as duplicates and a further 201 based on title and abstract screening. Full text was retrieved for 34 articles, of which 8 satisfied the inclusion criteria. Figure 1 illustrates the systematic review flow diagram.

Studies were conducted in the US [28; 29; 30; 31; 32; 33], the Netherlands [34] and Denmark [35]. Participants were aged 70.6±1.4 years and had a BMI of 25.3±0.7 kg.m^2 and included 297 males and 380 females.

Three of the studies were cross sectional comparing trained and untrained groups [28; 29; 32], one was a cross sectional cohort study [33]. Two of the studies were randomised control intervention trials [30; 34] and two were intervention trials with no control group [31; 35]. No acute studies were found during literature searching.

Physical activity descriptive

Physical activity was defined in a variety of different ways depending both on the type of the study (cross sectional versus intervention) (Electronic Supplementary Material Appendix S1).

Cross sectional

One cross sectional study examined individuals that had been resistance training ≥2 times per week for at least 6 months [29]. The other cross sectional study, by some members of the same research group, was based on requiring specific thresholds in both VO_{2max} and estimated weekly energy expenditure from activity [28]. In the Van Walleghen et al. [32] study, physically active subjects spent ≥150 min/week engaged in self-reported moderate and/or vigorous physical activity for ≥2 years. In the cohort study by Shahar et al. [33], physical activity was calculated from measuring total energy expenditure from doubly labelled water subtracting resting metabolic rate from indirect calorimetry and thermic effect of meals. Activity energy expenditure was then divided into tertiles.

Intervention

Four studies were intervention trials, one based on gradually increasing moderate intensity physical activity twice per week for 45 min for 17 weeks. Emphasis was placed on skills training to develop muscle strength, coordination, flexibility, speed and endurance. All were trained using activities such as walking, stooping and chair stands, thereby aiming to improve performance of daily pursuits [34]. Another was a resistance training intervention [30] consisting of high intensity progressive resistance training activities for the hip and knee extensors lasting 45mins for 3 days/week over 10 weeks. These two studies also had a nutrition arm and a combined nutrition and physical activity arm.

In Poehlman and Danworth [31], the cycling activity consisted of cycling 3 times/week for 8 weeks. Prior to each session 10 min of flexibility exercises were completed followed by cycling at 60% VO_{2max} to expend 150 kcal. This increased during the 8 weeks to 85% of their VO_{2max} and expending 300 kcal per session. In Rosenkilde et al. [35] a 14-day cycling trip with a total distance of 2706 km was monitored with the cyclists undertaking 193 ± 10 km/day. Both studies had no control group.

Measurements

Appetite measures

Appetite measures varied in the studies (Table 2). Appetite measures consisted of appetite questionnaires on a 13-point category scale [28; 29], 5 point Likert scale [33; 34], visual analogue scales. Energy intake measures consisted of 24 hour food records [28], 3 day food records [30; 31; 34], food frequency questionnaire [33], total energy intake during the cycle [35] and energy intake at an ad libitum meal [29; 32].

Endocrine measures

Endocrine measures that have been linked to appetite were also measured in some studies including total ghrelin, glucagon-like peptide- 1 (GLP-1) [29; 35], CCK [29], insulin [29; 31; 32; 35], PYY3–36 and plasma leptin [35].

Outcome

Cross sectional

In the cross sectional studies there was no effect of having a higher VO_{2max} [28] or resistance training [29] or self-reported physical activity [32] on appetite responses and no difference in energy intake [28], ad libitum energy intake [29; 32], postprandial ghrelin, GLP-1 [29; 32] or insulin [29; 32]. In Apolzan et al, [29] the resistance training group had a higher fasting and postprandial plasma levels of the satiety hormone cholecystokinin. However, in Shahar et al. [33] energy intake and the prevalence of good appetite was higher and fewer participants reported that they did not enjoy their meals in the highest tertile of Daily Activity Energy Expenditure (DAEE). Energy intake regulation over the course of a day was also more accurate in active vs sedentary adults in the Van Walleghen study [32].

Intervention

Over 17 weeks, a skills-based activity intervention showed no effect on perceived appetite. However the physical activity increased energy intake and carbohydrate intake compared with those not undertaking physical activity [34]. During a resistance training activity intervention, energy intake was reduced in the control and supplement groups, however the physical activity intervention caused less of a decrease in energy intake during the study. And total energy intake was significantly increased in the group receiving both supplement and physical activity [30]. Poehlman and Danforth [31] found energy intake from food diaries increased in 18 of 19 individuals with no change in plasma insulin. In contrast, Rosenkilde et al. [35] found fasting concentrations of insulin, GLP-1, and PYY3–36 increased and fasting leptin and ghrelin remained unchanged, although fasting ghrelin concentrations were lower in 5 of 6 subjects after cycling. Ratings of hunger increased in the evening and morning and ratings of fullness decreased in the evening. Net energy balance was negative.

Discussion

Current guidelines suggest that older adults who are concerned about a reduction in their appetite should increase their physical activity levels [21; 22]. This systematic review aimed to assess if either regular, habitual physical activity or physical activity interventions can influence appetite and energy intake and endocrine measures linked to appetite. However**,** the limited number of studies and the wide range of time-scales and interventions mean that definite outcomes are difficult to identify, indicating that at this stage these guidelines are not supported by sufficient evidence.

Four cross sectional studies were identified that compared groups of individuals that were either trained or untrained. All except one study found no difference in the appetite or energy intake [33] between groups. One of the studies [32] found that energy intake regulation over the course of a day was more accurate. Meaning that individuals who participated in physical activity were better at compensating for their previous food intake, but that acute energy intake (an ad libitum meal) regulation is impaired in older adults, which is not attenuated by physical activity status. However, this contradicts work by Flint et al. [36]. Their findings suggest that non-obese young and older adults of the same sex, BMI and physical activity level had a similar energy intake despite a significant age difference. Hence, it is possible that once declining physical activity levels in older adults are accounted for [37] there may be no differences between energy intakes in younger and older adults. One of the cross sectional studies included in this review [28] supports this point further. The study found that although older subjects had lower mean hunger and desire to eat responses and lower peak hunger and desire to eat, when adjusted for VO_{2max}, the mean hunger and desire to eat relationships for age remained significant, but the peak hunger and desire to eat responses were no longer significantly different for age. As age increases, the number of hours of physical activity decreases, as does their description of their appetite as 'average' or 'poor' [38]. Flint et al. [36] speculated that if older adults were to remain as active as they were when younger, they would not have any age-related reduction in appetite, though reductions in appetite due to illness and medication may still exist [39]. Cross sectional studies however can only provide limited evidence.

To date only four intervention studies have taken place, two were based on resistance and skills training and the others did not have a control group. All the intervention studies included in this review demonstrated increases in energy intake, though not all of the physical activity resulted in sufficient energy intake to compensate for the increase in energy expenditure associated with the activity [35]. It is interesting to note that none of the interventions met with or tried to meet the current UK guidelines for physical activity. Current UK guidelines state that older individuals should be undertaking moderate-intensity aerobic physical activity for at least 150 minutes/week; or in vigorous-intensity activity for 75 minutes/week as well as muscle strengthening activities involving the major muscle groups of the body on two or more days per week [40]. Only Rosenkilde et al [35] exceeded this in terms of amount of time spent in moderate/vigorous activity as the participants under took a 14-d cycling trip at a distance of 2706 km.

We hypothesised that energy intake might be increased in those that undertake regularly physical activity due to accelerated GE. This is based on research in habitually active younger adults by Horner et al. [18] and in older adults in Shimamoto et al. [19]. However, in Horner et al. [18] active was defined as undertaking four or more structured exercise sessions per week, where one exercise session was defined as at least 40 min of moderate to high intensity activity. Three of the four intervention studies in this review did not undertake as much physical activity as Horner et al [18] as they were based on resistance training [30] or a skills based activity session [34]. Another used a physical activity intervention that involved cycling 2706 km over 14 days, which is impractical for the majority of older adults, and resulted in a negative energy balance [35]. The final study [31] provided a physical activity intervention (cycling 3 times per week a stationary bike) that was more realistic but still did not meet recommended guidelines [40]. The research by Horner et al. [18] indicates that prescribed exercise may increase appetite by accelerating GE, however the research in older adults was unclear about how much activity was undertaken by the active elderly group [19]. Conversely research in cyclists versus untrained individuals (aged 18-30 years) found no differences between groups [41] indicating that other mechanisms such as lean body mass may need to be investigated [42].

As outlined in the introduction, the physiological benefits of physical activity to older adults are numerous. One potential benefit is the increase or maintenance of muscle mass [43]. Resting metabolic rate has been shown to predict energy intake and hunger, with resting metabolic rate being primarily determined by fat-free mass [44; 45]. Hence increases or maintenance of muscle mass may have implications for energy intake. Other potential mechanisms by which habitual physical activity may increase food intake could be by providing a social outlet for older adults. It is known that loneliness is one of the key factors causing decreased food intake in older adults [46; 47]. Hence if physical activity is performed habitually in a social context it potentially has the ability to help decrease loneliness.

This systematic review was limited by the number of studies available. Although a large number of studies collect data on both physical activity and food intake, the majority do not compare the relationship between the two. The physical activity used in the reviewed studies varied considerably, and none of the studies looked at the effect of acute physical activity on appetite, suggesting a potential area for further research. Measurement of appetite and energy intake was via a variety of methods. They included 24 hour food records, 3 days food records and food frequency questionnaires all of which are indirect measures of food intake and have been shown to have limitations, particularly in the elderly, who may have diminished functional ability and a reduction in short term memory [48]. Only two studies used measurements of *ad libitum* food intake in a controlled laboratory environment which made it harder to draw conclusions from the data and suggests the need for more clinical trials using accurate measures of food intake. The heterogeneity of the study cohorts and range of intervention details are also factors, with the inclusion of frail individuals and interventions including intense endurance activities making it hard to make definitive recommendations.

Conclusions

This systematic review indicates that there is no sufficient evidence currently available to support the advice that physical activity may attenuate the decrease in appetite and energy intake that occurs due to ageing. However there are many benefits associated with physical activity including increasing lean body mass and increasing resting metabolic rate [23] which are positively associated with appetite [49; 50]. This review calls for further placebo controlled, clinical intervention trials using guideline physical activity goals and incorporating a complete spectrum of the satiety measures and direct measures of food intake.

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Conflict of interest

There are no conflicts of interest associated with this paper.

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Figure headings:

Figure 1. Flowchart of methodology used for identifying studies included in the systematic review.

Tables

Table 1. Keywords included in database search strategy

Physical activity	Ageing	Appetite	Energy intake	Endocrine measures
Motor activity	Elderly	Feeding behavior or food preferences	Diet	Gut peptide
Exercise	Older	Hunger	Calori* intake	Peptide YY or PYY
Oxygen consumption	Senescent	Satiety	Food intake	Ghrelin
Physical Fitness	Geriatric	Satiation	Meal size	Glucagon-like peptide-1 or GLP-1
Exercise tolerance	Retired	Fullness	Energy compensation	Pancreatic polypeptide or PP
Exercise test		Motivation to eat	Energy density	Leptin
Physical endurance		Food choice	Dietary protein or dietary fat or dietary carbohydrate	Insulin
Physical performance		Food selection	Macronutrient	Cholecystokinin or CCK
Aerobic		Desire to eat		
Aerobic capacity		Palatability		
Training		Food reward		
Maximal VO2		Hedonic		
Physical capacity		Liking		
		Wanting		

Table 2: Appetite related outcome measures and results in the studies included in the systematic review. The studies highlighted in grey indicate intervention studies.

	Food intake	**Ad libitum meal**	**Appetite rating**	**Endocrine measures**
Apolzan et al. (2009) [28]	24 hour food records =	n/a	13 point category scale =	n/a
Apolzan et al (2011) [29]	n/a	ad libitum meal =	13 point category scale =	CCK + total ghrelin = glucagon-like peptide- 1 (GLP-1) = insulin =
De Jong et al (2000) [34]	3 day food records +	n/a	5 point likert scale =	n/a
Fiatarone et al. (1994) [30]	3 day food records +	n/a	n/a	n/a
Poehlman et al. (1991) [31]	3 day food records +	n/a	n/a	Insulin =
Rosenkilde et al. (2015) [35]	n/a	n/a	visual analogue scales +	total ghrelin = glucagon-like peptide- 1 (GLP-1) + PYY3–36 + Leptin = insulin +
Sharar et al. (2009) [33]	food frequency questionnaire +	n/a	n/a	n/a
Van Walleghen et al. (2007) [32]	n/a	ad libitum meal =	visual analogue scales =	Insulin =

=indicates no significant difference

+indicates it significantly increased

n/a indicates that this measure was not collected in this study

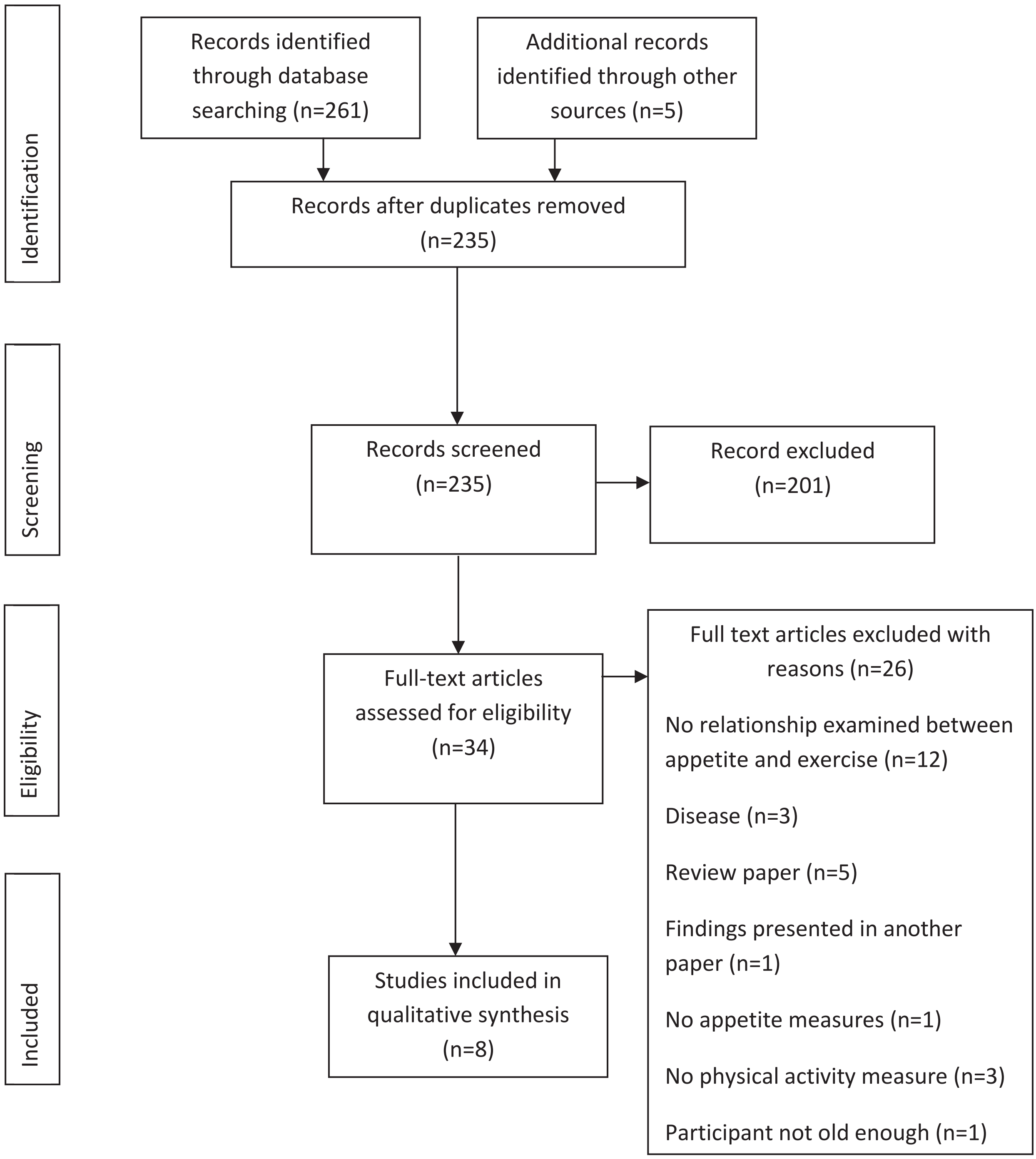

Figure 1. Flowchart of methodology used for identifying studies included in the systematic review.

Appendix 1: Summary of included studies and their characteristics and findings

	Study type	Participants			Setting	Physical activity measure	Food intake / appetite measure / Endocrine measures	Results
		Sex	Age (years) BMI (kg/m^2)	Any other				
Apolzan et al. (2009) [1]	Cross-sectional	YA: 7 m, 4 f YI:8 m 5 f OI: 8 m 8 f OA: 8 m 8 f	YA: 25±1 YI: 25±1 OI: 69±1 OA: 72±1 YA:23.5±0.6 YI: 26.1±1.0 OI:27.7±1.0 OA:24.2±0.7	VO_{2max} (mL/kg/min) YA:47.5±1.9 YI:33.7±1.6 OI:39.5±2.0 OA:25.0±1.4	Comm unity based	Inactive participants: VO_{2max} below average for their age group and a sedentary lifestyle of <1000 kcal/week. Active participants: VO_{2max} above average for their age group and an active lifestyle >2500 kcal/week.	Appetite questionnaire hourly during waking hours for 24 hours. 24-h food record completed on the same day	Appetite responses were altered by age, but not activity status No physical activity status differences were observed for energy intake.
Apolzan et al (2011) [2]	Randomised, mixed-model, cross-over design study. Cross-sectional for training status	S: 9m 9f RT: 7m 9f	S: 75±2 RT: 69±1 S: 25.7±0.5 RT: 24.0±0.6	Vigorous activity index [3] per month S: 10.8±3.4 RT: 40.0±3.3	Comm unity based	S: Not engaged in RT in the previous 6 months. RT: Engaged in RT ≥2 times/week ≥ 6 months.	Effects of food form on ratings of hunger, fullness, desire to eat, insulin, ghrelin, CCK, GLP-1. Food intake at an ad libitum meal	The RT group had a higher fasting and postprandial plasma CCK concentration. No difference in appetite responses, ad libitum food intake, postprandial ghrelin, GLP-1 or insulin
De Jong et al (2000) [4]	Intervention (randomised placebo controlled) for 17 weeks in 4 groups: (1) C (2) Nut (3) Ex (4) Com	159 frail elderly participants 46 m, 113 f C:25 f 12 m N:30 f 11 m Ex:28 f 11 m Com: 30 f 12 m	(Mean±SD) C:79.3±6.6 Nut: 79.6±4.8 Ex: 76.7±4.4 Com:79.2±6.1 C: 24.1 ±3.2 Nut: 24.4 ±2.5 Ex:24.5 ±3.0 Com: 25.0±2.5	Activity score based on the PASE (0±400) for the median score (P10±P90)) C: 59 (34-97) Nut:59(27-	Comm unity based	Group exercise sessions 2/ week for 45 min. Moderate gradually increasing intensity. Emphasis placed on skill training; muscle strength, coordination, flexibility, speed and	At baseline and week 17, a 3day estimated dietary record was collected. Measurements of perceived appetite on a likert scale taken at 0 and 17 weeks.	No effect of the exercise intervention on perceived appetite. Exercise increased energy intake and carbohydrate intake (P = 0.05) compared with the non-exercisers.

				117) Ex: 63 (27-100) Com: 59 (30-111)		endurance.		
Fiatarone et al. (1994) [5]	Intervention (randomised placebo controlled) for 10 weeks in 4 groups (1) Rex (2) Supp (3) Com (4) C	100 frail nursing home residents Rex: 16 f 9 m Com: 16 f 9 m Supp:17 f 7 m Control:14 f 12 m	Rex: 86.2±1.0 Com: 87.1±1.2 Supp: 85.7±1.2 Control: 89.2±0.8 Rex: 24.9±0.7 Com: 24.5±0.8 Supp: 25.4±0.7 Control: 25.8±0.5		Residential care facility	High intensity progressive resistance training 3 days/week for 10 weeks for 45 min. Exercises for the hip and knee extensors.	3 day weighed food diary before and at 10 weeks. Measures were intake from diet (ad libitum intake) and combined intake form diet and supplements (total intake)	Exercise significantly blunted the decrease in ad libitum food intake during the study. Total energy intake was significantly increased only in the group receiving both supplement and exercise.
Poehlman et al. (1991) [6]	Intervention – not randomised controlled	19 individuals 13 m; 6 f	64.0±1.6 25.0±0.7	VO_{2max} (mL/kg/min) 29.2±1.4	Community based	Cycling exercise 3 times/week for 8 weeks. 10 min of flexibility exercises followed by cycling at 60% VO_2max to expend 150 kcal this increased during the 8 weeks to 85% of their VO_2max and expending 300 kcal per session.	Energy intake before the exercise program and at week 10were recorded for 3 days. Plasma insulin	Energy intake from food diaries increased in 18 of 19 individuals. No change in plasma insulin.
Rosenkilde et al. (2015) [7]	Intervention – not randomised controlled	6 men	61 ± 3 Not given	VO_{2max} (mL/kg/min) 48 ± 2 Height: 178±3cm Weight 77.4±4.2 kg	Community based	14-d cycling trip with a distance of 2706 km	Subjective appetite ratings by VAS for hunger, satiety, fullness, and prospective food intake. Total ghrelin, GLP-1, and PYY3–36, plasma leptin Total EI during the cycle	Net energy balance was negative. Fasting concentrations of insulin, GLP-1, and PYY3–36 increased. Fasting leptin and ghrelin remained unchanged, although fasting ghrelin concentrations were lower in 5 of 6 subjects

								after cycling. Ratings of hunger increased in the evening and morning and ratings of fullness decreased in the evening.
Sharar et al. (2009) [8]	Cross sectional cohort	302 individuals 150 m 152 f	In tertiles of DAEE; (mean±SD): 1(<521 kcal/d): 75.3±2.9 2(521-761): 74.8±2.8 3(>761): 74.4 ±3.0 1:m 25.5±4.6 F 26.8±5.2 2: m 27. 4±3.7 f 27.1±5.1 3: m 27.7±3.9 F 28.9 ±6.2		Not clear	Activity energy expenditure measured from doubly labelled water	A modified Block FFQ. A self-evaluation of appetite. Ratings of current appetite or desire to eat compared with one year ago. Appetite using section 1 of the Three factor eating questionnaire [9].	Energy intake and the prevalence of good appetite was higher and fewer participants reported that they did not enjoy their meals in the highest tertile of DAEE.
Van Walleghen et al. (2007) [10]	Cross-sectional	29 young and 25 older adults: YA: 7 m, 8 f YS: 7 m, 7 f OA: 8 m, 6 f OS: 5 m, 6 f	YA:23 ±1 YS: 26±1 OA: 68±2 OS: 69±2 YA:23.1 ±0.7 YS: 23.5±0.8 OA: 24.5±0.8 OS: 24.8±0.7	VO_{2max} (mL/kg/min) YA: 55.6±2.7 YS:37.9 ±1.9 OA: 32.8±2.3 OS: 21.7±1.0	Community based	Physically active subjects spent ≥150 min/week engaged in moderate and/or vigorous physical activity for ≥2 years.	Ad libitum lunch following either a preload (1988 kJ men, 1507 kJ women or no preload. Total daily energy intake. VAS scales for hunger and fullness. Plasma insulin	No age by physical activity interaction for acute compensation or for shorter term compensation for energy intake. There was also no age by physical activity interaction for VAS scales. Fasting insulin and insulin sensitivity was greater in the exercising groups

YA: Younger physically active	S: Sedentary	C: control	Rex: Resistance exercise	PYY: peptide tyrosine tyrosine	YA: young active
YI: Younger physically inactive	RT: Resistance trained	Nut: nutrition intervention	Supp: Multinutrient supplementation	EI: energy intake	YS: young sedentary
OI: Older physically inactive	CCK: Cholescystokinin	Ex: exercise		DAEE: Daily Activity Energy Expenditure	OA: older active
OA: Older physically active	GLP-1: Glucagon-like peptide-1	Com: Both interventions		FFQ: Food Frequency Questionnaire	OS: older sedentary
		PASE: Physical Activity Scale for the Elderly		VAS: visual analogue scales	

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Appendix 2: Analysis of bias using the Cochrane Collaboration's tool for assessing risk of bias

	Random sequence generation.	Allocation concealment	Blinding of participants and personnel	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	Other sources of bias
Apolzan et al. (2009)	n/a	Not clear	Not clear	High risk	Not clear	Low risk	Low risk
Apolzan et al (2011)	n/a	Not clear	Not clear	Low risk	Not clear	Low risk	Low risk
De Jong et al (2000)	Low risk	Not clear	Low risk	Not clear	Not clear	High risk	Low risk
Fiatarone et al. (1994)	Low risk	Low risk	Low risk	Not clear	Low risk	High risk	Low risk
Poehlman et al. (1991)	n/a	n/a	n/a	Low risk	Not clear	High risk	High risk
Rosenkilde et al. (2015)	n/a	n/a	n/a	High risk	High risk	Low risk	High risk
Sharar et al. (2009)	n/a	n/a	n/a	Low risk	Low risk	High risk	Low risk
Van Walleghen et al. (2007)	Low risk	n/a	n/a	Low risk	High risk	Low risk	High risk