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Opinion Paper

Development of an approach for identifying overnutrition among older adults in community health care settings: - an opinion paper

Tenna Christoffersen [a, *], Anne Marie Beck [b], Inge Tetens [c], Anja Weirsøe Dynesen [a], Margit Dall Aaslyng [a]

[a] University College Absalon, Slagelse, Denmark
[b] The Dietetic and Nutritional Research Unit, EATEN, Herlev and Gentofte University Hospital, Herlev, Denmark
[c] Department of Nutrition, Exercise and Sports, Copenhagen University, Copenhagen, Denmark

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S U M M A R Y

Background: Along with demographic changes, a larger number of older adults may encounter health risks related to overweight and obesity. According to the obesity paradox, it is still uncertain whether nutritional interventions aiming at weight loss in older adults has favorable or adverse effects on health.
Aims: We aim to propose an approach that can be applied in community health care settings for identifying overnutrition among older adults with overweight or obesity in order to find those who may benefit from a nutritional intervention aimed at controlling body weight and maintaining or increasing physical function and quality of life. A second aim is to substantiate the proposed approach with results from the scientific literature on nutritional interventions.
Methods: The approach was developed in a stepwise, followed by a narrative literature review.
Results: The approach proposed for risk screening of older adults includes BMI $\geq$ 25 kg/m^2, minimum one physical function criterion (muscle strength or physical performance) or one metabolic criterion (presence of non-communicable disease (NCDs)). Appropriate criteria, assessment tools and cut-off values adapted to older adults in community care settings are proposed for both. A total of 10 intervention studies (13 papers) identified in the narrative literature search supports that nutritional interventions including exercise are

* Corresponding author.
E-mail addresses: tch@pha.dk (T. Christoffersen), Anne.Marie.Beck@regionh.dk (A.M. Beck), ITE@ku.dk (I. Tetens), andy@pha.dk (A.W. Dynesen), mada@pha.dk (M.D. Aaslyng).

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effective for older adults with overnutrition (BMI $\geq$ 25) and concurrently low physical function and/or NCDs.

Conclusion: An approach was proposed including screening for BMI $\geq$ 25, functional and NCD criterion. The approach confirmed by a narrative literature review, revealed a high heterogeneity of nutritional intervention studies in overweight and obese adults in community health care settings.

Abbreviations

ADL	Activities of Daily Living
BC	Body composition
BDD	Balance Deficit Diet
BIA	Bioelectrical Impedance Analysis
BMD	Bone Mass Density
BMI	Body Mass Index
BW	Body weight
DBW	Desirable Body Weight
CR	Caloric Restriction
DEMMI	De Morton Mobility Index
DRM	Disease Related Malnutrition
DXA	Dual-energy X-ray Absorptiometry
ESPEN	European Society for Clinical Nutrition and Metabolism
EWGSOP	European Working Group on Sarcopenia in Older People
EX	Exercise
FFQ	Food Frequency Questionnaire
HE	Healthy Eating advice
HGI	High Glycemic Index
HPI	High Protein Intake
GS	grip strength
IBC	Individual Behavioral Counseling
IL-6	InterLeucin-6
ILCD	Intensive Low Calorie Diet
IPAQ-SF	International Physical Activity Questionnaire – Short Form
LCD	Low Calorie Diet
LE	Low Extremity
LGI	Low Glycemic Index
MGF	MechanoGrowth Factor
MM	Muscle Mass
MNA	Mini Nutritional Assessment
MRI	Magnetic Resonance Imaging
MUST	Malnutrition Universal Screening Tool
6MWT	6-Minute Walk Test
NCD	Non-Communicable Disease
NCEP ATP III	National Cholesterol Education Program's Adult Treatment Panel III
NPI	Normal Protein Intake
NRS-2002	Nutritional Risk Screening
OS	Obesity Sarcopenia
PF	Physical Function

PPT	modified Physical Performance Test
QoL	Quality of Life
SAT	abdominal subcutaneous adipose tissue
SD	Standard Deviations
SPPB	Short Physical Performance Battery
RT	Randomized Trial
RCT	Randomized Controlled Trial
1-RM	one-Repetition Maximum
T2D	Type 2 diabetes
TEE	Total Energy Expenditure
TLR-4	Toll-Like Receptor-4
TNF-α	Tumor Necrosis Factor α
TUG	Timed Up and Go
UE	Upper Extremity
VAT	Visceral Adipose Tissue
VLCD	Very Low Calorie Diet
VO_2max	max/peak aerobic power
WC	Waist Circumference
WHO	World Health Organisation
WL	Weight Loss
WS	Weight Stable

Introduction

The world's population is becoming increasingly older and concurrently more overweight and obese [1]. Overweight and obesity (Overnutrition) is defined as *"abnormal or excessive fat accumulation that may impair health"* [2] and is classified by body mass index (BMI) [2]. Overnutrition is associated with decreased physical function i.e. low muscle strength and functional ability to perform physical tasks [3–5] as well as increased risk of non-communicable diseases (NCD) [3,4,6,7] which together is associated with obesity sarcopenia [8,9], all considered important aspects to prevent according to the WHO definition of healthy ageing [9]. Community health care requires effective interventions to overcome these problems [10].

The 'obesity paradox', refers to the hypothesis that in some older adults, a high BMI at least up to 30 kg/m^2 [11–13] may be protective and associated with decreased morbidity and mortality [14]. However, for other older adults, BMI $\geq$ 25 has been shown to promote inflammation and reduce muscle mass [15,16], leading to an increased risk of morbidity and mortality [4,17,18].

Ageing alone is associated with increased fat mass, decreased muscle mass [19] and increased levels of inflammation [4,12,20]. In combination with overnutrition, reduced muscle mass and NCD-related inflammation may synergistically worsen each of these conditions [21].

Interventions with nutrition-induced weight loss and exercise have in some studies [10,11,21–28] been effective in increasing physical function, although concerns remain whether weight loss may increase unintentional adverse effects such as loss of muscle mass [21] with potentially detrimental effects on Quality of Life (QoL).

Malnutrition defined as *"a state resulting from lack of intake or uptake of nutrition that leads to altered body composition and body cell mass leading to diminished physical and mental function and impaired clinical outcome from disease"* [29] among older adults has received intensive attention, compared with overnutrition, although this is also classified as a nutrition-related condition [30]. Nevertheless, overnutrition classified by BMI $\geq$ 25 [2] is hardly ever a part of the criteria in screening models [31–33] when identifying older adults who may benefit from nutritional interventions [10,11,21–28]. Due to high prevalence of overnutrition, an approach focusing on overnutrition may be a valuable next step in conceptualizing a strategic framework for public health action targeted at the community health care closest to the older adults. However, an approach must also consider other criteria, including metabolic and functional criteria, as is the case for GLIM criteria for the diagnosis of malnutrition [32,34,35].

The aim is to propose an approach in community care settings for identifying overnutrition among older adults who may benefit from an intervention aimed at controlling body weight and maintaining or increasing physical function and QoL. The approach will be substantiated with results from the scientific literature.

Methods

The methods used are divided into two parts

Part 1: Proposal for an approach for identifying overnutrition in older adults in community care settings

Initially, the relevance of assessing BMI was investigated, based on existing literature and including a mapping of the relevance of physical function. This was followed by considerations in the literature of the significance of NCD in relation to overnutrition. A classification of different groups of overnutrition was established on the basis of the results and considerations of the importance of NCD and of physical function. By combining this information, an approach was proposed. As a next step, an extensive examination of existing approaches and tools used in screening and assessment of sarcopenia, malnutrition or frailty was conducted to determine relevant criteria. Both the approach and the selected criteria were aimed at representing measures that should be readily available and easy to use and understand for health care professionals in a community care setting.

Part 2: Substantiation of the approach to identify overnutrition among older adults who may benefit from a nutritional intervention

Substantiation of the approach was conducted by reviewing the literature on randomized nutritional interventions targeted at older adults with overnutrition. The relevant literature was identified by a literature search using Cochrane Library, PubMed, and CINAHL from January 2006 to June 2020 with pre-defined inclusion and exclusion criteria and search terms according to the Cochrane recommendations [36] as described in Table 1.

Selection of relevant studies against the background of the inclusion criteria was independently confirmed by at least two of the authors, and all authors participated in the analysis and interpretation of findings for each topic. Data were collected and organized into three groups according to the approach.

Results

Part 1: Proposal for an approach for identifying overnutrition in older adults in community care settings

The relevance of using BMI as a tool to classify older adults with overnutrition

Identifying and assessing overnutrition in older adults is not a straightforward process. BMI is an easy screening tool that correlates with the percentage of fat in young and middle-aged adults [4] but not necessarily in older adults, who usually have a larger proportion of fat mass compared with younger adults with the same BMI [4]. In addition, age-related loss of height due to the compression of

Table 1
Search terms and inclusion and exclusion criteria for identification of randomised studies on nutritional interventions in older overweight and obese adults.

'Overweight' OR 'obesity' OR 'obese'	AND	'Geriatric' OR 'elderly' OR 'ageing' OR 'older'	AND	'Nutritional intervention' OR 'dietary intervention' OR 'dietary intake'
Inclusion criteria	English language, age ≥ 65 years, BMI≥ 25, randomized trial including dietary interventions.			
Exclusion criteria	Single makers of vitamin and/or mineral supplementation intake and/or novel agents e.g. coffee.			

vertebral bodies and kyphosis can alter the relation between BMI and percentage of fat [11,37–39]. Accordingly, age-related changes in body composition using BMI in older adults tend to underestimate fatness, whereas loss of height will tend to overestimate fatness [4,37]. In summary, BMI may classify some older adults without excess fat mass as overnutrition and fail to classify others who have excess fat mass [4,11,37]. This will potentially bias the prevalence of overnutrition in older adults.

Besides BMI, other tools for assessing Overnutrition are available [11] eg. Waist Circumference (WC), percentages of fat, or assessing body composition by Bioelectrical Impedance Analysis (BIA) or Dual-energy X-ray Absorptiometry (DXA). However, these tools are also inadequate in terms of evidence-based cut-off values adapted to older adults and not feasible in practice [11].

While BMI does not entirely predict the adverse effect of obesity in older adults, BMI is easy to determine and is available in community health care and clinical practice and is therefore still considered to be the most valid and commonly used criterion to classify overnutrition [40]. The European Society for Clinical Nutrition and Metabolism (ESPEN) and the World Health Organisation (WHO) define overnutrition in older adults > 65 years as abnormal or excessive fat accumulation that may impair health and is determined by BMI [2,41] using the same cut-off values as in younger people [2,41,42]. We therefore consider BMI to be the most appropriate tool for assessing overnutrition in older adults with the same cut-off points suggested by ESPEN and WHO, even though we acknowledge the limitation in this definition [39].

BMI is also used in other screening tools like Nutrition Risk Screening (NRS)-2002, Mini Nutritional Assessment –Short Form (MNA-SF) and Malnutrition Universal Screening Tool (MUST) applied to older adults [34,43–45], but only targeting low BMI. High BMI and weight gain may be overlooked, and is therefore a criterion in the approach.

The significance of physical function in relation to overnutrition

A decline in physical function caused by late-life overnutrition surpasses the decline that is associated with 'normal' ageing alone [46]. Several studies have shown that overnutrition in older adults is associated with decreased muscle strength and physical performance [3,46].

Several studies [47–50] have investigated the association between overnutrition and physical function in community dwelling older adults. Some studies found that a BMI<30 was associated with an improved physical function [50], while other studies found that BMI and WC were not associated with physical function [49,50]. However, it has also been described that declined muscle quality was associated with a decline in physical function [47,49] and that the obesity sarcopenia affected physical function more negatively than obesity or sarcopenia alone [48]. In summary, the studies indicate that physical function is impacted by the level of muscle mass, muscle quality and not by BMI alone.

A recent cross-sectional study (n=295) found that community-dwelling older adults with low muscle mass but without poor physical performance had fewer disabilities with obesity compared to older adults with low muscle mass and physical function combined with other conditions (e.g. type 2 diabetes (T2D) and coronary disease) [51]. Other studies verify the use of physical function as a prognostic indicator for disablement, frailty, nursing homes admission, hospitalization and mortality [52–55]. This supports that an approach for overnutrition in older adults including an assessment of physical function may provide a more meaningful approach than assessing overnutrition by BMIalone. On this basis, physical function is therefore included in the approach. In the community care setting, the selected physical function criteria include assessment of both muscle strength and physical performance.

The significance of NCD in relation to overnutrition in older adults

It is well established that excess fat mass in overnutrition in older adults contributes to a number of NCDs. NCDs are common among older adults, as a result of the metabolic changes associated with ageing, the accumulation of fat mass with a pro-inflammatory cascade of events such as intramuscular fat infiltration and insulin resistance occur [8]. This negative interrelationship between adipose and muscle tissue [56] is likely to be intensified by the presence of obesity-related NCDs such as cardiovascular disease [4,57,58], T2D [58,59] and chronic respiratory disease [12,37].

Most of these NCDs are associated with chronic or reoccurring inflammation of a mild to moderate degree [34]. The inflammatory processes enhance the catabolism of muscle mass and catalyze the development of sarcopenia, especially at advanced age [30,60,61]. Overnutrition and chronic NCDs are an underlying cause of disability in older adults [62].

Ageing in combination with overnutrition is considered a risk factor for morbidities (e.g. NCDs) and low-level inflammation [4,12,20], and current validated screening models and criterion aimed at identifying malnutrition, e.g. GLIM criteria, Nutritional Risk Screening 2002 (NRS-2002), Mini Nutritional Assessment Short Form (MNA-SF) and Malnutrition Universal Screening Tool (MUST) include the presence of acute disease or injury and chronic disease [30,34,63]. If NCDs related to both overnutrition and age are included as a metabolic criterion, this will potentially create an accurate identification of overnutrition older adults in need of an intervention. Therefore, NCDs related to overnutrition are included in the approach.

Classification of different categories of overnutrition

Overnutrition and malnutrition are generally classified as two different clinical nutritional concepts, however ESPEN raises a concern regarding malnutrition among overnutrition persons with disease, injury or high energy poor quality diets [30]. Excess fat mass may contribute to the formation of malnutrition by causing low-grade inflammation [30]. However, it is unclear how the present diagnostic criteria (e.g. low BMI and weight loss) from ESPEN identify a possible concomitant presence of these conditions in older adults with overnutrition. Furthermore, the above-mentioned studies [47–50] underline the need for addressing physical function in these older adults when evaluating their nutritional status. overnutritionThe concept that overnutrition may hold a health risk especially in older adults with low physical function, i.e., muscle strength or physical performance or who have NCD combined with low physical function is the understanding that underlies the present proposed approach to identify overnutrition.

Proposal for an approach for identifying overnutrition in community care settings among older adults who may benefit from nutritional interventions

Against the background of the various factors described above and inspired by the classification of malnutrition and the GLIM criteria by Cederholm et al. [30,34], three different potential subgroups of older adults with overnutrition assessed as a high BMI ($\geq$25 kg/m^2) are suggested in our proposed approach: 1) overnutrition without NCD and with normal physical function, 2) overnutrition with NCD *or* low physical function, and 3) overnutrition with NCD *and* low physical function (Fig. 1).

Assessment criteria for the approach

The assessment criteria for the approach and appropriate cut-off values are shown in Table 2 and discussed below. The physical function criteria include tests, tools and cut-off values for assessing muscle strength and physical performance recommended by the European Working Group on Sarcopenia in Older People (EWGSOP) [64]. NCD criteria include disease burden including intermediates (BP, serum-lipids) assessed from medical records.

Overnutrition: assessment of BMI. The basic anthropometric data of body weight and height are essential for each risk screening, and calculating the BMI is the first step in approach. Weighing should be carried out in the morning before breakfast [65]. Due to loss of stature or vertebral compression, height can be difficult to measure precisely in older adults [39]. Height can also be measured in recumbent position [66,67] with minimal trouble to the older person. BMI is calculated as body weight (in kg) divided by the square of height (in m) [41].

Based on the BMI, [41] overweight is defined as BMI $\geq$ 25 and <30 kg/m^2 and obesity as BMI $\geq$ 30 kg/m^2, aligned with WHO and ESPEN guidelines [41,42].

Physical function criteria: assessing muscle strength. Muscle strength can be defined as “the amount of force a muscle can produce with a single maximal effort” [68]. In the present approach, muscle strength is evaluated by grip strength or the chair stand test (five times sit-to-stand) as suggested by EWGSOP [64]. Grip strength is a simple tool that represents the hand and arm muscles and can be substituted by lower limb measurement in case of hand impairment [64] (Table 2). The chair stand test measures the

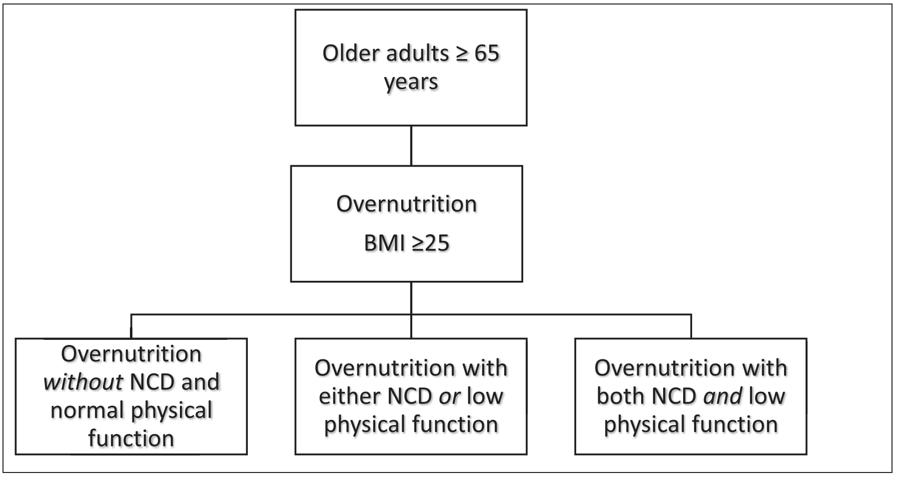

Fig. 1. Classification of overnutrition relevant for identifying overnutrition among older adults who may benefit from nutritional interventions.

Table 2
Assessment criteria to be used for the approach for identifying older adults with overnutrition who may benefit from a nutritional intervention.

Overnutrition		Physical function tests and criteria			NCD assessment criteria	
BMI	AND	Low muscle strength	OR	Low physical performance	AND/OR	Presence of NCDs
$\geq$ 25 kg/m^2 Body weight (kg) and height (m)		Grip strength <20 kg for women and <27 kg for men [69] **OR** Chair stand test (chair rise test) five repetitions > 11.4 sec (60–69 years), 12.6 s (70–79 years), and >14.8 sec. (80–89 years) [70]		Gait speed <0.8 m/s [71] or <1.0 m/s [60] **OR** Short physical performance battery (SPPB) ($\leq$8 point score) [72] **OR** Timed up-and-go test (TUG) ($\geq$20 s) [73] **OR** 400-m walk (Completion time >6 min) [74]		**Yes/no** Presence of cardiovascular disease, chronic respiratory disease and/or type 2-diabetes [75] or hypertension [76,77], hyperglycemia [76,77] or hyperlipidemia [77].

duration of time the participant needs to rise five times from a seated position without using the arms, and represents the strength of leg muscles [64]. A variation of this test is the timed chair stand test, which counts how many times a participant can rise from and sit down on the chair during a 30-second interval [64].

Physical function criteria: assessing physical performance. Various tests can be used to measure physical function in community health care settings, either as measurements of muscle function or as physical performance.

As for assessing muscle strength EWGSOP recommendations are used similar to GLIM criteria. Gait speed is recommended for predicting and evaluating physical function related to sarcopenia [64].

Table 3
Nutritional interventions targeting older adults aged ≥ 65 and with a BMI ≥ 25 with NCD *or* low physical function.

First author (year) and country	Study design, sample size and duration	Study population	Physical function assessment criteria	NCD assessment criteria	Interventions	Outcome measures	Key findings
Ard (2016) USA [78]	RT, n = 28 Duration: 6 months	Community dwelling Males and females 70.3 yrs, Obese (BMI ≈ 41.5 kg/m^2)	No	T2D, hypertension and hyperlipidemia	WL + EX + IBC (n=14) WS + EX + IBC (n=14) No Control group	BW, BC (DXA), physical performance (SPPB) and adverse event frequency.	No changes (P > 0.5) in physical function.
Ard (2018) USA [79]	RCT, n=164 Duration: 52 weeks	Community dwelling Males and females 70.3 ± 4.7 yrs Obese (BMI 30–40 kg/m^2)	No	T2D, hypertension, hyperlipidemia	WS + EX, (n=55) WL + EX, (n=55) EX, (n = 54) No control group	BW, (VAT by MRI), SAT (DXA), BMD (DXA), Physical performance: 6MWT, SPPB, hand GS, knee extension strength and chair sit and reach test). QoL (SF-36v2) and Impact of Weight on Quality of Life-Lite.	No changes (P > 0.5) in physical function. WL group did not have P > 0.5) loss of VAT or LM compared with EX at 12 months, despite a loss of BF and BW compared to the WS and EX groups. QoL improved in all groups.
Beavers (2019) USA [83]	RCT, n = 96, Duration: 6 months	Community dwelling Males and females 70.3 ± 3.7 yrs Obese (BMI 35.4 ± 3.3 kg/m^2)	Self-reported mobility disability	No	WL, (n = 47) WS, (n = 49) No control group	BW, self-reported meal replacement, 24-h urinary nitrogen level (urine samples), height, physical performance gait speed (400-m walk) and BC (DXA).	No changes (P > 0.5) in physical function. At 6 months, total body mass was reduced (*P* < 0.5) in the WL group compared with the WS group with 87% of total mass lost as fat. No change in lean mass.
Frimel (2008) USA [84]	RT, n = 30 Duration: 6 months	Community dwelling Male and females 70 ± 5 yrs Overnutrition (BMI 37 ± 5 kg/m^2)	Frailty meeting at least two of three of the criteria for mild to moderate physical frailty	None	WL + IBC, n = 15) WL + IBC + EX, n = 15 No control group	BC (DXA), muscle strength (1-RM). The volume of UE and LE EX training	WL+IBC+EX group increased UE and LE strength in response to exercise (17–43%), whereas the WL+ IBC group maintained strength. Both groups had similar (P > 0.05) decreases in weight, but the WL+IBC+EX group lost less FFM and LM (P < 0.05).
Kelly (2011) USA [85]	RT, n = 28 Duration: 12 weeks	Community dwelling Males and females 66 ± 1 yr Obese (BMI 34.2 ± 0.7 kg/m^2)	No	Insulin resistance (prediabetic)	Low glycemic index diet + EX, (LGI, n = 13) High glycemic index diet + EX, (HGI, n = 15) No control group	BC (DXA), oral glucose response, and inflammation (TNFα and IL-6).	Both interventions decreased (P < 0.05), BMI, fasting plasma glucose, and insulin. Markers of inflammation were lower

(*continued on next page*)

Table 3 (*continued*)

First author (year) and country	Study design, sample size and duration	Study population	Physical function assessment criteria	NCD assessment criteria	Interventions	Outcome measures	Key findings
							($P = 0.02$) in the LGI than in HGI.
Muscariello (2016) Italy [86]	RT, n = 104, Duration: 3 months	Outpatients Females ≈66 yrs Obese (BMI ≈ 32 kg/m^2)	Sarcopenia defined according to the MM index.	No	WL+NPI (0.8 g/kg/d of protein), (n = 50) WL+HPI (1.2 g/kg/d of protein), (n = 54) No control group	BW, WC, BC (BIA), handgrip strength, dietary intake (FFQ) and physical activity (questionnaire IPAQ-SF)	No change in muscle strength or physical activity Reductions in BMI in both groups; $P < 0.01$. The MM index improved in both NPI and HPI groups, $P < 0.01$ vs baseline.
Nicklas (2018) USA [87]	RT, n = 180 Duration: 20 weeks	Community dwelling Male and females 69.2 ± 3.5 yrs Obese (BMI ≈ 34.5 kg/m^2)	No	T2D, hypertension, hyperlipidemia	EX, (n = 44) WL (LCD), + EX (n=58) WL (VLCD) + EX, (n=53) No control group	Peak aerobic capacity (VO_2 peak) (treadmill exercise test). BC (DXA), lipid and glucose (blood samples). Physical performance (SPPB), (400-m walk). Self-reported disability (19-item questionnaire) Fatigue (Medical Outcome Study 36-item short-form measure)	VO_2 peak increased in all groups. No effects on physical function. LCD and VLCD groups had improvements in fatigue and disability compared to EX group.

OvernutritionBC: Body composition; BF, Body Fat; BIA, Bioelectrical Impedance Analysis; BMD, Bone Mass Density; BMI, Body Mass Index; BW: Body weight; DBW, Desirable Body Weight; DXA, Dual-energy X-ray Absorptiometry; EX, Exercise; 1-RM, one-Repetition Maximum; FFQ, Food Frequency Questionnaire; GS, grip strength; HGI, High Glycemic Index; HPI, High Protein Intake; IBC, Individual Behavioral Counseling; IL-6, interleukin-6; IPAQ-SF, International Physical Activity Questionnaire – Short Form; LCD, Low Calorie Diet; LE, Low Extremity; LGI, Low Glycemic Index; LM, Lean Mass; MM, Muscle Mass; 6MWT, 6-Minute Walk Test; MRI, Magnetic Resonance Imaging; NPI, Normal Protein Intake; Overnutrition, Overweight and Obese; QoL, Quality of Life; RT, Randomized Trial; RCT, Randomized Controlled Trial; SAT, abdominal subcutaneous adipose tissue; SPPB, Short physical performance battery; TNF-α, Tumor Necrosis Factor α; T2D, Type 2 Diabetes; UE, Upper Extremity; VAT, Visceral Adipose Tissue; VLCD, Very Low Calorie Diet; VO_2max, max/peak aerobic power; WC, Waist Circumference; WL, Weight Loss; WS, Weight Stable.

Additionally, the Short Physical Performance Battery (SPPB) is recommended and includes a balance test, habitual gait speed and the five-repetition chair stand test. [55,64]. Timed Up and Go (TUG) is an assessment tool to determine mobility and includes timing rising from a chair, walking three meters, turning around a physical mark and walking back to the chair and sitting down [55]. The 400-m walk test assesses mobility over a long distance, and participants are instructed to walk at a normal pace. The SPPB, TUG and 400-m walk are also recommended as assessment tools by EGWSOP to determine physical function [64]. It is not necessary to implement all assessments – just one can be selected.

NCD criteria: assessing the presence of NCD. NCD information should be derived from medical/health care records and include cardiovascular diseases, chronic respiratory disease, T2Dand cancer [62].

The key metabolic changes that increase the risk of NCDs are also included such as hypertension, hyperglycemia and hyperlipidemia.

The presence of the diseases (*Yes/No*) will potentially identify older adults with adverse effects of overnutrition.

Based on the above, the assessment criteria for the approach and appropriate cut-off values are shown in Table 2.

When older adults with BMI $\geq$ 25 kg/m^2 is classified according to the approach (Fig. 1), the next steps in the nutrition care process should followed according to ESPEN guidelines [30].

Part 2:Nutritional interventions among older adults with overnutrition that are effective in improving or maintaining physical function and quality of life

To validate the approach, a number of nutritional interventions were reviewed in order to determine whether the approach would identify older adults with Overnutrition in need of a nutritional intervention better than BMI itself. Tables 3 and 4 summarize the 10 intervention trials (described in 13 papers) that met our inclusion criteria [78–90]. Details of the studies are shown in supplementary files.

Nutritional interventions targeting older adults with overnutrition without NCD and with normal physical function

No trials within the pre-defined inclusion and exclusion criteria and search terms (Table 1) were found, and it is, therefore, unclear whether an intervention benefits older adults only with a BMI ≥ 25 and without NCD and with normal physical functionality.

Nutritional interventions targeting older adults with overnutrition and either NCD or *low physical function*

Seven studies were identified investigating nutritional interventions targeting older adults (age ≥ 65) with a BMI ≥ 25 and also NCDs or low physical function [78,79,83–87] (Table 3 and supplementary files). Three of the studies included participants with a low physical function in relation to mobility disabilities and mild to moderate physical frailty and difficulty in or in need of assistance with activities of daily living [83,84,86] Additionally, the four other studies investigated older adults (age ≥ 65) with a BMI ≥ 25 and NCD [78,79,85,87].

Two trials by Ard *et al.* [78,79] found no effects on physical function and no significant difference between groups in lean mass was found, although the intervention groups intendedly lost body weight and fat mass [78,79], however quality of life (QoL) improved in all groups [79]. The studies investigated the effect of low energy diets combined with physical training in obese community dwelling older males and females suffering from T2D, hypertension and hyperlipidemia [78,79]. A larger randomized trial from Nicklas *et al.* investigated the effects of exercise (EX) alone or EX with low calorie diet (LCD) or EX with very LCD (VLCD) on several metabolic parameters [87]. VO_2 max increased in all groups, and there was a significant treatment effect, although no effect on physical function measures was found [87],oth groups had significant improvement in self-reported fatigue and disability compared to the EX group [87].

In the study by Beavers *et al.*, a weight loss intervention had no effects on physical function in the weight loss (WL) group compared to the weight stable (WS) group, although the WL group lost body weight and fat mass [83].

Frimel *et al.* included community dwelling older adults with frailty and intervened either with WL alone or with WL and EX [84]. In this trial, loss of lean mass was prevented in the upper extremities, but not in the lower extremities. Both groups lost body weight, but the WL + EX group lost less lean mass and improved strength compared to the WL group ($P < 0.05$) [84]. The paper suggested that this improvement may be due to the effects of a decrease in muscle fat infiltration and inflammation associated with the loss of weight and body fat [84].

Kelly *et al.* recruited community dwelling older adults with obesity and with insulin resistance [85] for an intervention containing either a low glycemic index (LGI of 40) diet and EX or high glycemic index (HGI of 80) diet and EX [85]. Both interventions decreased BMI ($P < 0.001$), fasting plasma glucose and insulin (both $P < 0.05$), although markers of inflammation were lower in the LGI compared to the HGI ($P < 0.05$).

Muscariello *et al.* reported no changes in physical function, although significant reductions in BMI were found in both intervention groups receiving either normal or high protein WL diets [86].

In summary, all interventions aimed at inducing weight loss in the participating groups of older adults with either NCD and/or low physical function were successful. The combination of energy restriction and exercise showed the most significant results in relation to body weight [78,79,83–87] and limited the loss of muscle mass [78,79,83–87]. Although changes in body composition were achieved, significant improvements in physical function were observed only in one study [84] where exercise combined with a nutritional intervention reduced muscle mass loss during weight loss and increased muscle strength in frail obese older adults [84].

Nutritional interventions targeting overnutrition older adults with both NCD and *low physical function*

Three studies investigating nutritional interventions targeted at older adults aged ≥65 and with a BMI ≥ 25 in combination with NCD *and* low physical function are reported in six articles [80–82,88–90] as described in Table 4.

Haywood *et al.* reported improved physical function independent of intervention (EX+HE vs. EX+LCD vs. EX+VLCD) [88]. Weight was reduced in the EX+LCD and the EX+VLCD groups, while the EX+VLCD group had significant reductions in fat mass and lean mass but an increase in relative lean mass [88].

Three papers by Villareal *et al.* (two in 2006 and one in 2008) reported the same cohort with an intervention consisting of WL and EX, compared to a control group [80,89,90]. Energy deficiency was ≈750 kcal/day supplemented with a daily multivitamin tablet [80,89,90]. Physical function improved significantly in modified physical performance test (PPT), max/peak aerobic power (VO_2 max) test and functional status in the WL+EX group compared to the control group, and changes in body composition, decrease in body weight and fat mass decreased significantly in the intervention group [80,89,90]. All cardiovascular risk factors improved significantly in the WL+EX group, and the number of subjects with the metabolic syndrome decreased by 59% in the WL + EX group [90]. In addition, an increase in bone turnover in response to weight loss was seen, but the clinical significance of the decrease in bone mass density was not clear as all participants had high baseline scores and there was no evidence of osteoporosis following the weight loss [80]. It was suggested that weight loss reduced the mechanical stress on the hip without negatively altering the spine or wrist [80].

As in the other RCTs by Villareal *et al.* [80,89,90], a fourth paper by Villareal *et al.* (2011) found changes in body composition and physical function, whereas WL was only achieved in the WLand WLt+EX groups and not in the EX or control group. Physical function and QoL improved significantly in all groups except for the control group [81].

A follow-up study of the one-year lifestyle RCT by Villareal *et al.* (2011) [81] is reported by Waters *et al.* [82]. This shows that, except for the self-reported functional status and health-related QoL, which achieved the highest scores at 12 months, all measures remained improved relative to baseline at 30 months [82].

In summary, the largest weight loss was seen in groups receiving calorie restrictions (WL) and EX combined [80–82,88–90]. The combination of diet-induced WL and EX limited the loss of muscle mass [80–82,88–90]. Unlike the trials described in Table 3 [78,79,83–87], these studies report intervention effects on physical function or function [80–82,88–90] and on QoL [81,82,89]. [88] These studies also cover a range of complex nutrition and exercise interventions, though not as diverse as those in Table 3 [78,79,83–87]. Only one study had no control group [88].

The results in Table 4 show that older adults with overnutrition and NCD and low physical function may gain positive effects from nutrition and EX interventions on physical function, body composition and QoL. Additionally, the studies report other beneficial effects on metabolic syndrome. The results of these trials also show that there is no difference in outcomes of physical function or QoL, regardless of whether the interventions include a weight stable or a weight loss intervention combined with exercise. No serious adverse effects was found in any of the intervention studies (table 3 and 4).

Discussion

The present opinion paper proposes a novel approach that combines a measure of BMI with a physical function criterion and a NCD criteria for identifying older adults with overnutrition who may benefit from a nutritional intervention. The novelty of the present approach is that in addition to BMI, the presence of overnutrition is combined with the presence of NCD and low physical function i.e. low muscle strength and physical performance.

The approach was developed for use in a community health care setting, and the criteria were defined by reliable tests available in community health care settings. Aligned with the EWGSOP consensus,

Table 4
Nutritional interventions targeting older adults aged ≥ 65 and with a BMI ≥ 25 with NCD *and* low physical function

First author (year) and country	Study design, sample size and duration	Study population	Physical function assessment criteria	NCD assessment criteria	Interventions	Outcome measures	Key findings
Haywood (2018) Australia [88]	RT, n = 117 Duration: 12 weeks	Community dwelling Male and females 70 yrs Obese (BMI 40 kg/m^2)	Low/moderate function	T2D, hypertension and hyperlipidemia	HE + EX, (n = 36) WL (LCD) + EX (n = 40) WL (VLCD) + EX (n = 41) No control group	Physical function (DEMMI and 6MWT), BC (DXA) bone mineral density (DXA), blood pressure, glucose monitoring and nutritional parameters.	Physical function improved in all groups. All groups lost weight. VLCD group had significant reduction in FM, LM and BMD, but increased relative LM.
Villareal (2006a) USA [89]	RT, n = 27 Duration: 26 weeks	Community dwelling Males and females ≈70 yrs Obese (BMI ≈ 39 kg/m^2)	Mild to moderate frailty	The number of chronic diseases was 1.6 ± 0.8 (mean ±SD) in the control group and 2.0 ±0.7) (mean ±SD) in the intervention group.	WL +EX (n = 17) Control group (n = 10)	Physical function (PPT score, VO_2 max, and Functional Status Questionnaire score), BC (DXA), Health-Related Quality-of-Life Assessment (The Medical Outcomes Survey 36-Item Short-Form Health Survey (SF-36))	The PPT score (P =0.001), VO_2 max (P–= 0.02), and Functional Status Questionnaire score (P = 0.02) improved in WL group compared with control group. WL group also improved strength, walking speed, obstacle course, 1-leg limb stance time, and health survey physical subscale scores (all P < 0.05). The WL group lost 8.4%±5.6% of body weight, whereas weight did not change in the control group (P < 0.001). Likewise, WL group lost FM but contained LM, unlike the control group. The WL group had improvements in QoL compared to the control group, though not significant.
Villareal (2006b) USA [90] Same study as 54	RCT n = 27 Duration: 26 weeks	Outpatients, Males and females ~ 70 yrs Obese (BMI 39± 5 kg/m^2)	Mild to moderate frailty	Metabolic syndrome	WL + EX (n = 17) Control group (n=10)	WC, blood pressure, serum lipids, fatty acids and inflammatory markers, oral glucose intolerance test, metabolic syndrome criteria and BC (DXA)	Changes in weight loss, WC, plasma glucose, serum triacylglycerols, and systolic and diastolic blood pressure were different between WL group and control group (P< 0.05 for all). The number of subjects with the metabolic syndrome decreased by 59% in WL group but did not change significantly in

(*continued on next page*)

Table 4 (*continued*)

First author (year) and country	Study design, sample size and duration	Study population	Physical function assessment criteria	NCD assessment criteria	Interventions	Outcome measures	Key findings
							the control group (P < 0.05).
Villareal (2008) USA [80] Same study as 54	RCT, n = 27, Duration: 52 weeks	Community dwelling Males and females 70±5 yrs, Obese (BMI 39 ± 5 kg/m^2)	Mild to moderate frailty 40% had sarcopenia	Metabolic syndrome	WL + EX (n = 17) Control group (n = 10)	BW and BMD and BMC of the lumbar spine, proximal femur, and total body (DXA). Skeletal muscle mRNAs for TLR-4, MGF, TNFα, and IL-6 were also assessed.	Relative improvements in strength, assessed by 1-RM, were detected for both upper body and lower body and all muscle groups (all *P* < 0.05). Compared with the control group, WL group had greater changes in BMD, bone markers, and hormones.
Villareal (2011) USA [81]	RCT, n = 107 Duration: 1 year	Community dwelling Males and females ≈ 70 yr, Obese (BMI ≈37 kg/m^2)	Physical frailty	Chronic disease and routine medications	WL (n = 26) EX (n=26) WL+EX (n = 28) Control group, no treatment, (n = 27)	Physical function (PPT), frailty, BC (DXA and MRI), BMD (MRI), and QoL (The Medical Outcomes 36-Item Short-Form Health Survey (SF-36))	Physical function increased in all groups except the control group. BW decreased in WL group and in the WL+EX group, but did not decrease in the EX or control group QoL increased in all three groups

ADL, Activities of Daily Living; BC, Body Composition; BIA, Bioelectrical Impedance Analysis; BMD, Bone Mass Density; BMI, Body Mass Index; BW, Body Weight; DBW, Desirable Body Weight; DEMMI, De Morton Mobility Index; DXA, Dual-energy X-ray Absorptiometry; EX, Exercise; HE, Healthy Eating advice; IL-6, InterLeukin-6; IPAQ-SF, International Physical Activity Questionnaire – Short Form; LCD, Low Calorie Diet; MGF, MechanoGrowth Factor; MM, Muscle Mass; MRI, Magnetic Resonance Imaging; 6MWT, 6-Minute Walk Test; NCEP ATP III, National Cholesterol Education Program's Adult Treatment Panel III; 1-RM, one-Repetition Maximum; Overnutrition, Overweight and Obese; PF, Physical function; PPT, modified Physical Performance Test; RT, Randomized Trial; RCT, Randomized Controlled Trial; SD, Standard Deviations; TLR-4, Toll-Like Receptor-4; TNF-α, Tumor Necrosis Factor α; T2D, Type 2 Diabetes; VAT, Visceral Adipose Tissue; VLCD, Very Low Calorie Diet; VO_2max, max/peak aerobic power; WC, Waist Circumference; QoL, Quality of Life.

muscle strength and physical function are criteria for risk screening of reduced muscle mass. The purpose of the approach is not to diagnose sarcopenia, but to use the framework provided by EWGSOP to identify overnutrition older adults in need of a nutritional intervention. Presumably some older adult have low physical function without sarcopenia, and they are also in need of a nutritional intervention.

The cut-off values used in the approach are based on current knowledge and might be inadequate, especially for the BMI.

Limitations of using BMI as a measure alone is that BMI does not take body composition and fat distribution into account. Therefore the use of BMI alone is associated with certain limitations that may alter the relation between overnutrition and mortality, which partly explains the obesity paradox. Nevertheless, a BMI ≥25 is included and referred to as a high BMI in the approach, despite the ongoing debate concerning the cut-off values for older adults [11,38,91–93].

Muscle strength and physical performance are considered accurate indicators for reduced physical function, at least when the objective is not to try to identify sarcopenia or obesity sarcopenia. Assessing muscle strength and physical performance is a key step in identifying older adults with overnutrition who might benefit from an intervention. The absence of these parameters is a limitation in existing validated assessment tools (NRS-2002, MNA -SF and MUST [31,32,63]).

Muscle strength and physical function can be measured in various ways, but the present opinion paper chooses to focus on tests included in the EWGSOP consensus [64].

Regarding co-morbidities and inflammation, NCD associated with overnutrition includes cardiovascular disease [4], chronic respiratory disease, diabetes and cancer [58,59] Recognition of a disease and inflammation is, a widely accepted criterion in current screening tools such as NRS-2002 [43] and MNA-SF [31]. However, mild to moderate inflammation requires laboratory indicators such as serum C-reactive protein, TNF-α, interleukins, albumin and pre-albumin [34,94] and is not necessarily obtained in community health care settings, and therefore the present approach focuses on the presence of NCD as a determinant for inflammation. Obesity-related comorbidities such as osteoarthritis may also be relevant to include, and may be a short coming to this approach.

To validate the approach, a number of nutritional intervention trials included in the literature search were reviewed. Our literature search to identify relevant intervention studies in the particular target group and settings revealed that interventions have, to a large extent, been performed in the target group of older overweight or obese subjects with either NCD or low physical function at baseline.

No studies were identified in older overnutrition without disease and with normal physical function, which probably illustrates the "obesity paradox" in real life where it is uncertain whether or not overnutrition alone is beneficial for physical function. It remains unclear whether this group of older adults would benefit from a nutritional intervention or perhaps some of these individuals appeared in the study control groups. Besides, ethical considerations may speak against intervening a healthy group of older adults.

Seven studies targeted older adults (age $\geq$ 65) with a BMI $\geq$ 25 *and* NCD *or* low physical function [78,79,83–87] (Table 3). The studies were very heterogeneous, with a broad range of complex nutritional and exercise interventions. None of the studies included a control group, which is a major limitation. However, all interventions had positive effects on WL and body composition, and the studies generally indicate that identifying this group of overnutrition older adults, as suggested in the approach, offers a beneficial tool to the community care setting. Overall, these studies reported that the combination of diet-induced WL and EX resulted in the most significant WL, while still limiting the loss of muscle mass.

Three studies (six papers) were identified targeting older adults aged $\geq$ 65 with a BMI $\geq$ 25 *and* NCD *and* low physical function [27,80,88–90,95] (Table 4). Overall, the results of the interventions, which included nutritional and EX interventions, were positive in terms of body composition and WL. These studies included control groups, which strengthens the conclusion on the effects of the interventions. The studies covered a range of complex nutritional and EX interventions, and they reported positive effects of the nutritional interventions on physical function or function and on QoL. Although only a few studies were available, and since they had a control group, compared to the studies on overnutrition with either NCD or low physical function, the overall results confirm that older adults in community health care settings with overnutrition and NCD and low physical function gain positive effects from nutritional interventions on physical function, body composition and QoL.

Even though the included trials and a large number of reviews [10,21,23,25,26,96–99] suggest interventions that combine nutrition and exercise, more research in this particular target group and specific community health care setting is needed. Lack of scientific evidence in this field is a major barrier to any actions that might be taken in this area. It seems like both groups with older adults with either NCD or low physical function or older adults with both NCD and low physical function, gain positive effects from a nutritional intervention. However, knowledge on which nutritional intervention is safe and beneficial for the different needs of older adults with overnutrition is lacking [11]. Assessing overnutrition, not only by BMI classification but also by considering overnutrition combined with low physical function and/or related to disease and inflammation (Fig. 1) may enlighten the obesity paradox and partly explain why excess fat mass appears to be protective in some older adults and related to morbidity, mortality and disabilities in others.

Lack of evidence in this field is largely due to the absence of consensus on definitions and cut-off points and terms, making it hard to compare results of the different studies [21]. However, it may also be explained by the inclusion and exclusion criteria used in past research. To overcome some of these confounding factors and hopefully enhance our understanding of *who* will benefit from the most nutritional interventions and not merely who is overnutrition, the approach presented in this paper may prove to be a valuable assessment tool. Clearly, the approach requires validation to be further tested and qualified and adjustments made if necessary. However, when applying the approach retrospectively to recent trials carried out including older adults with overnutrition, the criteria of the approach seem to be promising.

Conclusion

For identification in community health care settings of older adults with overnutrition who may benefit from nutritional interventions, we propose an approach using a BMI of $\geq$ 25 kg/m^2 and at least one physical functional criterion (muscle strength or physical performance) or one metabolic criterion (NCDs) as inclusion criteria. We also propose cut-off values adapted to older adults in community care settings. The proposed approach was supported by a narrative literature review, that suggested that interventions combining nutrition and exercise interventions had positive effects on physical function and quality of life, especially on older adults with functional limitations and NCDs.

The narrative literature review also revealed a high heterogeneity of nutritional intervention studies in older adults with overnutrition in community health care settings and more research in this particular target group and specific community health care setting is needed.

Statement of authorship

Tenna Christoffersen: Conceptualization, Methodology, Investigation, Writing – Original draft, Writing – Review & Editing. Anne Marie Beck: Conceptualization, Methodology, Investigation, Writing – Original draft, Writing – Review & Editing. Inge Tetens: Conceptualization, Methodology, Investigation, Writing – Original draft, Writing – Review & Editing. Anja Weirsøe Dynesen: Conceptualization, Methodology, Project administration, Investigation, Writing – Original draft, Writing – Review & Editing. Margit Dall Aaslyng: Supervision, Writing – Review & Editing.

Conflict of Interest Statement and Funding sources

The authors declare no conflict of interest.

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