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Original Article

Adherence to resistance training and hypocaloric diet among persons near retirement age — A secondary data analysis of three randomized controlled trials[☆]S. Bauer^a, L. Reiter^a, P.J.M. Weijts^{b,c}, J.D. Schoufour^b, Y. Boirie^d, E. Topinková^e, R.G. Memelink^f, A.M. Verreijen^g, A. Borenich^h, D. Eglseer^{a,*}, the SO-NUTS consortium^a Medical University of Graz, Institute of Nursing Science, Neue Stiftungsstraße 6 P06 WEST, 8010 Graz, Graz, Austria^b Faculty of Sports and Nutrition, Centre of Expertise Urban Vitality, Amsterdam University of Applied Sciences, Dr Meurerlaan 8, 1067 SM, Amsterdam, The Netherlands^c Department of Nutrition and Dietetics, Amsterdam University Medical Centers, Amsterdam Public Health Institute, VU University, Amsterdam, The Netherlands^d University Clermont Auvergne, Human Nutrition Unit, INRA, CRNH Auvergne, CHU Clermont-Ferrand, Clinical Nutrition Department, 28 Place Henri Dunant, 63001 CLERMONT-FERRAND Cedex 1, Clermont-Ferrand, France^e Charles University, First Faculty of Medicine, Department of Geriatric Medicine, Katerinska 1660/32, 12108 Nove Mesto, Praha, Czech Republic^f Amsterdam University of Applied Sciences, Faculty of Sports and Nutrition, Center of Expertise Urban Vitality, Dr. Meurerlaan 8/1067 SM Amsterdam, Amsterdam, The Netherlands^g HAS Green Academy, Onderwijsboulevard 221, 5223 DE 's-Hertogenbosch, DE 's-Hertogenbosch, The Netherlands^h Medical University of Graz, Institute of Medical Informatics, Statistics and Documentation, Auenbruggerplatz 2, 8010 Graz, Graz, Austria

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ABSTRACT

Objectives: Adherence to lifestyle interventions is crucial for the treatment of obesity. However, there is little research about adherence to lifestyle interventions in persons around retirement age. The objectives of this study are (1) to identify factors associated with the adherence to resistance training and a hypocaloric diet and (2) to describe the association between adherence and changes in body composition outcome parameters.**Design:** This secondary data analysis included three randomized controlled trials.**Setting & participants:** The inclusion criteria of the participants were an age of 55–75 years, a BMI ≥ 25 kg/m² and receiving both a hypocaloric diet and resistance training. All participants were residing in the community.**Measurements:** Adherence to hypocaloric diet was measured through the mean dietary intake on the basis of a 3-day dietary record. If the participant consumed at least 600 kcal less than the individual caloric requirements, they were considered adherent. Adherence to resistance training was achieved if $\geq 67\%$ of the recommended training sessions were attended over the course of the study periods.**Results:** 232 participants were included, 47.0% female, mean age 64.0 (± 5.5) years. 80.2% adhered to resistance training and 51.3% adhered to a hypocaloric diet. Older age (Beta 0.41; 95% CI 0.05, 0.78; $p = 0.028$) and male sex (Beta 7.7; 95% CI 3.6, 11; $p < 0.001$) were associated with higher resistance training adherence. A higher BMI at baseline (Beta 6.4; 95% CI 3.6, 9.2; $p < 0.001$) and male sex (Beta 65; 95% CI 41, 88; $p < 0.001$) were associated with higher adherence to hypocaloric diet.**Conclusion:** We identified several associated factors (sex, age and BMI at baseline) that should be considered to promote adherence in future lifestyle intervention studies in persons around retirement age. We recommend including behavior change techniques in lifestyle interventions and consider sex-specific interventions to improve the adherence of women.© 2024 The Authors. Published by Elsevier Masson SAS on behalf of SERDI Publisher. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).[☆] The trials were registered in the Dutch Trial Register <http://www.trialregister.nl>. MPS: NL2623; <https://www.onderzoekmetmensen.nl/en/trial/34540>. WelPrex: NL4434; <https://www.onderzoekmetmensen.nl/en/trial/40428>. PROBE: NL4357; <https://www.onderzoekmetmensen.nl/en/trial/21917>.

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1. Introduction

Obesity is a serious threat to healthy aging and a major public health concern [1]. Excess body weight increases mortality and morbidity, particularly in respect of cardiovascular disease [2]. Obesity affects about 13 to 20% of European adults and another 35% are overweight, with a growing tendency [3]. Obesity prevalence rates peak in ages 50 to 64 [2], which is near retirement age in most European countries [4].

Literature shows that lifestyle habits might change both for the better or worse near retirement [5–9]. This time can therefore be an opportunity to incorporate new healthy habits into daily life [5].

Nutrition and exercise interventions are important components of comprehensive lifestyle interventions in persons who are overweight or obese [10,11]. For persons of retirement age, it is particularly beneficial to combine nutrition and exercise interventions to reduce body fat and increase muscle mass. Recent reviews indicate that energy restriction alone also reduces body fat, but to a lesser extent, yet ultimately tends to decrease muscle mass [12,13].

Adherence, is defined as the extent to which a person's behavior corresponds with health recommendations [14] and is crucial to lifestyle interventions. A systematic review of 24 studies found that early weight loss success (i.e., during the first 4–5 weeks of a weight loss program), a lower baseline BMI, better baseline mood, older age and being male are associated with better adherence to lifestyle interventions in adults with obesity [15]. Another recent systematic review added that the inclusion of behavior change techniques improves lifestyle intervention adherence [16].

Little research exists on the adherence to nutrition and exercise interventions of older persons, either in general or near retirement age. A systematic review on general health programs in retirement identified a lack of programs specifically tailored to retirees [17]. Improving adherence to lifestyle interventions in persons near retirement age can also improve health outcomes [18]. For clinical practice, it is nevertheless material to know the extent to which an intervention needs tailoring to a target group and which persons require extra attention.

Thus, the aims of this study were (1) to identify factors associated with adherence to resistance training and a hypocaloric diet and (2) to describe the changes in body composition parameters (body weight, fat mass, handgrip strength, gait speed and muscle mass) occurring in the course of the studies and to determine their possible associations with adherence.

2. Methods

2.1. Design and sample

This secondary data analysis was conducted on data collected in three studies performed at the Amsterdam Nutritional Assessment Center at the Amsterdam University of Applied Sciences in Amsterdam, the Netherlands. The following parallel-designed randomized controlled trials were included:

- (1) The MPS (Muscle Preservation Study) investigated the effects of a high whey protein-, leucine- and vitamin D-enriched Oral Nutritional Supplement (ONS), hypocaloric diet and resistance training in older obese adults [19].
- (2) The WelPrex (Weight Loss with Protein and Exercise) study tested the effects of a high protein diet, hypocaloric diet and/or resistance training in older overweight or obese adults [20].
- (3) The PROBE (protein and lifestyle intervention to preserve muscle mass in obese older type 2 diabetes patients) study analyzed the effects of the same high whey protein-, leucine- and vitamin D-enriched supplement as in the MPS, hypocaloric diet and resistance training [21].

The trials were registered in the Dutch Trial Register (MPS: NL2623; WelPrex: NL4434; PROBE: NL4357; <https://onderzoekmetmensen.nl/en>) and were performed between March 2011 and January 2017. The studies were approved by the responsible ethical committee (MPS: METC Amsterdam UMC (24-01-2011); WelPrex: IRB Nijmegen: Independent

Review Board Nijmegen (Wijchen) (25-04-2014); PROBE: Medical Ethics Committee Assen (08-04-2014)). All participants signed an informed consent and the studies conform to the Declaration of Helsinki [19–21]. Further detailed information on the studies can be found in both Supplementary Material 1 and the Dutch Trial Register.

The inclusion criteria for this secondary data analysis were an age between ≥ 55 and ≤ 75 years, a BMI ≥ 25 kg/m² and receiving both a hypocaloric diet and resistance training. Ultimately, data from 232 participants was included in the analysis (Fig. 1).

2.2. Variables

The following variables from the primary studies were included in the two linear mixed models on factors associated with adherence. General characteristics (sex, age, ethnicity (Caucasian/other) and smoking status (current smoker/no current smoker)) were self-reported at baseline [19–21]. Weight and height were measured at baseline and at the conclusion of the study periods and were used to calculate BMI. Body weight was measured on calibrated scales as part of the BODPOD system. Body height was measured to the nearest 0.5 cm using a wall-mounted stadiometer. Fat mass was measured by air displacement plethysmography, also as part of the BODPOD system [19–21]. Early weight loss was defined as a loss of ≥ 1 kg of body weight after 5–7 weeks (mid-term measurement) [19–21]. The variable “high protein recommendation” is related to all patients in the WelPrex study who received the recommendation to consume a high-protein diet (1.3 g) [20].

The third linear mixed model on factors associated with changes in body composition outcomes involved the following variables of sex and age as well as the variable “high protein recommendation”. Furthermore, in this model, body weight, fat mass, appendicular muscle mass, gait speed and hand grip strength were included as parameters for body composition, physical performance and strength at baseline and at the end of the study periods. Appendicular muscle mass was measured with dual-energy X-ray absorptiometry, and physical performance was assessed with a 4-m usual gait speed test [23]. Hand grip strength was measured with an isometric hand grip dynamometer (JAMAR 5030J1; Sammons Preston Rolyan) while the subject was in a sitting position [19–21].

For all three linear mixed models, adherence to lifestyle interventions was calculated separately for the intervention components. Adherence to hypocaloric diet was measured by calculating the individual caloric requirements (based on the Harris-Benedict formula) for each person based on weight, height and age while considering a physical activity level (PAL) value of 1.4 [24]. If the participant consumed at least 600 kcal less than the individual caloric requirements, which was the aim in all three of the included studies, they were considered to be adherent. Dietary intake was measured on the basis of a 3-day dietary record before the intervention, at the midterm and subsequent to the intervention. The average daily dietary intake after the intervention was used to calculate adherence. Attendance of the resistance training sessions was documented as “present” or “not present” by the trainers in writing after each session in an MS Excel file. Adherence was achieved if $\geq 67\%$ of the recommended training sessions were completed during the whole study period. This cut-off is based on the Dutch physical activity guideline for adults and older adults regarding muscle and bone strengthening activities that advises two sessions per week [25]. Adherence to hypocaloric diet and resistance training was also calculated individually in percentages. Regarding resistance training, this was the percentage of training session attendance. Regarding the hypocaloric diet, we set the boundary condition of 600 kcal less than the requirements at 100% according to the Dutch guideline [22] and calculated the individual goal attainment in percentages [19–21]. For instance, if a person consumed 200 kcal less than their individual requirement, the percentage adherence would be 33%, while the percentage of adherence would be –50% for a person who consumed 300 kcal more than their individual requirement.

We also calculated the differences prior to and following the interventions for five parameters of body composition, physical performance and strength, namely differences in body weight in percent, fat mass

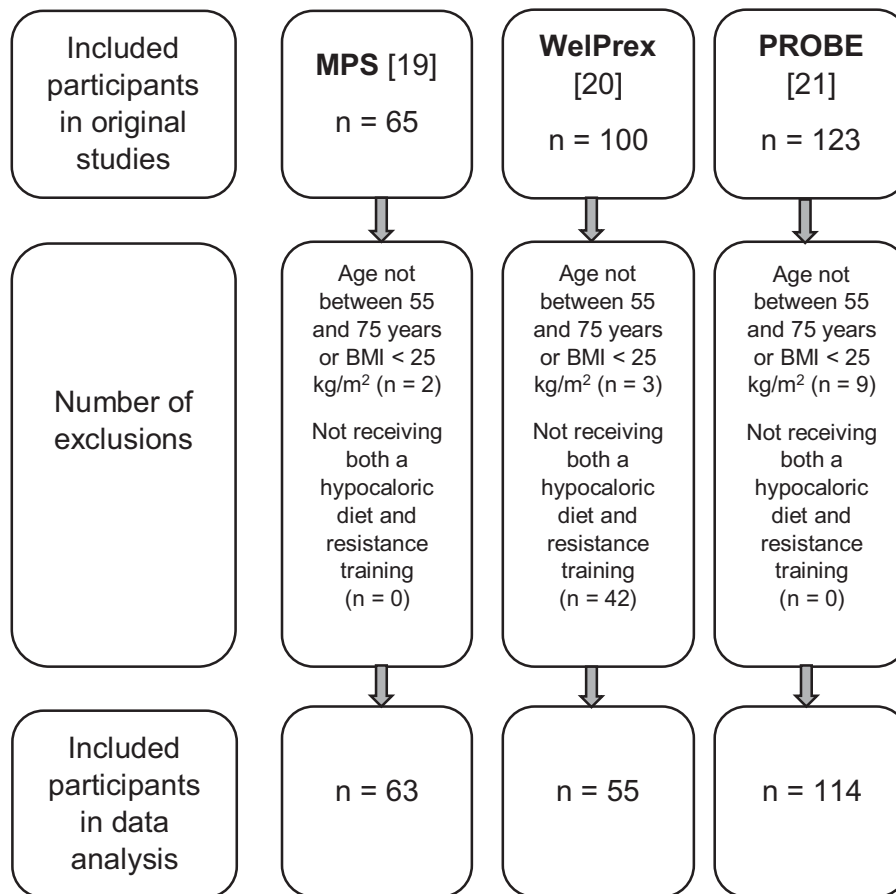


Fig. 1. Participant Flow Diagram.

in percent, handgrip strength in kg, gait speed in m/s and appendicular muscle mass in kg. Early weight loss was defined as a loss of ≥ 1 kg of body weight after 5–7 weeks (mid-term measurement). The variable “high protein recommendation” related to all patients in the WelPrex study who received the recommendation to consume a high-protein diet (1.3 g).

2.3. Statistical analysis

Patient characteristics were reported as absolute and relative frequencies for categorical data and numerical data as mean \pm standard deviation (SD) or median and interquartile range (q1, q3), as appropriate. Comparisons between the studies were performed using the ANOVA, Kruskal-Wallis test or chi-square tests, as appropriate. Univariable and multivariable linear mixed models were used to identify factors which were associated with resistance training adherence in percent and hypocaloric diet adherence in percent. All variables with a p -value < 0.2 in the univariable analysis were included in the multivariable analysis. P -values were based on two-sided tests, and a p -value of 0.05 or less was considered statistically significant. To identify the association of resistance training adherence and hypocaloric diet adherence separately regarding the outcomes body weight, fat mass, appendicular muscle mass, gait speed and hand grip strength, linear mixed models were used and adjusted for the high protein recommendation, age and sex with the study as random effect. All assumptions for the linear mixed models were carefully checked and were met. All statistical analyses were conducted using R version 4.2.3.

3. Results

3.1. Participant characteristics

In total, 47.0% of the participants were female and the mean age was 64.0 (± 5.5) years. Most participants were Caucasian (84.1%) and the

mean BMI at baseline was 32.9 (± 4.2) kg/m². Sex ($p = 0.003$) and age ($p < 0.001$) were significantly different between the three studies included, meaning that more men were included in PROBE than in the other two studies. The mean age was also higher in PROBE than in the others. Out of the whole group of participants, 55.8% experienced early weight loss within the first 5 or 7 weeks (Table 1).

In total, 80.2% adhered to resistance training ($\geq 67\%$ of training sessions attended) and 51.3% adhered to a hypocaloric diet (≥ 600 kcal less than the individual caloric requirements). Participants in PROBE were significantly more likely to adhere to hypocaloric diet (60.9%) than participants in MPS and WelPrex. Of all participants, 46.1% adhered to both resistance training and a hypocaloric diet (Fig. 2).

3.2. Resistance training adherence

The multivariable linear mixed model revealed that two factors, namely, age and sex, were positively associated with resistance training adherence. With each additional year in age, the adherence was 0.41% higher (Beta 0.41; 95% CI 0.05, 0.78; $p = 0.028$). Men had an estimated 7.7% higher adherence to resistance training than women (Beta 7.7; 95% CI 3.6, 12; $p < 0.001$) (Table 2).

3.3. Hypocaloric diet adherence

The multivariable linear mixed model revealed that sex and BMI at baseline were positively associated with hypocaloric diet adherence. Men had an estimated 65% higher adherence to hypocaloric diet than women (Beta 65; 95% CI 41, 88; $p < 0.001$). People with a higher BMI at baseline had a higher likelihood of adhering to a hypocaloric diet (Beta 6.4; 95% CI 3.6, 9.2; $p < 0.001$) meaning that the adherence was 6.4% higher with each 1 kg/m² of higher BMI (Table 3).

Table 1
Participant characteristics.

	Total (n = 232)	MPS (n = 63)	WelPrex (n = 55)	PROBE (n = 114)	p-Value
Sex - female % (n)	47.0 (109)	54.0 (34)	61.8 (34)	36.0 (41)	0.003
Age in years mean (SD)	64.0 (5.5)	62.7 (5.4)	62.0 (5.1)	65.7 (5.3)	< 0.001
Caucasian ethnicity % (n)	84.1 (195)	87.3 (55)	78.2 (43)	85.1 (97)	0.368
Smoker % (n)	10.8 (25)	11.3 (7)	9.1 (5)	11.4 (13)	0.894
Weight in kg baseline mean (SD)	96 (15)	94 (13)	92 (14)	100 (16)	0.005
BMI in kg/m ² baseline mean (SD)	32.9 (4.2)	32.9 (3.7)	32.0 (3.9)	33.3 (4.5)	0.182
BMI in categories % (n) [#]					
Overweight	26.7 (62)	23.8 (15)	24.6 (28)	34.5 (19)	0.674
Obesity class 1	47.0 (109)	54.0 (34)	45.6 (52)	41.8 (23)	
Obesity class 2	21.1 (49)	19.0 (12)	22.8 (26)	20.0 (11)	
Obesity class 3	5.2 (12)	3.2 (2)	7.0 (8)	3.6 (2)	
Fat mass in % baseline mean (SD)	42 (8)	43 (9)	42 (8)	41 (9)	0.336
Handgrip strength in kg baseline mean (SD)	43 (17)	31 (10)	34 (11)	54 (15)	< 0.001
Gait speed in m/s baseline mean (SD)	1.16 (0.23)	1.07 (0.24)	1.26 (0.20)	1.16 (0.21)	< 0.001
Appendicular muscle mass in kg baseline mean (SD)	25.4 (5.6)	22.9 (5.3)	–	26.8 (5.3)	< 0.001
Early weight loss ≥1 kg (after 5 resp. 7 weeks) % (n) [*]	55.8 (115)	62.3 (38)	68.2 (30)	46.5 (47)	0.026
Resistance training adherence in % median (IQR)	81 (71–87)	79 (71–87)	79 (47–88)	83 (73–88)	0.355
Resistance training adherence yes/no % (n) ^{**}	80.2 (162)	77.4 (48)	65.4 (17)	85.1 (97)	0.060
Hypocaloric diet adherence in % median (IQR)	101 (57–154)	82 (51–141)	81 (51–142)	118 (67–161)	0.094
Hypocaloric diet adherence yes/no % (n) ^{***}	51.3 (96)	43.3 (26)	40.0 (14)	60.9 (56)	0.035
Combined hypocaloric diet and resistance training adherence yes/no % (n) ^{****}	46.1 (77)	33.3 (20)	40.0 (6)	55.4 (51)	0.025

p-Value based on Pearson’s chi-squared test; one-way ANOVA.

[#] Obesity was categorized according to the WHO [26] (BMI < 30.0 kg/m²; class 1 BMI 30.0–34.9 kg/m²; class 2 BMI 35.0–39.9 kg/m²; class 3 BMI > 40.0 kg/m²).

^{*} Total n = 206.

^{**} Total n = 202.

^{***} Total n = 187.

^{****} Total n = 167.

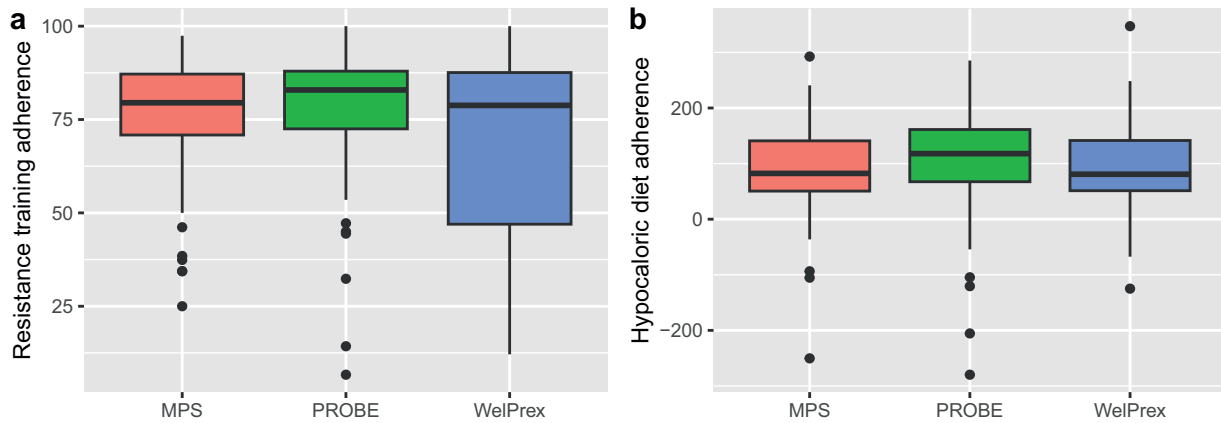


Fig. 2. Adherence to resistance training and hypocaloric diet.

Table 2

Linear mixed models on factors associated with resistance training adherence (in %) with the study as a random effect.

	Univariable			Multivariable (n = 181)		
	Beta	95% CI ¹	p-Value	Beta	95% CI ¹	p-Value
Age (n = 202)	0.64	0.18, 1.1	0.007	0.41	0.05, 0.78	0.028
Sex - male (n = 202)	7.8	2.8, 13	0.002	7.7	3.6, 12	< 0.001
BMI in kg/m ² baseline (n = 202)	−0.44	−1.0, 0.13	0.133	−0.15	−0.62, 0.31	0.518
Smoker (n = 201)	−4.8	−13, 3.1	0.233			
Caucasian ethnicity (n = 202)	8.3	1.4, 15	0.018	4.3	−1.4, 10	0.138
Early weight loss (n = 181)	3.6	−0.58, 7.9	0.090	2.6	−1.5, 6.7	0.220
High protein recommendation (n = 202)	−2.5	−7.5, 2.4	0.313			

¹ CI: Confidence Interval.

Table 3
Linear mixed models on factors associated with hypocaloric diet adherence (in %) with the study as random effect.

	Univariable (n = 187)			Multivariable (n = 183)		
	Beta	95% CI ¹	p-Value	Beta	95% CI ¹	p-Value
Age (n = 187)	-1.0	-3.4, 1.3	0.390			
Sex - male (n = 187)	62	38, 86	<0.001	65	41, 88	<0.001
BMI in kg/m ² baseline (n = 187)	5.9	3.0, 8.9	<0.001	6.4	3.6, 9.2	<0.001
Smoker (n = 186)	5.0	-42, 51	0.833			
Caucasian ethnicity (n = 187)	23.0	-15, 60	0.235			
Early weight loss (n = 183)	23	-3.6, 49	0.090	12	-12, 35	0.325
High protein recommendation (n = 187)	-13.0	-38, 13	0.339			

¹ CI: Confidence Interval.

Table 4
Changes in outcomes during the intervention period in mean or median (95% CI).

	Total (n = 232)	MPS (n = 63)	WelPrex (n = 55)	PROBE (n = 114)
Change in body weight in % mean (95% CI ¹)	-3.1 (-3.5, -2.6)	-3.1 (-4.0, -2.3)	-3.8 (-4.7, -2.9)	-2.7 (-3.3, -2.1)
Change in body fat in % median (95% CI)	-2.43 (-2.8, -2.0)	-1.93 (-3.2, -1.8)	-3.07 (-3.9, -1.8)	-2.44 (-2.8, -1.7)
Change in gait speed in m/s median (95% CI)	0.06 (0.03, 0.10)	0.05 (0.05, 0.17)	0.16 (0.12, 0.26)	0.00 (-0.05, 0.03)
Change in handgrip strength in kg mean (95% CI)	1.4 (0.5, 2.3)	2.0 (0.89, 3.1)	0.4 (-1.1, 2.0)	-
Change in appendicular muscle mass in kg median (95% CI)	0.03 (-0.18, 0.25)	-0.13 (-0.59, 0.33)	-	0.13 (-0.07, 0.34)

¹ CI: Confidence Interval.

3.4. Changes in outcomes regarding body composition, physical performance and strength during the intervention period

In total, the participants lost 3.1% (95% CI -3.5, -2.6) of their body weight, increased their gait speed by 0.06 m/s (95% CI 0.03, 0.10) and their handgrip strength by 1.4 kg (95% CI 0.5, 2.3). There was no significant change in appendicular muscle mass (95% CI -0.18, 0.25) (Table 4).

Applying the linear mixed model revealed the negative association between the change in body weight and resistance training adherence; meaning that a 10% higher adherence was associated with a 0.48% higher decrease in body weight (Beta -0.48; 95% CI -0.89, -0.064; $p = 0.024$). Men had a 3.5-kg higher increase in hand grip strength (Beta 3.5; 95% CI 1.5, 5.6; $p < 0.001$) than women. Furthermore, the recommendation of high protein intake appears to be associated with a larger increase in appendicular muscle mass (Beta 0.45; 95% CI 0.00, 0.89; $p = 0.051$). However, this association is not statistically significant. No other associations (with the exception of body weight and resistance training adherence) between adherence and body composition outcomes were identified (Table 5).

4. Discussion

The aim of this study was to identify factors associated with the adherence to resistance training and a hypocaloric diet and to describe changes in body composition outcomes and their possible association with adherence in persons of retirement age. It was established that, in total, 80.2% of the participants adhered to resistance training (attendance of $\geq 67\%$ of the recommended training sessions) and 51.3% adhered to a hypocaloric diet (consumption of at least 600 kcal less the individual caloric requirements). Older age, a higher BMI at baseline and being male were positively associated with adherence. Adherence to resistance training was associated with a decrease in body weight, but no other associations between adherence (to a hypocaloric diet and resistance training) and body fat, gait speed, handgrip strength or with muscle mass were found.

Although adherence to interventions is of utmost importance [27], only a few studies included purposive interventions to improve adherence

Table 5

Linear mixed models on factors associated with changes in body composition outcomes with study as random effect.

	Beta	95% CI ¹	p-Value
Change in body weight in % (n = 200)			
High protein recommendation (yes/no)	-0.02	-0.97, 0.93	0.966
Age	0.02	-0.07, 0.11	0.613
Sex - male	0.27	-0.80, 1.3	0.620
Resistance training adherence (per 10% increase)	-0.48	-0.89, -0.064	0.024
Hypocaloric diet adherence (per 10% increase)	-0.026	-0.083, 0.031	0.366
Change in body fat in % (n = 186)			
High protein recommendation (yes/no)	-0.03	-0.85, 0.80	0.949
Age	-0.02	-0.10, 0.06	0.603
Sex - male	-0.76	-1.7, 0.17	0.111
Resistance training adherence (per 10% increase)	0.11	-0.25, 0.46	0.558
Hypocaloric diet adherence (per 10% increase)	0.000	-0.048, 0.049	0.984
Change in gait speed in m/s (n = 193)			
High protein recommendation (yes/no)	0.02	-0.05, 0.09	0.508
Age	0.00	-0.01, 0.01	0.816
Sex - male	0.00	-0.08, 0.08	0.953
Resistance training adherence (per 10% increase)	-0.020	-0.050, 0.010	0.194
Hypocaloric diet adherence (per 10% increase)	0.002	-0.002, 0.006	0.390
Change in handgrip strength in kg (n = 100)			
High protein recommendation (yes/no)	-0.05	-2.0, 1.9	0.961
Age	0.05	-0.13, 0.24	0.569
Sex - male	3.5	1.5, 5.6	<0.001
Resistance training adherence (per 10% increase)	-0.15	-0.84, 0.54	0.669
Hypocaloric diet adherence (per 10% increase)	0.012	-0.11, 0.13	0.838
Change in appendicular muscle mass in kg (n = 151)			
High protein recommendation (yes/no)	0.45	0.00, 0.89	0.051
Age	0.00	-0.04, 0.05	0.850
Sex - male	0.12	-0.39, 0.64	0.633
Resistance training adherence (per 10% increase)	-0.002	-0.20, 0.20	0.985
Hypocaloric diet adherence (per 10% increase)	-0.022	-0.049, 0.004	0.097

¹ CI: Confidence Interval.

or measured adherence in people of retirement age. Regarding our study populations, a satisfying 80.2% adhered to the resistance training, while only approximately 50% adhered to a hypocaloric diet intervention. Nevertheless, limited reference values impede effective comparisons. A recent meta-analysis of 27 studies described an overall adherence rate (as described in the primary study) of 60.5% to weight loss interventions (nutrition and/or exercise components) in persons with obesity [28]. The subgroup analysis revealed that self-monitoring weight loss programs exhibited a lower adherence rate (41.5%) and supervised interventions showed a higher one (68.6%) [28]. Another cross-sectional study reported adherence rates of 83.8% in Poland and 78.3% in Germany in patients which were surgically or conservatively treated for morbid obesity [29]. Adherence was measured with a self-developed questionnaire and was based on self-reported data on, e.g., previous slimming diets, physical exercise, caloric consumption control and use of dietary supplements. The reported adherence rates correlate roughly with our results despite differences in patient populations, measurement methods and interventions. Also, possible aspects like training intensity might have reduced hypocaloric diet adherence. Furthermore, adherence rates depend on the used definitions. Our definitions were quite strict and not tailored to individual aims. Consequently, we used the adherence in percent for the linear mixed model because a lower adherence (e.g., consuming 400 kcal less than the requirement) is indeed a type of adherence requiring consideration.

Several demographic characteristics such as male sex, older age and a higher BMI at baseline were found to be strongly associated with adherence to resistance training and a hypocaloric diet. These results correspond well with those of a recent systematic review of studies on adults with obesity [15]. We found that especially the adherence to a hypocaloric diet was much higher in men (Beta 65; 95% CI 41, 88; $p < 0.001$) than in women. This may be explained by the fact that men have higher energy requirements than women and, therefore, a caloric restriction of 600 kcal may be more feasible for them [30]. Men also exhibited a higher adherence rate to resistance training, which may be due to resistance training being more popular among men than women [30,31]. A recent survey of Canadians aged 12 years and older revealed that across all age groups, males were significantly more likely than females to meet the resistance training recommendations [32]. Therefore, the high ratio of men in the PROBE study might also have influenced these results.

The results indicate that early weight loss success may be positively associated with resistance training adherence, but the results are not significant. This observation is nevertheless noteworthy, since early weight loss not only improves adherence but also determines later weight loss [30] due to its association with motivation and confidence [15,30].

We also described changes in five relevant outcomes regarding body composition, physical performance and strength and their possible associations with adherence. On average, the participants lost 3.1% of their body weight and displayed improvements in physical function parameters like gait speed and handgrip strength. Various recommendations define clinically important changes [33–35]. Some report a loss of 5% in body weight as minimally clinically important [33]. A body weight decrease of 3.1% found in our study falls short of these recommendations, meaning that its clinical importance might be limited.

Ageing has been associated with an increase in body fat and a decrease in appendicular muscle mass and function [5,11,36,37]. Particularly near the retirement age (50–65 years), a peak in excessive fat accumulation occurs [5,11,37]. It can therefore be regarded as very positive that the participants' body weight decreased while their physical function parameters increased and appendicular muscle mass could be maintained. This counteracts sarcopenic obesity, a condition combining the loss of appendicular muscle mass, strength and function with obesity [36].

Nevertheless, we were able to identify only limited associations between changes in body composition outcomes and adherence. The mixed linear regression revealed a negative association between a change in body weight and resistance training adherence. This corresponds to the fact that we identified early weight loss as a factor significantly associated

with resistance training adherence. Associations with other outcomes, such as gait speed or appendicular muscle mass, were not identified. This may be explained by the fact that training intensity might have influenced effects and, respectively, the corresponding success.

4.1. Limitations

This study has some limitations that should be addressed. We compared the adherence rates between three related RCTs. These RCTs were chosen purposively, and the three included RCTs had some minor differences. All three RCTs included resistance training in a fitness center, but the WelPrex study used circuit training as well [19–21]. The PROBE study included significantly more men than the other studies and only patients with diabetes mellitus, which might also have influenced the results (e.g., the BMI) [21]. However, we applied mixed linear models and thus considered these differences. Dietary intake was measured with a 3-day food record, which might have enabled underreporting resulting in a misclassification of some participants as adherent. In any case, this information must be classified as self-reported and interpreted as such. Due to the study design (secondary data analysis), it was not possible to consider other important factors such as education, income, type of (former) occupation, or incidence of depression or anxiety [15]. Most participants were Caucasian, which limits the generalizability of the results to other ethnicities. Furthermore, the effects of the applied interventions (e.g., protein supplements in two studies) are not primarily part of this paper but might also have influenced our results.

4.2. Recommendation for future studies and clinical practice

The identified adherence rates can be explained by the fact that only the PROBE study included specific behavior change interventions, like goal setting or barrier identification [38]. Such behavioral change strategies in lifestyle interventions are known to result in improved adherence rates [16,18]. In order to facilitate comparisons between the studies and to harmonize terms and definitions, a behavior change techniques (BCT) taxonomy was developed in 2013 [39]. This taxonomy has previously been implemented in exercise and nutritional interventions in persons with obesity [40,41] and was found to be reliable and helpful. Furthermore, a systematic review identified several BCTs like “barrier identification/problem solving” and a “plan for social support/social change” that are associated with effectiveness of dietary interventions in persons of retirement age [42]. Future studies, therefore, should include behavioral treatment strategies and apply common and established terms [18,37].

Psychosocial factors like depression, anxiety, stress, hopelessness and dissatisfaction also determine of adherence to lifestyle interventions [15]. An exploratory analysis of an RCT found that people who are most in need of lifestyle interventions are the least likely to be adherent [27]. Therefore, we recommend tailoring lifestyle interventions to target populations and considering psychosocial support in order to increase adherence rates and efficacy [27].

Additionally, intervention studies should establish flexible and realistically achievable aims to facilitate sustainable lifestyle changes. Future studies should also consider the aspect of sex-sensitivity by including sex-specific interventions to improve adherence in women, sex-specific cut-offs for caloric restrictions and training sessions tailored to women's needs and abilities.

4.3. Conclusions

This study is one of the first to describe adherence to resistance training and hypocaloric diet in people nearing retirement. Our analysis revealed that about 80% of the participants adhered to resistance training, whereas only about 50% adhered to a hypocaloric diet. Several

factors were associated with improved adherence, like male sex, older age or higher BMI at baseline. The results of our secondary data analysis may serve as a guide to designing future lifestyle interventions for persons of retirement age. It is indispensable to include BCTs in studies on lifestyle interventions [18], to consider influencing factors (like sex, age and early weight loss) and to tailor interventions to individual circumstances in order to improve adherence to these interventions and, in turn, health outcomes, while decreasing the negative consequences of overweight and obesity [18].

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Conflict of interest

The authors declare no conflict of interests. The funder had no role in the conduct of this study.

Declaration of interests

Peter Weijs reports financial support was provided by JPI HDHL. Robert Memelink reports a relationship with Dutch Research Council that includes: funding grants. Yves Boirie reports a relationship with University Hospital Centre Clermont-Ferrand that includes: employment. Josje Schoufour reports a relationship with by Joint Programming Initiative A Healthy Diet for a Healthy Life that includes: funding grants. Eva Topinkova reports a relationship with Charles University First Faculty of Medicine that includes: funding grants. Lea Reiter reports a relationship with Joint Programming Initiative A Healthy Diet for a Healthy Life that includes: funding grants. Silvia Bauer reports a relationship with Joint Programming Initiative A Healthy Diet for a Healthy Life that includes: funding grants. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data sharing

Data described in the manuscript, code book and analytic code will not be made available because of the sensitive nature of the data.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.jnha.2024.100344>.

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