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Associations of EAT-*Lancet* diet food groups with sarcopenia components, self-reported sarcopenia risk and health-related quality of life in older Australians performing exercise training, following their normal diet: Six-month pretest-posttest study

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ABSTRACT

Planetary health diets recommend plant rather than animal proteins. Since protein is important for skeletal muscle, the purpose of this study was to examine associations of the EAT-*Lancet* diet food groups with sarcopenia components (muscle strength, appendicular lean mass [ALM] and physical performance), self-reported sarcopenia risk (via SARC-F), and health-related quality of life (HRQoL) via Assessment of Quality of Life (AQoL-4D} among older adults performing exercise training. Community-dwelling older adults (n = 66, mean age ± SD 76.8 ± 6.6) were measured as above at baseline, and after 6 months of continuous training (average once per week) at Uniting AgeWell's four gyms in Melbourne, Australia. Participants followed their normal habitual diets, which were assessed at baseline by the Australian Eating Survey and subsequently aligned to the eight food groups of the EAT-*Lancet* diet. At pretest, whole grains (r = 0.276), vegetables (r = 0.282) and fruits (r = 0.257) were all positively associated with the HRQoL mental health dimension (all $p < 0.05$). Similarly, beef/lamb/pork (r = 0.329, $p < 0.01$), dairy food (r = 0.258) and fish (r = 0.275) (both $p < 0.05$) were positively associated with the HRQoL relationships dimension. Pearson associations of the baseline diet with the changes occurring after 6 months of continued resistance training showed vegetables were positively associated with gait speed (r = 0.252), whereas added sugars were associated with lower chair stand time (r = −0.245) (both $p < 0.05$). Beef/lamb/pork (r = 0.349), and chicken/other poultry (r = 0.247), were positively correlated with self-reported sarcopenia risk (both $p < 0.05$), while they were negatively correlated with the HRQoL relationship dimension (beef/lamb/pork, r = −0.338, chicken/other poultry r = −0.360; $p < 0.01$). Given the benefits of whole grains, vegetables and fruits on the HRQoL mental health dimension, and dairy foods, red meats and fish on the HRQoL relationship dimension at baseline, and the negative effects of higher meat consumption on self-reported sarcopenia risk, older adults should include them as part of a balanced diet combined with exercise training at least once per week.

Abbreviations: AES, Australian Eating Survey; ALM, Appendicular lean mass; AQoL-4D, Assessment of Quality of Life-4 Dimensions; BMC, Bone mineral content; BMI, Body mass index; DXA, Dual-energy X-ray absorptiometry; EWGSOP2, European Working Group on Sarcopenia in Older People (January 2019 update); GS, Gait speed; HGS, Hand grip strength; HRQoL, health-related quality of life; CS, chair stand; SPPB, Short physical performance battery; SARC-F, Sarcopenia screening tool assessing strength, assistance in walking, rising from a chair, climbing stairs and falls; TUG, Timed up and go

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1. Introduction

The EAT-*Lancet* diet brought together 37 world leading scientists from 16 countries to create the first full scientific review of what constitutes a healthy diet from a sustainable food system perspective, contributing to UN Sustainable Development Goal (SG12) "to ensure healthy lives and well-being at all ages".[1–3] The diet advocates reduced animal protein sources and increased plant based proteins (legumes and nuts).[2] There is evidence of the strength of muscle anabolism in response to dairy proteins and animal proteins, with a lower response occurring from plant-based proteins.[4] However, there is limited literature regarding plant-based food groups in relation to muscle health, self-reported sarcopenia risk and health-related quality of life (HRQoL). Given the ageing population and higher rates of mortality and morbidity in individuals with sarcopenia (low muscle mass and function),[5,6] it is imperative to evaluate the effect of habitual dietary intakes on skeletal muscle to ensure maintenance of sufficient muscle to preserve healthy weight, prevent diabetes and promote healthy ageing, particularly in the current United Nations 'Decade of Healthy Ageing' 2021–2030 announced by the World Health Organisation.[7]

The full report of the EAT-*Lancet* diet first appeared in the Lancet in 2019, and it will require shifting attitudes, production and diets to realise the project by 2050. Currently, there are limited data on the potential impact of the EAT-*Lancet* diet on muscular health.

The purpose of this study was to determine whether the EAT-*Lancet* diet food groups, concurrent with exercise training, correlated with sarcopenia components (muscle strength, lean mass and function), self-reported sarcopenia risk and HRQoL among community-dwelling older adults. We hypothesized that EAT-*Lancet* food groups are linked to enhancements in sarcopenia components, lower self-reported sarcopenia risk and higher HRQoL in older adults participating in exercise training, following their normal diet.

2. Materials and methods

2.1. Study design and participants

Convenience sampling was used to observe exercising participants under supervision of exercise physiologists and physiotherapists at four gyms owned and operated by aged care provider, Uniting AgeWell, in Melbourne, Australia.[8] Eligibility criteria included all Uniting AgeWell gym clients participating in resistance training. Training duration was usually one hour, and the frequency was once or twice per week depending on individual programs, ranging from 2–3 sets of 8–20 repetitions of standard resistance training exercises as designed by the exercise physiologists and physiotherapists. This project used data collected at baseline and after 6 months of training. Participants followed their usual diet, with no specific nutritional guidance or dietary intervention provided. The study did not assess whether participants were following the recommendations of EAT-*Lancet* diet, rather associations of measured variables with the food groups contained within the EAT-*Lancet* diet. Detailed descriptions of the functional tests and self-reported measures have been detailed elsewhere.[8]

A total of 66 participants completed all pretest measures and returned 6 months later to repeat the same tests, except for AES, whichwas only collected at pretest (Fig. 1).

Ethical approval for this study was obtained from the Victoria University Human Research Ethics Committee (approval number HRE18–195). All subjects provided written informed consent before data collection.

2.2. Measures

2.2.1. Sarcopenia components

Components making up major sarcopenia definitions included lean mass, muscle strength and physical performance. Appendicular lean mass (ALM) and weight were obtained using dual-energy X-ray absorptiometry (DEXA) (Hologic Horizon A, MeasureUp, Melbourne). Height was measured with a stadiometer (Charder HM200P, Charder Electronic Co. Ltd, Tachung City, Taiwan). Based on the revised European Working Group on Sarcopenia in Older People (EWGSOP2) definition, low lean mass was calculated as low ALM adjusted for height^2 (kg/m^2).[9,10] Using the Foundation for the National Institutes of Health (FNIH) Sarcopenia Project criteria, ALM was adjusted for body mass index (ALM/BMI), with BMI calculated as weight divided by height squared (kg/m^2).[11] Muscle strength was measured by hand grip

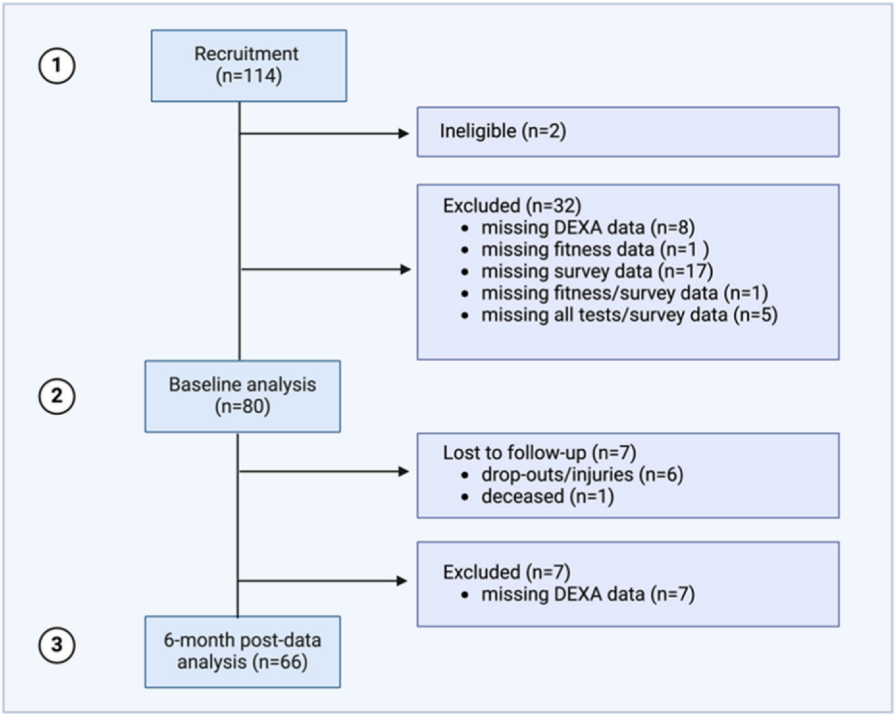

Fig. 1. Study profile. Dual-energy X-ray absorptiometry (DEXA).
(a) Adapted from "Flow Chart (Parallel Randomised Trial of Two group)", by BioRender.com (2024). (b) Retrieved from https://app.biorender.com/biorender-templates.

strength (HGS; Jamar Plus+, SI Instruments, Adelaide, Australia) and five-chair stand (CS) test consisting of five chair rises as fast as possible, as part of the short physical performance battery (SPPB), which also incorporates gait speed (GS) timed over a 4-metre course at normal walking speed, and balance with three different stances. A timed up and go (TUG) test over a 3-metre course was also performed.

2.2.2. Self-reported nutrition

The Australian Eating Survey (AES) for adults was used comparing food and nutritional intake with Nutrient Reference Values and food groups as per the Australian dietary recommendations for the past 3–6 months.[12] AES is a 120-item food frequency questionnaire with 15 supplementary questions.[12,13] Before testing and during the 6 months of continued training, participants followed their normal diet. Prior literature shows that among individuals regularly exercising in gyms and fitness centres, those who are more physically active have a greater self-determined regulation of their eating habits compared to those who are less physically active.[14] Physically active people are also more motivated to regulate healthy eating habits.[14] Our study participants were already a high functioning group at baseline due to high SPPB and Physical Activity Scale for the Elderly (PASE) scores, with high Australian Recommended Food Score (ARFS), indicating healthier eating patterns and higher diet quality.[8] As such, they were only required to complete AES at pretest, as they were already undertaking exercise training, thus there was a reasonable assumption they would follow a similar diet for the next 6 months. Nutritional data obtained from the AES was aligned to the 8 EAT-*Lancet* food groups by two of the research team, one being an Accredited Practicing Dietitian. The 8 food groups according to the EAT-*Lancet* diet included whole grains, tubers/starchy vegetables, vegetables, fruits and dairy foods. Protein sources consisted of beef/lamb/pork, chicken/other poultry, eggs, fish, legumes and nuts. Added fats included unsaturated and saturated oils and the last food group was added sugars.[1]

2.2.3. Self-reported function

A rapid questionnaire was used to screen for sarcopenia using self-reported information about strength, assistance in walking, rise from a chair, stair climb, and falls (SARC-F).[15] SARC-F scale score of 0–3 indicates health and 4 + is predictive of sarcopenia risk and poor functional outcomes.[15]

2.2.4. Self-reported HRQoL

A 12-item Assessment of Quality of Life (AQoL-4D) survey was used to assess 4 self-reported HRQoL dimensions including independent living, relationships, senses and mental health over the previous week. AQol-4D utility score with negative utilities implies health worse than death; zero equals death, and one equals full health.[16]

2.3. Statistical analysis

Continuous variables are presented as mean (standard deviation) unless otherwise specified. Continuous data were assessed for normality and parametric tests used as appropriate. Pearson correlations were used to explore associations between the baseline EAT-*Lancet* diet components with sarcopenia components (muscle strength, lean mass and physical performance), self-reported sarcopenia risk and HRQoL at pretest and with changes over 6 months. The Pearson coefficient was interpreted as weak (0.1–0.3), moderate (0.3–0.7) or strong (0.7–1.0). Paired-samples t-tests (continuous data) were used to compare sarcopenia components at pretest and at 6-month posttest. An alpha value of < 0.05 was considered significant at 95 % confidence intervals. Statistical analyses were performed using IBM SPSS Statistics for Mac, version 26 (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Baseline characteristics

Participants had already been undergoing resistance training once a week on average, for a little over a year (Table 1).

All data are mean (SD) or frequency (%). BMI: body mass index; DEXA: dual-energy X-ray absorptiometry; BMC: bone mineral content; ALM: appendicular lean mass; EWGSOP2: Eureopean Working Group on Sarcopenia in Older People (January 2019 update); FNHI: Foundation for the National Institutes of Health Sarcopenia Project; HGS: hand grip strength, CS: chair stand; GS: gait speed; TUG: timed up and go SPPS: short physical performance battery; IQR: interquartile range; AES: Australian Eating Survey; SARC-F: sarcopenia screening tool assessing strength, assistance in walking, rising from a chair, climbing stairs and falls; HRQoL: health-related quality of life; AQoL-4D: Assessment of Quality of Life-4 Dimensions.

3.2. Associations of EAT-Lancet food groups with sarcopenia components, self-reported sarcopenia risk and HRQoL at pretest

Regarding sarcopenia components, Pearson associations revealed a significant moderate, negative correlation for HGS with vegetables and weak, negative correlations with fruits, indicating that a lower intake of vegetables and fruits were associated with higher HGS (Table 2).

Added sugars showed a significant weak, positive correlation with ALM and a moderate, positive correlation with ALM/BMI, indicating that a higher intake of added sugars was associated with a higher ALM

Table 1
Baseline characteristics (n = 66).

Demographics	Age (yr), mean (SD)	76.83 (6.59)
	Women, frequency (%)	64
	English/Australians, frequency (%)	83
Training	Years trained, mean (SD)	1.24 (0.66)
	Weekly gym visits, mean (SD)	1.01 (0.44)
Anthropometric measurements	Height (cm), mean (SD)	163.97 (9.12)
	Weight (kg), mean (SD)	76.07 (17.52)
	BMI (kg/m^2), mean (SD)	28.19 (5.71)
DEXA	Total lean mass (kg), mean (SD)	47.64 (10.92)
	Total fat mass (kg), mean (SD)	26.33 (10.76)
	Total fat (%), mean (SD)	34.00 (8.57)
	Total BMC (kg/cm^2), mean (SD)	2.11 (0.49)
Lean mass	ALM (kg), mean (SD)	19.32 (5.18)
EWGSOP/EWGSOP2	ALM/h^2 (kg/m^2), mean (SD)	7.09 (1.37)
FINH	ALM/BMI, mean (SD)	0.69 (0.16)
Muscle strength	HGS (kg), mean (SD)	26.55 (8.54)
	CS (s), mean (SD)	9.75 (3.86)
Physical performance	GS (m/s), mean (SD)	1.32 (0.25)
	TUG (s), mean (SD)	8.22 (2.84)
	SPPB (score), median (IQR)	12.00 (1)
Self-reported nutrition (via AES)	Whole grains (g), mean (SD)	22.88 (8.37)
	Tubers or starchy vegetables (g), mean (SD)	10.50 (3.97)
	Vegetables (g), mean (SD)	86.15 (22.13)
	Fruits (g), mean (SD)	118.39 (13.41)
	Dairy foods (g), mean (SD)	35.61 (9.63)
Protein sources	Beef, lamb & pork (g), mean (SD)	20.45 (9.37)
	Chicken & other poultry (g), mean (SD)	11.64 (5.55)
	Eggs (g), mean (SD)	5.64 (2.35)
	Fish (g), mean (SD)	10.21 (4.58)
	Legumes (g), mean (SD)	6.05 (5.09)
	Nuts (g), mean (SD)	8.24 (4.89)
Added fats	Unsaturated oils (g), mean (SD)	40.10 (14.44)
	Saturated oils (g), mean (SD)	34.84 (13.12)
	Added sugars (g), mean (SD)	87.44 (35.29)
Self-reported sarcopenia risk	SARC-F (score), mean (SD)	1.67 (1.68)
Self-reported HRQoL	AQoL-4D (utility score), mean (SD)	0.71 (0.21)
	Independent Living, mean (SD)	0.92 (0.12)
	Relationships, mean (SD)	0.93 (0.13)
	Senses, mean (SD)	0.93 (0.08)
	Mental Health, mean (SD)	0.88 (0.10)

Table 2
Associations of EAT-*Lancet* diet food groups with sarcopenia components at pretest (n = 66).

EAT-*Lancet* diet food group (g)		Muscle strength		Lean mass			Physical performance		
		HGS (kg)	CS (s)	ALM (kg)	ALM/$_{BMI}$ (kg/m^2)	ALM/h^2 (kg/m^2)	GS (m/s)	TUG (s)	SPPB (score)
Whole grains	Pearson Coefficient	0.067	-0.035	-0.016	0.184	-0.052	0.104	-0.016	0.035
	p	0.594	0.778	0.899	0.14	0.678	0.405	0.897	0.78
Tubers or starchy vegetables	Pearson Coefficient	-0.094	0.092	0.018	0.212	-0.04	-0.06	0.068	-0.075
	p	0.454	0.464	0.889	0.087	0.749	0.631	0.587	0.55
Vegetables	Pearson Coefficient	**-0.370** **	0.148	-0.171	-0.066	-0.142	-0.225	0.185	-0.226
	p	**0.002**	0.237	0.171	0.601	0.255	0.07	0.138	0.068
Fruits	Pearson Coefficient	**-0.293** *	0.067	-0.091	0.018	-0.13	-0.088	0.11	-0.099
	p	**0.017**	0.595	0.47	0.887	0.298	0.484	0.378	0.428
Dairy foods	Pearson Coefficient	-0.1	-0.16	-0.132	0.022	-0.204	0.106	0.085	-0.008
	p	0.425	0.199	0.291	0.859	0.1	0.398	0.497	0.948
Protein sources									
Beef, lamb & pork	Pearson Coefficient	-0.06	0.197	0.118	0.08	0.093	0.155	-0.132	0.091
	p	0.633	0.113	0.346	0.525	0.457	0.213	0.291	0.468
Chicken & other poultry	Pearson Coefficient	-0.075	0.146	0.115	-0.054	0.099	-0.004	0.216	-0.065
	p	0.548	0.243	0.359	0.669	0.429	0.973	0.081	0.603
Eggs	Pearson Coefficient	-0.128	0.064	0.005	-0.015	-0.011	0.174	-0.115	0.113
	p	0.307	0.611	0.965	0.902	0.927	0.162	0.359	0.368
Fish	Pearson Coefficient	-0.063	0.218	0.144	-0.081	0.157	-0.052	0.207	-0.124
	p	0.615	0.079	0.25	0.52	0.207	0.676	0.096	0.322
Legumes	Pearson Coefficient	-0.027	-0.187	0.13	0.239	0.09	-0.085	**0.294** *	-0.031
	p	0.83	0.133	0.299	0.053	0.472	0.498	**0.017**	0.806
Nuts	Pearson Coefficient	-0.166	-0.011	-0.218	0.078	**-0.307** *	0.014	0.058	-0.02
	p	0.182	0.929	0.078	0.531	**0.012**	0.908	0.645	0.875
Added fats									
Unsaturated oils	Pearson Coefficient	-0.047	-0.038	0.016	0.224	-0.092	0.078	0.226	-0.116
	p	0.705	0.76	0.899	0.07	0.462	0.532	0.068	0.355
Saturated oils	Pearson Coefficient	-0.005	-0.063	0.016	0.115	-0.047	0.106	0.165	-0.06
	p	0.971	0.615	0.897	0.359	0.706	0.396	0.186	0.634
Added sugars	Pearson Coefficient	0.075	0.053	**0.262** *	**0.315** *	0.233	-0.06	0.164	-0.104
	p	0.549	0.671	**0.034**	**0.01**	0.059	0.635	0.189	0.407

HGS: hand grip strength; CS: chair stand; ALM: appendicular lean mass; BMI: body mass index; GS: gait speed; TUG: timed up and go; SPPB: short physical performance battery; All analyses are Pearson correlations; ** $p < 0.01$, * $p < 0.05$.

and ALM/BMI. There was a significant weak, positive association for legumes with TUG, implying that a lower legume intake was associated with lower TUG time (better mobility). No significant relationship was observed for EAT-*Lancet* diet components with CS, GS and SPPB.

Similarly, there was no significant association for EAT-*Lancet* diet components with self-reported sarcopenia risk, HRQoL (utility score) and HRQoL on the independent living dimension (Table 3).

However, there was a significant moderate, negative association for legumes with HRQoL on the senses dimension, indicating that a higher legumes intake was associated with worse senses. There was a significant weak, positive association for dairy foods and fish with HRQoL on the relationships dimension and a moderate, positive association for beef/lamb/pork consumption, indicating that a higher intake of dairy foods, fish and beef/lamb/pork was associated with better relationships. A significant weak, positive relationship was observed for whole grains, vegetables and fruits with HRQoL on the mental health dimension, suggesting that higher intakes were associated with better mental health. Benefits of resistance training and nutrition on HRQoL in community-dwelling older adults are shown in Fig. 2.

3.3. Associations of EAT-Lancet diet components with change in sarcopenia components, self-reported sarcopenia risk and HRQoL over 6 months

There was a significant weak, positive correlation for vegetables with GS, implying that a higher consumption of vegetables at baseline was associated with an improvement in GS (better mobility) (Table 4). Added sugars showed a significant weak, negative association with CS, indicating that a higher intake of added sugars was associated with a decline in CS time (greater lower-limb strength). No significant relationship was observed for the baseline EAT-*Lancet* diet food groups with change in HGS, lean mass, TUG and SPPB over 6 months.

3.4. Associations of EAT-Lancet diet recommendations with change in self-reported sarcopenia risk and HRQoL over 6 months

There was a significant weak, negative correlation for baseline fruit intakes with HRQoL (utility score), indicating that higher intake of fruits was associated with lower HRQoL (Table 5). There was a significant moderate, positive association for beef/lamb/pork and saturated oils with change in self-reported sarcopenia risk, implying that higher intakes of beef/lamb/pork at baseline was associated with greater sarcopenia risk over 6 months (Table 5).

Similarly, chicken/other poultry and unsaturated oils showed a significant weak, positive correlation with self-reported sarcopenia risk, implying that higher intakes were associated with an increase in self-reported sarcopenia risk scores (poorer function).

A significant moderate, negative relationship was observed for dairy foods, beef/lamb/pork, chicken, and fish with the HRQoL relationship dimension. The similar trend was observed for unsaturated and saturated oils, suggesting that higher intakes were associated with a decline in HRQoL on the relationships dimension. No significant relationship was observed for EAT-*Lancet* diet food groups with change in HRQoL on the independent living, senses and mental health dimensions over 6 months.

3.5. Change in sarcopenia components, self-reported function and HRQoL from pretest to posttest

Over a 6-month period, only 32 % (n = 21) participants attended gyms more than 20 times and the remaining 69 % (n = 45) attended the gyms less than 20 times. Following 6 months of continued training, BMI significantly lowered (p = 0.022), while HGS tended to increase (p = 0.055), but CS and GS did not change (Table 6). The SPPB median

Table 3
Associations of EAT-*Lancet* diet food groups with self-reported sarcopenia risk and HRQoL at pretest (n = 66).

EAT-*Lancet* diet food group (g)		SARC-F (score)	AQoL-4D (utility score)	Independent Living (score)	Relationships (score)	Senses (score)	Mental Health (score)
Whole grains	Pearson Coefficient	-0.174	0.211	0.141	0.105	0.067	**0.276** *
	p	0.162	0.089	0.258	0.399	0.592	**0.025**
Tubers or starchy vegetables	Pearson Coefficient	0.069	0.118	-0.018	0.048	0.227	0.06
	p	0.58	0.344	0.888	0.7	0.067	0.63
Vegetables	Pearson Coefficient	0.173	0.077	-0.164	-0.092	0.142	**0.282** *
	p	0.165	0.538	0.187	0.462	0.257	**0.022**
Fruits	Pearson Coefficient	0.134	0.141	-0.015	0.036	0.046	**0.257** *
	p	0.284	0.257	0.902	0.772	0.715	**0.037**
Dairy foods	Pearson Coefficient	-0.165	0.163	0.197	**0.258** *	-0.012	0.04
	p	0.187	0.191	0.112	**0.036**	0.925	0.749
Protein sources							
Beef, lamb & pork	Pearson Coefficient	-0.204	0.228	0.062	**0.329** * *	0.205	0.022
	p	0.101	0.065	0.623	**0.007**	0.099	0.864
Chicken & other poultry	Pearson Coefficient	0.012	-0.013	-0.108	0.238	-0.126	-0.027
	p	0.927	0.92	0.388	0.054	0.312	0.833
Eggs	Pearson Coefficient	-0.137	0.007	0.072	0.079	-0.166	-0.053
	p	0.274	0.955	0.566	0.529	0.183	0.675
Fish	Pearson Coefficient	0.015	0.017	-0.134	**0.275** *	-0.036	-0.018
	p	0.902	0.891	0.282	**0.025**	0.771	0.889
Legumes	Pearson Coefficient	0.148	-0.168	-0.11	-0.11	**-0.321** * *	-0.028
	p	0.236	0.177	0.379	0.381	**0.009**	0.821
Nuts	Pearson Coefficient	-0.026	-0.026	0.062	-0.019	-0.018	-0.077
	p	0.838	0.838	0.618	0.878	0.886	0.54
Added fats							
Unsaturated oils	Pearson Coefficient	0.024	0.037	-0.013	0.188	-0.027	-0.057
	p	0.847	0.77	0.92	0.131	0.833	0.647
Saturated oils	Pearson Coefficient	-0.051	0.112	0.028	**0.278** *	-0.032	0.033
	p	0.683	0.37	0.824	**0.024**	0.802	0.794
Added sugars	Pearson Coefficient	0.014	0.141	0.055	0.205	0.04	0.101
	p	0.908	0.258	0.659	0.099	0.75	0.421

HRQoL: health-related quality of life; SARC-F: sarcopenia screening tool assessing strength, assistance in walking, rising from a chair, climbing stairs and falls; AQoL-4D: Assessment of Quality of Life-4 Dimensions. All analyses are Pearson correlations; * * $p < 0.01$, * $p < 0.05$.

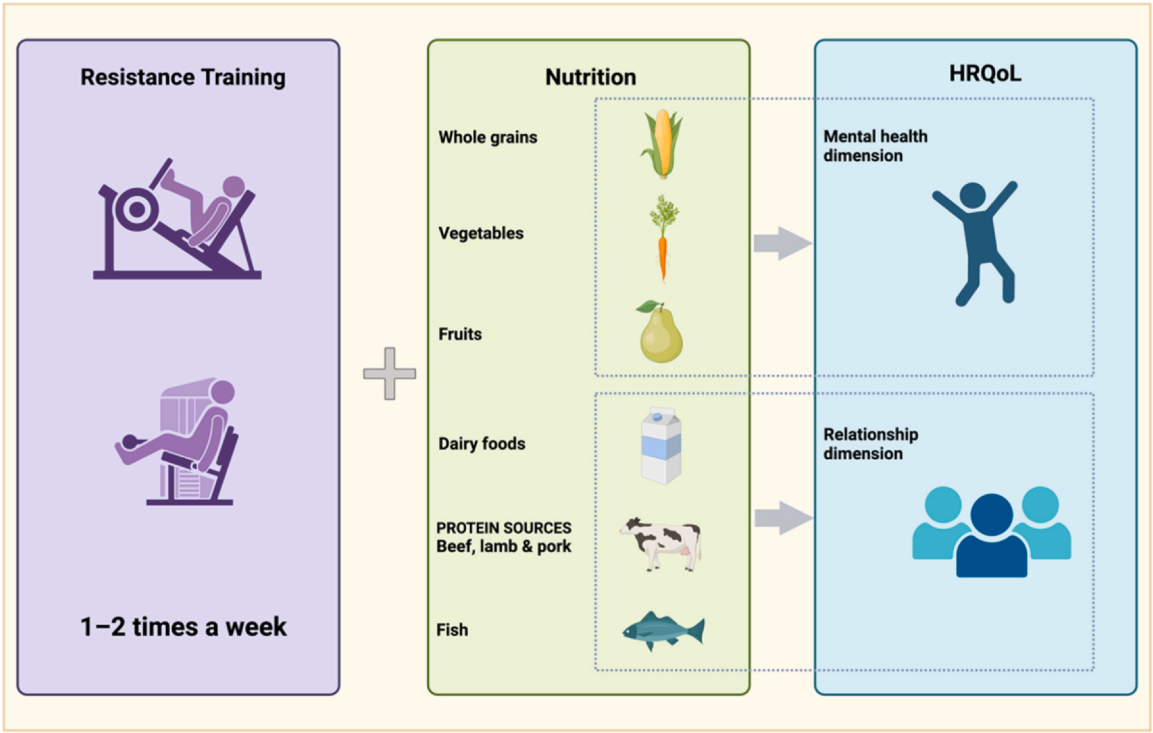

Fig. 2. Benefits of resistance training and nutrition on HRQoL in community-dwelling older adults. HRQoL: health-related quality of life.
(a) Adapted from "Heavy Metals Impact on the Food Chain", by BioRender.com (2024). (b) Retrieved from https://app.biorender.com/biorender-templates.

Table 4
Associations of EAT-*Lancet* diet recommendations with change in sarcopenia components over 6 months (n = 66).

		Muscle strength		Lean mass			Physical performance		
EAT-*Lancet* diet food groups (g)		HGS (kg)	CS (s)	ALM (kg)	$ALM/_{BMI}$ (kg/m^2)	ALM/h^2 (kg/m^2)	GS (m/s)	TUG (s)	SPPB (score)
Whole grains	Pearson Coefficient	0.184	-0.108	0.078	0.073	0.031	0.203	0.114	0.057
	p	0.138	0.391	0.531	0.561	0.806	0.103	0.362	0.647
Tubers or starchy vegetables	Pearson Coefficient	0.129	-0.001	0.004	0.086	0.009	0.023	0.017	-0.131
	p	0.302	0.991	0.974	0.493	0.943	0.856	0.892	0.293
Vegetables	Pearson Coefficient	0.020	0.050	-.061	-0.099	-0.063	**0.252***	0.202	-0.090
	p	0.874	0.694	0.624	0.427	0.617	**0.041**	0.104	0.472
Fruits	Pearson Coefficient	0.208	-0.087	0.169	-0.042	0.199	0.163	0.104	-0.005
	p	0.094	.491	0.174	0.738	0.108	0.192	0.406	0.969
Dairy foods	Pearson Coefficient	0.047	0.122	0.062	-0.068	0.087	-0.121	0.133	-0.094
	p	0.706	0.334	0.619	0.585	0.485	0.333	0.286	0.452
Protein sources									
Beef, lamb & pork	Pearson Coefficient	0.137	-0.085	-0.148	-0.168	-0.116	0.013	-0.183	0.002
	p	0.272	0.500	0.235	0.178	0.352	0.915	0.142	0.987
Chicken & other poultry	Pearson Coefficient	0.198	-0.159	-0.095	-0.230	-0.070	0.077	0.198	-0.049
	p	0.110	0.207	0.449	0.064	0.574	0.539	0.110	0.697
Eggs	Pearson Coefficient	0.066	-0.020	-0.197	-0.202	-0.204	0.182	-0.032	0.089
	p	0.599	0.874	0.113	0.104	0.101	0.144	0.796	0.479
Fish	Pearson Coefficient	0.117	-0.209	-0.164	-0.206	-0.155	0.065	0.193	-0.008
	p	0.350	0.094	0.188	0.097	0.215	0.605	0.120	0.947
Legumes	Pearson Coefficient	-0.004	0.115	-0.093	-0.067	-0.086	0.196	0.239	-0.193
	p	0.971	0.364	0.460	0.592	0.490	0.115	0.053	0.120
Nuts	Pearson Coefficient	-0.068	0.128	0.074	0.013	0.107	-0.072	0.146	-0.032
	p	0.588	0.310	0.554	0.916	0.395	0.567	0.242	0.796
Added fats									
Unsaturated oils	Pearson Coefficient	0.174	0.070	-0.054	-0.078	-0.022	-0.034	0.229	-0.156
	p	0.163	0.579	0.667	0.533	0.859	0.784	0.065	0.212
Saturated oils	Pearson Coefficient	0.202	0.032	0.010	-0.020	0.026	-0.114	0.182	-0.135
	p	0.105	0.803	0.933	0.874	0.837	0.363	0.144	0.279
Added sugars	Pearson Coefficient	0.138	**-0.245***	0.078	0.105	0.071	0.073	0.053	0.083
	p	0.269	**0.049**	0.532	0.400	0.569	0.558	0.674	0.505

HGS: hand grip strength; CS: chair stand; ALM: appendicular lean mass; BMI: body mass index; GS: gait speed; TUG: timed up and go test; SPPB: short physical performance battery; All analyses are Pearson correlations; * $p < 0.05$.

score remained at its maximum score of 12, indicative of the already high functioning of participants at pretest, while TUG became slightly longer ($p = 0.044$), with the days of training not influencing any of these changes. Concerning self-reported measures, the overall HRQoL (utility score) significantly improved ($p = 0.014$), which was primarily driven by improvements in the mental health dimension ($p = 0.002$), although there was also a tendency for an improvement in the independent living dimension ($p = 0.052$).

3.6. Sarcopenia prevalence

Using EWGSOP2 definition, at baseline, 9.1 % (n = 6) of participants had probable sarcopenia, but none had confirmed sarcopenia or severe sarcopenia. High SARC-F scores (> 4) showed 13.6 % (n = 9) at sarcopenia risk, predicting 2 cases of probable sarcopenia. After 6 months, according to EWGSOP2, probable sarcopenia increased to 15.2 % (n = 10) and confirmed sarcopenia increased from zero to 4.5 % (n = 3). Two-thirds of participants, including the 3 now sarcopenic subjects attended the gyms less than 20 times during the 6-month period. According to SARC-F, 2 participants identified at risk of sarcopenia at pretest test were no longer at risk, but 7 remained at risk. Two subjects without risk at pretest were identified at risk posttest. Two subjects with probable sarcopenia at the pretest stage were tested non-sarcopenic posttest, while 4 remained with probable sarcopenia. However, 6 participants without probable sarcopenia at the pretest stage were detected with probable sarcopenia posttest. Despite this, McNemar's test showed no significant change in the proportion of participants detected with probable sarcopenia ($p = 0.289$) or with confirmed sarcopenia ($p = 0.250$), when compared with the proportion prior to the intervention.

4. Discussion

There is limited data regarding associations of planetary health diets that promote plant protein and reductions in animal protein, such as the EAT-*Lancet* diet, with sarcopenia components, self-reported sarcopenia risk and HRQoL in older adults. Overlapping recommendations between the planetary health diet and Australian Dietary Guidelines are consumption of more fruits, vegetables and whole grains and less starchy vegetables, red meat and refined foods.[17]

Regarding the vegetables and fruits, research shows that a greater intake of whole fruit and lower adherence to added sugars have significant effects on improved HGS.[18] Further, in a randomised controlled trial of 83 community-dwelling older adults over a period of 16 weeks, there is a trend towards a higher change in HGS in the 5 portions of fruit and vegatables per day as opposed to the 2 portion/day group ($p = 0.06$) but no significant change in physical function between the groups.[19] This supports our findings that a greater consumption of fruits and vegatables was not significantly associated with muscle strength and physical performance as eating more vegetables and fruits was linked to worse HGS at pretest (Table 2), and eating more vegetables was linked to a lower GS time (worse mobility) after 6 months of training (Table 4). HGS is a marker of nutritional status [20–22] and adherence to the Mediterranean diet (MD) is positively associated with HGS in older women.[23] It is known that HGS is higher for men than women, thus different HGS cut-offs for both genders when measuring sarcopenia.[10,11] In our study, 64% were women, which may explain the negative association with the HRQoL relationship dimension. Added sugars were negatively associated with CS time (better lower-limb mobility) but not with HGS as recently reported that lower adherence to added sugars have significant effects on improved HGS.[18]

Animal-based proteins are associated with improved HGS and CS time in Italian community-dwellers across ages.[23] Conversely, our study

Table 5
Associations of EAT-*Lancet* diet food groups with self-reported sarcopenia risk and HRQoL with change in self-reported sarcopenia risk and HRQoL over 6 months (n = 66).

EAT-*Lancet* diet food group (g)		SARC-F (score)	AQoL-4D (utility score)	Independent Living (score)	Relationships (score)	Senses (score)	Mental Health (score)
Whole grains	Pearson Coefficient	0.129	-0.196	-0.154	-0.080	-0.084	-0.170
	p	0.303	0.115	0.216	0.521	0.505	0.173
Tubers or starchy vegetables	Pearson Coefficient	0.129	-0.084	0.023	-0.059	-0.135	0.085
	p	0.301	0.502	0.851	0.640	0.279	0.497
Vegetables	Pearson Coefficient	-0.155	-0.052	0.059	0.089	-0.066	-0.232
	p	0.214	0.677	0.638	0.479	0.601	0.061
Fruits	Pearson Coefficient	0.015	**-0.260***	-0.138	-0.111	-0.189	-0.158
	p	0.907	**0.035**	0.271	0.377	0.128	0.205
Dairy foods	Pearson Coefficient	0.201	-0.206	-0.120	-0.317**	0.068	-0.183
	p	0.106	0.096	0.337	0.009	0.589	0.142
Protein sources							
Beef, lamb & pork	Pearson Coefficient	**0.349****	-0.167	0.070	**-0.338****	-0.089	0.059
	p	**0.004**	0.180	0.579	**0.006**	0.479	0.637
Chicken & other poultry	Pearson Coefficient	**0.247***	-0.193	-0.133	**-0.360****	-0.096	0.082
	p	**0.045**	0.120	0.286	**0.003**	0.442	0.515
Eggs	Pearson Coefficient	0.209	-0.045	-0.050	-0.232	0.237	-0.036
	p	0.092	0.719	0.692	0.061	0.056	0.774
Fish	Pearson Coefficient	0.240	-0.190	-0.067	**-0.379****	-0.078	0.039
	p	0.052	0.126	0.590	**0.002**	0.535	0.759
Legumes	Pearson Coefficient	0.082	-0.207	-0.229	-0.098	-0.010	-0.215
	p	0.515	0.095	0.064	0.436	0.936	0.082
Nuts	Pearson Coefficient	0.087	-0.165	-0.110	-0.188	0.032	-0.150
	p	0.488	0.185	0.378	0.131	0.801	0.230
Added fats							
Unsaturated oils	Pearson Coefficient	**0.273***	-0.237	-0.051	**-0.362****	-0.086	-0.110
	p	**0.026**	0.055	0.685	**0.003**	0.490	0.381
Saturated oils	Pearson Coefficient	**0.303***	-0.191	-0.023	**-0.339****	-0.043	-0.123
	p	**0.013**	0.124	0.855	**0.005**	0.734	0.325
Added sugars	Pearson Coefficient	0.211	-0.238	-0.097	-0.211	-0.219	-0.074
	p	0.089	0.054	0.440	0.089	0.077	0.553

HRQoL: health-related quality of life; SARC-F: sarcopenia screening tool assessing strength, assistance in walking, rising from a chair, climbing stairs and falls; AQoL-4D: Assessment of Quality of Life-4 Dimensions. All analyses are Pearson correlations; * * $p < 0.01$, * $p < 0.05$.

Table 6
Change in sarcopenia components, self-reported function and HRQoL from pretest to posttest (n = 66).

	Pretest	Posttest	P-value for difference from pretest
HGS (kg), mean (SD)	26.55 (8.54)	27.75 (9.67)	0.055
CS (s), mean (SD)	9.75 (3.89)	9.64 (3.66)	0.796
ALM (kg), mean (SD)	19.32 (5.18)	19.18 (5.02)	0.126
BMI (kg/m^2), mean (SD)	28.19 (5.71)	27.94 (5.67)	**0.022** *
ALM/BMI (kg/m^2), mean (SD)	0.69 (0.16)	0.70 (0.17)	0.268
ALM/h^2 (kg/m^2), mean (SD)	7.09 (1.37)	7.05 (1.30)	0.213
GS (m/s), mean (SD)	1.32 (0.25)	1.29 (0.27)	0.176
TUG (s), mean (SD)	8.22 (2.84)	8.54 (3.71)	**0.044** *
SPPB (score), median (IQR)	12 (1)	12 (1)	0.924
SARC-F (score), mean (SD)	1.67 (1.68)	1.70 (1.72)	0.798
AQoL-4D (utility score), mean (SD)	0.71 (0.21)	0.75 (0.18)	**0.014** * *
Independent Living, mean (SD)	0.92 (0.12)	0.94 (0.12)	0.052
Relationships, mean (SD)	0.93 (0.13)	0.94 (0.09)	0.486
Senses, mean (SD)	0.93 (0.08)	0.92 (0.08)	0.864
Mental Health, mean (SD)	0.88 (0.10)	0.90 (0.08)	**0.002** * *

All data are mean (SD). HRQoL: health-related quality of life; HGS: hand grip strength; CS: chair stand; ALM: appendicular lean mass; BMI: body mass index; GS: gait speed; TUG: timed up and go test; SPPB: short physical performance battery; IQR: interquartile range; SARC-F: sarcopenia screening tool assessing strength, assistance in walking, rising from a chair, climbing stairs and falls; AQoL-4D: Assessment of Quality of Life-4 Dimensions. All analyses are paired samples t-test; ** $p < 0.01$ * $p < 0.05$.

did not prove any associations between animal-based proteins and muscle strength (Tables 2 & 4), which may be due the fact they had been training for a year, on average, prior to testing.

Based on our findings, a higher intake of legumes was associated with higher TUG time (worse mobility) at baseline (Table 2). Legume lectins are carbohydrate-binding proteins able to reduce growth by binding to gut mucosa and slowing absorbtion.[24] The highest amounts of lectines can be found in raw legumes (e.g., black beans, kidney beans, lentiles, soybeans) and whole grain products,[24] however whether raw legumes were the predominant form ingested in the current study cannot be established. Legumes are negatively associated with functional disability of instrumental activitities of daily living (IADL) (grooming, housework, meal preparation, taking medications, money management, doing laundry, going outside, using public transport and phone, and shopping) but not of activities of daily living (ADL) (dressing, washing, bathing, eating, transferring, using the toilet) among older Korean women.[25] This could be due to legumes affecting less severely impaired (ADL) individuals, such as the participants in the current study, who are in a progressive stage of disability, than those severely impaired (IADL).[25]

Nuts can improve diet quality, without negatively affecting body weight,[26] while a review reported that almond supplementation enhances exercise performance, but not pistachio supplementation, in young athletes.[27] Whether nuts can improve physical function and body composition in older adults is limited.[27] In a narrative review, preliminary data imply that nut intake may be associated with lower sarcopenia risk, greater cognition and longer telomere length in older adults, where associations seem to be more consistent when nuts were included in the overall diets of older adults, thus pointing to a synergistic effect between nuts and other food groups.[28] In our study, a higher intake of nuts was associated with lower ALM/h^2 in older adults at baseline (Table 2). While our results showed no relationship for other plant-based and animal-based proteins with lean mass, the prior literature suggests that healthy dietary patterns (fruits, vegetables, fish, potatoes, seaweeds, legumes, whole grains, mushrooms, eggs, dairy and

red meat) have higher ALM than those with unhealthy Western dietary patterns (high intake of red meat, noodles, bread, poultry, fast food, and soft drinks) in older Korean men.[29]

In our study, positive associations for baseline meat and saturated oils with the change in self-reported sarcopenia risk over 6 months (Table 5) could be a contributor to worse TUG performance (Table 6). Due to lower gym attendance over 6 months, perhaps individuals perceived themselves less functional. Poor diet among Australians is not a new phenomenon. Based on the Australian Health Survey in 2011–2012 people of all ages did not meet recommendations of the five food groups: grain (except for women over 71 years old), vegetables, fruit, meat and alternatives, and dairy products and alternatives.[30,31] Consumption of fruit and vegetables was consistently low between 2007–2008 and 2017–2018.[30] The high intake of discretionary food, which is high in energy and low in nutrients (cakes, muffins, biscuits, soft drinks, fruit and vegetable juices) lead to higher intake of added sugars, and foods, including sweet biscuits, processed meat and butter, lead to higher intake of saturated fat among Australians.[31] Our findings show that more added sugars were associated with higher ALM and ALM/BMI at baseline (Table 2), however foods high in added sugars are repeatedly linked to obesity [32,33] and the associated morbidity and mortality. It has been reported that obesity in the United States is linked to low-cost foods containing added sugars, fats and refined grains, which are cheaper, convenient and tasty, and thus, low-income consumers making unhealthy rather than healthy choices.[32]

Prior literature shows that both vegetarian/vegan and omnivorous diets in combination with training contributed to a high HRQoL in endurance runners.[34] Adherence to the MD is linked to higher HRQoL and its dimensions, including mental health in Spanish older adults [35] and North Americans (aged 45–79 years).[36] Similarly, adherence to Australian Guidelines is positively associated with HRQoL (via 36-item short form survey) five years later on physical function, general health, vitality and physical composite score (but not mental health) as well with functional status of IADL in older Australians.[37] In our study, positive associations of whole grains, vegetables, fruits with the HRQoL mental health dimension and of dairy food, red meat as well as fish with the HRQoL relationships dimension (e.g., with friends, partner or parents) at pretest (Table 3) may have contributed to improved HRQoL after 6 months, mainly due to HRQoL on the mental health dimension (Table 6). However, at pretest, animal source foods (dairy foods, beef/lamb/pork, chicken/other poultry), fish, saturated and unsaturated oils were significantly negatively correlated with the HRQoL relationship dimension (Table 3). Due to lower gym attendance over 6 months, perhaps individuals perceived relationships lower as the social aspect was missing.

It is possible that participants were aware of the link between diet and health, and thus regard their quality of life higher if they eat healthy foods.[37] Overall, research shows that fruits and vegetables have positive effects on mental health.[38–40] Healthy dietary patterns (vegetables, fruit, fish) can improve mental health as it is associated with lower levels of depressive symptoms among Australian women (but not men), whereas unhealthy dietary pattern (red and processed meat, hot chips, deserts, cakes and ice cream) is associated with higher levels of depressive symptoms also in women (but not men).[38] Consumption of raw fruits and vegetables is associated with better mental health than of processed ones since cooking or processing may lower the amount of micronutrients according to the study on young adults living in New Zealand and the United States.[39] A study on older adults from 11 European countries showed that regular intake of fruits and vegetables is associated with greater health outcomes, including mental and cognitive health, contributing to deceleration of physical disability.[40] A healthy diet including fruits and vegetables could result in improvements in HRQoL on the mental health dimension as observed in our study (Table 6).

Our results show that a higher intake of saturated fats is associated with higher HRQoL on the relationship dimension at baseline (Table 3). This may be related to social eating and the fact that red meats (beef/lamb/pork) and discretionary foods include saturated fats. Australian Dietary Guidelines and the EAT-*Lancet* diet recommend limiting foods containing saturated fats,[1,41] although this is based on cardiovascular risk, rather than self-perceptions of QoL. When weighing risks, consumption of higher amounts of animal-based protein is less risky than smoking, alcohol or white bread consumption (15 slices or more per week).[4] Similarly, in our study, a higher intake of fish was associated with the higher HRQoL relationships dimension at baseline (Table 3). A study of multiple sclerosis patients found that fish and omega 3 supplements were significantly and clinically associated with better HRQoL in all domains.[42] However, this needs to be considered in the context of the links to real or perceived reductions in disability and disease.[42]

To promote health and sustainability, the EAT-*Lancet* commission is calling for a 50 % increase of fruits, vegetables, nuts and legumes and a more than 50 % reduction of red meat and sugar in the diet by 2050.[1] However, according to the United States Department of Agriculture and Health and Human Services, giving up any specific food to stay healthy is not necessary if people take a common sense approach of 'variety, moderation and balance' based on personal, cultural and health needs.[43] In our study, given the benefits of dairy foods, red meats and fish on the HRQoL relationship dimension at baseline (Table 3), older adults should include them as part of a balanced diet.

The positive effects of meat on HRQoL at baseline (Table 3) are consistent with the global trend, showing that meat consumption increased by 58 % over the 20 years to 2018, mainly attributed to population, economic and income growth and changing consumer preferences towards fish and poultry in developing countries.[44] In Australia and the United States, poultry consumption was largely offset by decreases in beef, veal and sheep meat due to its greater affordability over red meat, which was expected to continue between 2019 and 2024.[44]

A global analysis revealed that the EAT-*Lancet* diets are affordable in high-income but not in low-income countries, generally 60 % more expensive than the foods meeting nutrient requirements, partially attributable to higher amounts of fruits and vegetables and animal-based foods.[45] Since current diets are different to the EAT-*Lancet* diet, many populations would require a mix of high income, lower prices and nutritional knowledge as well as change of tastes and habits.[45]

Due to a shortfall of vitamin B12, calcium, iron, and zinc in the EAT-*Lancet* diet, changes were suggested to meet micronutrient needs for adults (without fortification or supplementation), by increasing quantities of animal-based foods and decreasing foods rich in phytate.[44] Responses to resistance exercise have been shown to be augmented in response to additional protein intake.[46,47] Animal-based proteins are usually higher in lysine, leucine, and methionine than plant-based sources, resulting in higher protein synthesis rates. As such, greater amounts of plant-based protein are likely required to induce proportionate muscle hypertrophy compared to animal-based proteins.[4] A systematic review reported that although animal-based proteins may be regarded more anabolic than plant-based protein sources, diets rich in plant protein sources can potentially support the maintenance of muscle mass with ageing if adequate protein intake is consumed.[48] While animal-based foods (e.g., dairy, meat and fish), continue to have a high protein quality, the quality of plant-based foods (e.g., chickpea, cooked rice, wheat, whole grains) is not consistent, implying that animal source foods will be more beneficial for maintaining healthy muscle ageing.[49] A systematic review and meta-analysis revealed that while animal protein tends to be more beneficial for lean mass than plant proteins, especially in younger adults, protein source is unlikely to have an effect on muscle strength.[50]

Our study does have some limitations. AES was only collected at baseline and not at the 6-month follow-up. However, since the AES includes food intake from the past 3–6 months, it is a reasonable assumption that participants who remained healthy and continued to attend the gym routinely, would also continue to follow their routine diet for the next 6 months. People starting exercise programs often also change their diet, but in this study, participants were already participating in resistance training, so any dietary changes would likely

already have occurred. Almost two-thirds of our participants were female, but without sufficient numbers to undertake separate gender analysis, it is unclear whether this would have an effect on the results observed, although both genders had similar dietary intake patterns. Further research with groups specifically following the EAT-*Lancet* diet is required to determine whether this dietary pattern is beneficial for maintaining physical function and HRQoL during ageing.

5. Conclusions

Given the beneficial relationship of whole grains, vegetables and fruits on the HRQoL mental health dimension, and dairy foods, red meats, and fish on the HRQoL relationship dimension, older adults should include them as part of a balanced diet. Further, three participants, who attended the gym less than 20 times since pretest, were detected with sarcopenia probable at posttest. This indicates that attending the gym 1–2 times per week, combined with suitable diet consumption, is the minimum to help prevent sarcopenia (Fig. 2).

CRediT authorship contribution statement

Ewelina Akehurst: Writing – original draft, Writing – review & editing, Conceptualization, Methodology, Data curation, Formal analysis, Visualization, Project administration, Funding acquisition, Investigation; **Helen McCarthy:** Writing – review & editing, Conceptualization, Methodology, Funding acquisition; **David Scott:** Writing – review & editing, Conceptualisation, Methodology, Supervision; **Juan Peña Rodriguez:** Data Curation; **Carol Alonso Gonzalez:** Data curation; **Jasmaine Murphy:** Data curation; **Sandor Dorgo:** Conceptualization; **Emma Rybalka:** Writing – review & editing, Funding ac- quisition; **Alan Hayes:** Writing – review & editing, Conceptualization, Methodology, Data curation, Supervision, Funding acquisition, Investigation. **All authors:** Acceptance of the manuscript.

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Declaration of Competing Interest

The authors have no competing interests to declare.

Informed Consent Statement

Ethical approval for this study was obtained from the Victoria University Human Research Ethics Committee (approval number HRE18–195). All subjects provided written informed consent before data collection.

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