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Original article

Greater adherence to a Mediterranean Diet is associated with better gait speed in older adults with type 2 diabetes mellitus

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SUMMARY

Background & aims: Older adults with type 2 diabetes mellitus (T2DM) are vulnerable to the physical frailty phenotype. Adherence to a Mediterranean Diet (MedDiet) is emerging as a potential dietary strategy to attenuate physical disability with age. This cross-sectional analysis aimed to explore the association between adherence to a MedDiet and characteristics of the physical frailty phenotype in older adults with T2DM.

Methods: Adherence to a MedDiet was assessed using two dietary adherence tools: [1] alternate Mediterranean Food Score (MED); [2] Mediterranean Diet Adherence Screener (MEDAS). The short physical performance battery (SPPB) and gait speed was used to evaluate lower extremity physical function. Frailty was defined as having three of the following: exhaustion, low muscle strength, low physical activity, slow gait speed, and weight loss. Multiple regression analysis was used to summarise associations between dietary adherence, SPPB score, gait speed and muscle strength adjusted for age, physical activity and time since T2DM diagnosis.

Results: A total of $n = 87$ participants (71.2 ± 8.2 years) were included. A total of $n = 6$ (~7%) and $n = 32$ (~37%) participants were identified as frail and pre-frail respectively. After adjustment for age, physical activity and time since T2DM diagnosis, greater adherence to a MedDiet, using both adherence tools, was significantly associated with better gait speed (MED: $\beta = 0.365$; $P = 0.002$; MEDAS: $\beta = 0.313$; $P = 0.007$). When assessing the individual dietary elements included in the MED score, fish and seafood consumption was the single significant contributor to better gait speed ($\beta = 0.229$; $P = 0.05$). Nil associations were observed when assessing adherence against muscle strength.

Conclusions: Greater adherence to a MedDiet was associated with better lower extremity physical performance in older adults with T2DM. Future studies should investigate the efficacy of a MedDiet intervention for attenuation of physical frailty characteristics in older adults with T2DM.

1. Introduction

The physical frailty phenotype is a geriatric syndrome synonymous with a reduction in functional capacity and is predictive of increased vulnerability to negative health outcomes such as physical disability, falls and fractures, institutionalisation and mortality [1,2]. This syndrome is characterised by a deterioration of multiple systems within the body, resulting in a decline in overall muscle strength, physical activity, respiratory functioning, resting metabolic rate and unintentional weight loss [1,3]. According to the operational definition proposed by Fried et al. [1] the reported prevalence in cohorts of community-dwelling older adults from different countries varies from ~5% to ~27% [4]. Variations in the reported prevalence of frailty is likely due to differences in the subjective nature of portions of the frailty assessment, the use of sample-specific criterion cut-offs and the heterogeneous operationalization of some components of the frailty assessment.

The pathophysiological processes contributing to the development and progression of physical frailty are complex and are generally associated with increased circulating concentrations of pro-inflammatory cytokines, oxidative stress, mitochondrial dysfunction, disruption of anabolic hormones and physical inactivity [2]. Interestingly, the pathogenesis of medical comorbidities

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and chronic conditions such as type 2 diabetes mellitus (T2DM) share similar aetiological pathways which threatens functional status in older adults and promotes physical frailty [5,6]. Specifically, T2DM, and its associated comorbidities, promotes physical frailty by accelerating declines in lean body mass and muscle strength [7].

Effective interventions are required to attenuate declines in skeletal muscle, strength and physical disability in older adults with T2DM. There is little evidence to support the efficacy of common pharmacological agents used for the management of T2DM in preventing or reversing physical frailty in older adults. Lifestyle reform, including energy-restricted weight loss and physical activity [8] are two key therapeutic interventions for the general management of T2DM. However, energy restricted weight loss diets in obese older adults remain controversial. Of greatest concern is the potential threat associated with the loss of lean body mass and bone and may exacerbate functional decline [9]. The additive effect of combining resistance training to an energy restricted diet in obese older adults has been shown to reduce the loss of lean body mass, improve muscle strength and ameliorate frailty more effectively than each intervention alone [10]. However, additional novel dietary strategies are scant.

Investigating the efficacy of dietary patterns on health outcomes associated with ageing has recently emerged as an important area of investigation, with evidence suggesting that overall diet quality is associated with a reduction in the risk of age-related diseases [11]. The Mediterranean Diet (MedDiet) is an example of a dietary pattern that provides evidence for an association between diet quality and healthy ageing. The efficacy of a Mediterranean-style diet for the dietary management and prevention of T2DM is now one of the most widely investigated dietary patterns [12]. Moreover, adherence to a MedDiet and the association between risk of physical frailty is now gaining momentum within the emerging literature as a potential dietary strategy to preserve functional status in older adults [13–15]. However, few studies have examined the relationship between adherence to a MedDiet pattern and the physical frailty phenotype in older adults with T2DM, particularly in non-Mediterranean countries such as Australia.

Therefore, in this study, we explored the association between greater adherence to a MedDiet pattern and better lower extremity physical performance, in community-dwelling older adults with T2DM.

2. Methods

2.1. Participants and recruitment

This was a cross-sectional analysis of community-dwelling older adults, recruited from the Sunshine Coast, Queensland, Australia. Participants were recruited from January 2018 to September 2018 via local flyers, newspaper advertisements and social media platforms and eligible to participate if they were aged ≥50 years with a confirmed diagnosis of T2DM. This study was conducted in accordance with the guidelines described in the Declaration of Helsinki and all procedures involving human subjects were approved by the Human Research Ethics Committee (S/171/123), University of the Sunshine Coast, Queensland, Australia. Written informed consent was obtained from all participants.

2.2. Diagnostic algorithm for frailty

Assessment of physical frailty was undertaken using the operational definition proposed by Fried et al. [1] on the basis of the following five criteria: [1] self-reported unintentional weight loss of ≥5 kg in the previous 12 months; [2] self-reported feelings of exhaustion ≥2 times per week based on statements derived from the Centre for Epidemiologic Studies Depression Scale (CES-D), including (a) I felt that everything I did was an effort and (b) I could not get going; [3] low isometric hand-grip strength, stratified by gender and body mass index (BMI) quartiles (men: BMI ≤24 kg/m^2: ≤29 kg; BMI 24.1–26 kg/m^2: ≤30 kg; BMI 26.1–28 kg/m^2: ≤30 kg; BMI ≥28 kg/m^2: ≤32 kg; women: BMI ≤23 kg/m^2: ≤17 kg; BMI 23.1–26 kg/m^2: ≤17.3 kg; BMI 26.1–29 kg/m^2: ≤18 kg; BMI ≥29 kg/m^2: ≤21 kg); [4] slow usual gait speed (seconds (s) over 15 feet), stratified by gender and height (men: height ≤173 cm: ≥7 sec; height >173 cm: ≥6 sec; women: height ≤159 cm: ≥7 sec; height >159 cm: ≥6 sec); [5] low physical activity stratified by gender (men <383 kcal/week, women <270 kcal/week). In the present study, low physical activity was assessed using the previously validated short version of the International Physical Activity Questionnaire (IPAQ-S) [16], which assesses physical activity in the previous week. In accordance with the Fried et al. [1] operational definition, confirmation of physical frailty was determined as the incidence of three or more of these diagnostic criteria. Participants were further classified as pre-frail when one or two of these diagnostic criteria were met [1].

2.3. Outcome measures

Participants were required to present to the high-performance sports centre at the University of the Sunshine Coast for a single visit. Participants were asked to report their age, gender, level of mobility, use of community services (if any), medication and supplement use for an interviewer-administered demographic questionnaire. Key outcome assessments included anthropometric measures, isometric hand-grip strength, physical performance and adherence to a Mediterranean-style diet.

2.4. Anthropometry

A calibrated digital scale (AND Weighing; HW-KGL, Melbourne, Australia) was used to record body mass to the nearest 0.1 kg, with participants barefoot and wearing light figure-hugging clothing. Height was measured to the nearest 0.1 cm whilst barefoot using a wall-mounted stadiometer (Holtain Limited, Crymych, United Kingdom), with the participant's head positioned in the Frankfort plane. BMI was calculated as weight (kg) divided by the square of height (m^2).

2.5. Isometric hand-grip strength

Isometric hand-grip strength of the dominant hand was measured with a calibrated hand-held dynamometer (Smedley, Tokyo, Japan) that was adjusted to each participant's hand size. Participants were directed to be seated in an upright position, with the arm of the measured hand unsupported and raised above the head. Maximal force was exerted on the dynamometer whilst moving the hand down in a 180-degree arc. One trial was permitted before undertaking three consecutive test measurements, with ~60 s rest breaks between each measure. All measures were recorded to the nearest 0.5 kg with the mean of the three measures used for analyses.

2.6. Short Physical Performance Battery

The Short Physical Performance Battery (SPPB) was used to assess functional status and physical performance by evaluating lower body function through the assessment of three functional tests which mimic activities of daily living [17]: [1] lower body strength; [2] balance; [3] gait speed [17]. Physical assessments

included the ability to rise from a seated position without upper extremity assistance five times consecutively for lower extremity strength; three hierarchical standing postures with decreasing base of support for the assessment of balance; and usual gait speed over a distance of four metres (4 m). The scores from each test were ranked on a scale of 0–4 and summed, with higher total scores indicative of a higher level of function. An independent evaluation of usual gait speed (4 m walk) was also used in the present study. For the assessment of usual gait speed, participants were asked to walk the measured distance at their usual walking speed, without acceleration. Usual gait speed was timed in seconds using a stopwatch and recorded on two separate occasions, with the mean of the two measures used for the purpose of analyses.

2.7. Dietary intake and adherence to Mediterranean Diet

Habitual dietary intake over the preceding 12 months was assessed using the semi-quantitative Dietary Questionnaire for Epidemiological Studies (DQESV2), developed by Cancer Council Victoria. To minimize recall bias and increase accuracy of the dietary data collected, all questionnaires were administered by a member of the research team and further checked for error and missing responses following administration. Adherence to a MedDiet was assessed using two previously developed indices: [1] the MED, developed and validated for application in non-Mediterranean populations [18]; and [2] the MEDAS, used in the Prevención con Dieta Mediterránea (PREDIMED) study [19]. The MED, adapted from the original Mediterranean Diet Score (MDS), developed by Trichopoulou et al. [20] includes nine dietary elements; vegetables, legumes, fruits, nuts, whole-grains, fish, red and processed meat, alcohol and a high ratio of mono-unsaturated fatty acids (MUFA) to saturated fatty acids (SFA). In accordance with standardised scoring protocols, the MED score is established by assigning a value of 0 (negative score) or 1 (positive score) to the nine dietary elements with the use of gender-specific median intakes within the studied population (Table 1). For dietary elements including vegetables, legumes, fruits, nuts, whole-grains, MUFA to SFA ratio, fish and seafood, participants with an intake above gender-specific medians were assigned a score of 1. For red and processed meat, participants with an intake below gender-specific medians were assigned a score of 1. For alcohol intake, a score of 1 was assigned for low to moderate intake between 5 and 15 g/d for men and women. A total score was calculated as the sum of all dietary elements, ranging from 0 to 9 [18]. The MEDAS determines adherence scores according to pre-defined normative criterion cut-off points for the habitual frequency of consumption (pre-defined servings/day or servings/week) of 12 main elements and two food habits related to a MedDiet pattern. The 14 questions in the questionnaire were scored as either 0 or 1, generating a maximum score of 14. Higher scores, for both adherence tools, indicate greater levels of adherence to a MedDiet. Specifically, a MED score $\geq$6 is suggestive of high adherence, scores between 4 and 6 indicate moderate adherence, and a score $\leq$3 is indicative of low adherence [21]. Likewise, a MEDAS score $\geq$10 suggests high adherence, scores between 6 and 9 indicate moderate adherence, and a score $\leq$5 is considered low adherence [20].

Table 1
Frequency of intake for the nine dietary elements used to assess adherence to a Mediterranean Diet using the alternate Mediterranean Food Score (MED) adherence tool.[a]

Nutritional characteristics	Median intake (IQR) (g/day) Men	Median intake (IQR) (g/day) Women
Vegetables	300.1 (172.8)	296.0 (164.3)
Legumes	12.5 (22.2)	23.0 (41.0)
Fruit	309.4 (179.2)	243.0 (213.6)
Nuts	12.9 (28.9)	16.8 (28.1)
Whole grains	143.5 (116.0)	106.7 (131.7)
Fish	34.0 (31.3)	39.4 (42.9)
Red and processed meat	100.3 (102.4)	93.1 (89.6)
MUFA/SFA[b]	0.7	1.2
Alcohol[c]	5–15	5–15

Abbreviations: MUFA, monounsaturated fatty acids; SFA, saturated fatty acids.
[a] Dietary intake data derived from the Dietary Questionnaire for Epidemiological Studies Food Frequency Questionnaire (DQESV2).
[b] Values are ratios, therefore non-dimensional.
[c] Range (g) is set *a priori* based on 'moderate' intake.

2.8. Statistical analysis

All continuous variables are expressed as means ± standard deviation (SD) or median and interquartile ranges (IQR), and categorical data are presented as frequencies and percentages. All tests were evaluated for normality using the Kolmogorov–Smirnov statistic and multiple regression diagnostics were run to ensure assumptions of multicollinearity and homoscedasticity were not violated. All data were included in the final analyses. For the purpose of analyses, MED and MEDAS scores were analysed as continuous variables. However, adherence scores were categorised into tertiles (low, moderate and high adherence) to enable comparability of their results. Cohen's kappa (κ) statistic was applied to determine the degree of agreement between adherence scores. Multiple regression analysis was used to summarise the association between adherence to a MedDiet, SPPB score, gait speed and muscle strength adjusted for age, physical activity and time since T2DM diagnosis. We also performed additional analyses assessing the association between each food component of the MED score, SPPB score, gait speed and muscle strength using multivariable models that were also adjusted for each of the nine dietary elements of the MED score. Multiple regression analysis was powered using the predictor variables established in each of the multivariable models and performed using G*Power. Assuming an alpha of 0.05, with 80% power to detect a medium effect size for gait speed and SPPB as the primary outcomes [22], the estimated target sample size was $n = 80$ participants. One-way analyses of variances (ANOVA) were used to explore differences between baseline characteristics and MedDiet adherence scores across staging of physical frailty (frailty/pre-frailty/non-frail). Chi-square analysis using Fisher's Exact Test was conducted to explore differences amongst the identified prevalence of physical frailty between genders. Analyses was performed using Statistical Package for the Social Sciences (SPSS) for Windows 24.0 software (IBM Corp., Armonk, NY, USA) with statistical significance set at $P < 0.05$.

3. Results

A total of $n = 87$ older adults with T2DM (71.2 ± 8.2 years; male, $n = 58$; female, $n = 29$) were included in the final analyses. Baseline characteristics for the sample are presented in Table 2. The frequency of participants identified as pre-frail and frail is outlined in Table 3. A total of $n = 6$ (~7%) and $n = 32$ (~37%) were identified as frail and pre-frail respectively. Although no significant differences across the staging of physical frailty were observed between genders, frail participants were significantly older (frail: 80.7 ± 5.3 years; pre-frail: 71.3 ± 7.9 years; non-frail: 70.0 ± 8.0 years; $P = 0.006$), demonstrated slower gait speed (frail: 0.52 ± 0.13 m/s; pre-frail: 1.0 ± 0.21 m/s; non-frail: 1.2 ± 0.20 m/s; $P = <0.001$) and demonstrated worse lower extremity physical functioning based on overall SPPB score (frail: 6.5 ± 2.4; pre-frail: 10.4 ± 2.0; non-frail: 11.3 ± 1.3; $P = <0.001$). No additional significant difference across the different staging of physical frailty was observed.

Table 2
Baseline characteristics of study sample ($n = 87$).

Characteristics	Mean ± SD or *n* (%)
Age (years)	71.22 ± 8.18
Gender (male)	58 (66.7)
Time since diagnosis of T2DM (years)	11.66 ± 8.92
T2DM related medication use[a]	71 (81.6)
Energy intake (kJ/day)[b]	9377.03 (2809.35)
Physical activity (k/cal/week)	4267.81 ± 4520.65
Weight (kg)	85.08 ± 19.53
BMI (kg/m^2)	29.53 ± 5.88
Grip strength (kg)	33.38 ± 10.79
Gait speed (m/s)	1.06 ± 0.26
SPPB (points/12)	10.66 ± 2.07
MEDAS (points/14)	5.59 ± 2.25
MED (points/9)	3.74 ± 1.46

Abbreviations: T2DM, type 2 diabetes mellitus; BMI, body mass index; FM, fat mass; FFM, fat free mass; ASM, appendicular skeletal muscle; SPPB, Short Physical Performance Battery; MEDAS, 14-point Mediterranean Diet Adherence Screener; MED, alternate Mediterranean food score.
[a] Confirms participant use of either oral hypoglycaemic agent or insulin.
[b] Expressed as median (IQR).

Table 3
Frequency (percentage) of participants ($n = 87$) identified as frail using previously established diagnostic criterions[†].

Frailty (n, %)			
	Men ($n = 58$)	Women ($n = 29$)	Total ($n = 87$)
Non- frail	30	19	49
Pre-frail	23	9	32
Frail	5	1	6

The Fried consensus definition for frailty includes five criteria; (1) self-reported unintentional weight loss of ≥5 kg in the previous 12 months; (2) self-reported feelings of exhaustion ≥2 times per week; (3) low isometric hand-grip strength; (4) slow usual gait speed; (5) low physical activity. Participants were classified as pre-frail when one or two of these diagnostic criteria were met and confirmation of physical frailty was determined as the incidence of three or more of these diagnostic criteria. Chi-square analysis using Fisher's Exact Test found no significant differences in the prevalence of frailty between genders.

Median intake for each of the nine dietary elements (g/day) used to establish the MED score are presented in Table 1. Mean adherence scores were 3.74 ± 1.46 using the MED adherence tool and 5.59 ± 2.25 using the MEDAS tool. Agreement between the MED and MEDAS adherence scores was non-significant (κ value = 0.162; $P = 0.073$). Moreover, no significant differences in adherence scores across different staging of physical frailty were observed (all $P > 0.05$; Fig. 1). However, a linear trend towards greater adherence to a MedDiet and those identified as non-frail compared with those identified as frail was observed when using the MEDAS adherence tool (MEDAS: non-frail: 5.96 ± 2.51; pre-frail: 5.28 ± 1.82; frail: 4.17 ± 1.33; $P = 0.116$; Fig. 1). This same trend, however, was not observed when assessing adherence to a MedDiet with the MED tool and staging of physical frailty (Fig. 1).

Standardised beta coefficients (β) reported from multiple regression analysis for associations between adherence to a MedDiet and measures of physical performance and muscle strength are presented in Table 4. When assessing adherence to a MedDiet using the MED and MEDAS tools, all multivariable models demonstrated that greater adherence to a MedDiet was significantly associated with better gait speed, even after adjustment for age, physical activity and length of time since T2DM diagnosis and age (MED: $\beta = 0.365$; $P = 0.002$; MEDAS: $\beta = 0.313$; $P = 0.007$). Similarly, when using the MEDAS tool, greater adherence to a MedDiet was significantly associated with a higher level of physical performance when assessed against the SPPB (Table 4). However, this association was no longer significant in the adjusted model ($\beta = 0.178$; $P = 0.154$). Nil associations were observed when assessing adherence against muscle strength. Finally, when we assessed the individual dietary elements included in the MED score, fish and seafood consumption was the single significant contributor to better gait speed, even after adjustments for age, physical activity and length of time since T2DM diagnosis ($\beta = 0.229$; $P = 0.05$).

4. Discussion

The present study revealed that among community-dwelling older adults with T2DM, greater adherence to a MedDiet pattern

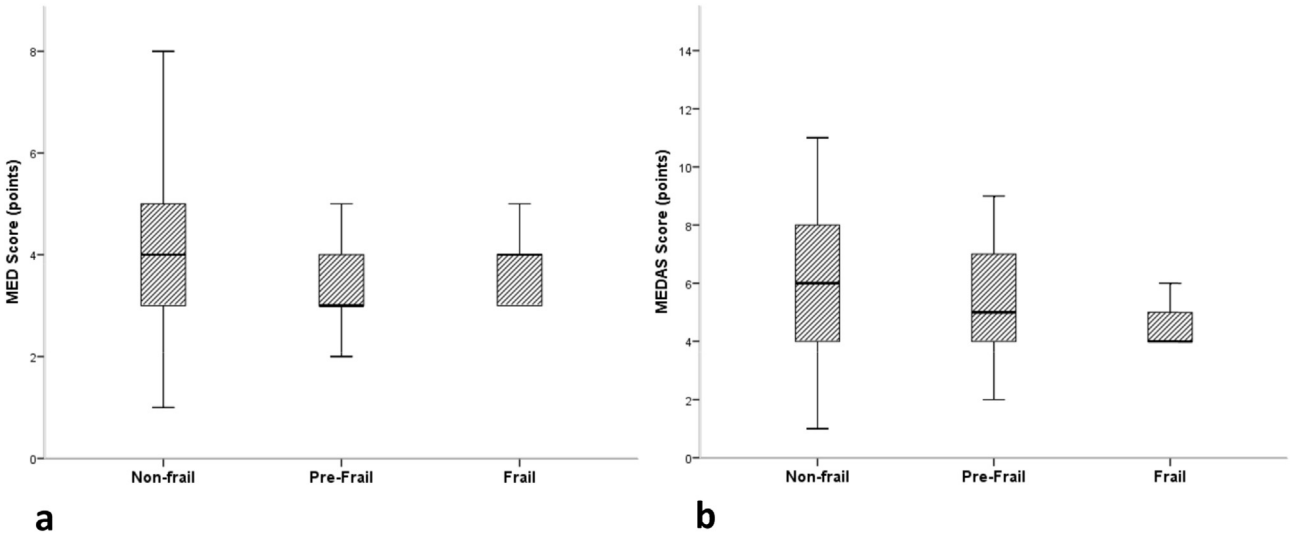

Fig. 1. Mediterranean Diet adherence scores across different staging of physical: (a) alternate Mediterranean food score (MED) (maximum 9 points) in non-frail ($n = 49$; 3.84 ± 1.52), pre-frail ($n = 32$; 3.56 ± 1.48) and frail ($n = 6$; 3.83 ± 0.75) participants; (b) 14-point Mediterranean diet adherence score (MEDAS) (maximum 14 points) in non-frail ($n = 49$; 5.96 ± 2.51), pre-frail ($n = 32$; 5.28 ± 1.82) and frail ($n = 6$; 4.17 ± 1.33) participants. The boxes represent the 25th–75th percentiles and the bold horizontal lines highlight the median scores. The whiskers represent the highest and lowest values lying within 1.5 box lengths from either end of the box. Differences in adherence scores across different staging of physical frailty were assessed using analysis of variance (ANOVA). No significant differences in adherence scores across the different stages were observed.

Table 4
Multiple regression coefficients expressing associations between adherence to a Mediterranean Diet (a) MED and (b) MEDAS and physical performance, muscle strength and appendicular skeletal muscle (standardised beta-coefficient (β)).

	(a) MED				(b) MEDAS			
	Crude model		Adjusted model[a]		Crude model		Adjusted model[a]	
	β	*P*-value	β	*P*-value	β	*P*-value	β	*P*-value
SPPB	0.046	0.672	0.100	0.941	0.243	0.023[b]	0.178	0.154
Gait speed	0.266	0.013[b]	0.365	0.002[b]	0.351	0.001[b]	0.313	0.007[b]
Strength	0.050	0.649	0.008	0.949	0.194	0.073	0.135	0.258

Abbreviations: SPPB, Short Physical Performance Battery; MED, alternate Mediterranean food score; MEDAS, 14-point Mediterranean Diet Adherence Screener.
[a] Adjusted for age, physical activity, and time since T2DM diagnosis.
[b] *P*-value refers to significant associations between adherence to a MedDiet, gait speed and physical performance.

was significantly associated with better lower extremity physical performance, as assessed by gait speed and the SPPB. Moreover, we reported a novel finding in that fish and seafood consumption was the most significant contributor to better gait speed, independent of age, physical activity and length of time since T2DM diagnosis.

In addition to the micro and macrovascular diseases which contribute to disability in older adults with T2DM, the physical frailty phenotype is now emerging as a third category of complications [3,23]. In the present study the relative proportion of older adults with T2DM identified as frail or with pre-frailty is consistent with previous literature investigating the prevalence of frailty in older adults with chronic diseases [24–26]. These findings continue to add to the growing body of literature suggesting that older adults with T2DM are vulnerable to physical frailty. Previous evidence is suggestive of an increased risk of mobility disability and poor muscle quality in older adults with T2DM relative to their nondiabetic counterparts [27,28]. Although speculative, a number of biological mechanisms describing the pathway to disability in T2DM have been postulated including insulin resistance, hyperglycaemia, oxidative stress and chronic inflammation [3,29].

In the present study, we demonstrated that greater adherence to a MedDiet was associated with better gait speed. These findings are also consistent with the overarching literature, suggesting that greater adherence to a MedDiet is associated with improved physical performance in older non-diabetic populations. Longitudinal analysis from the InCHIANTI study showed that greater adherence to a MedDiet significantly attenuated the decline in mobility over nine years of follow-up [30]. Moreover, a further five studies also reported significant associations between greater adherence to a MedDiet and preservation of lower body physical function, in particular gait speed, amongst community dwelling older adults [21,31–34].

Unlike previous literature, our study is one of the first of its kind to demonstrate positive associations between adherence to a MedDiet and lower body extremity performance in older adults with T2DM. Lopez-Garcia et al. [35] also recently reported that greater adherence to a MedDiet is associated with a reduced risk of physical frailty in older women with T2DM. Specifically, a two point increase in the MED score was significantly associated with a 28% risk reduction for frailty [35]. The exact mechanisms in support of these findings remains poorly understood. As with previous research on the proposed health benefits of the MedDiet, the most compelling theory relates to the potential synergy of nutrients and their role in attenuating the physiological mechanisms implicated with the physical frailty phenotype, including oxidative stress and inflammation [2,36]. The MedDiet offers a unique nutritional profile rich in monounsaturated and omega-3 (n-3) fatty acids, vitamins, minerals, antioxidants and non-nutritive compounds including polyphenols, carotenoids and flavonoids [37,38]. Synergistically, the interaction between these nutrients may exert multifactorial benefits on skeletal muscle functioning by reducing oxidative stress and pro-inflammatory cytokines [13–15]. Moreover, previous clinical trials have demonstrated that a MedDiet intervention attenuates inflammation, oxidative stress and improves insulin resistance [39,40] in adults with and without diabetes, which are all key physiological components in the biological pathway to physical frailty. Therefore, these mechanisms could help explain the positive association between adherence to a MedDiet and better gait speed observed from our study.

In accordance with standardised scoring protocols, equal weights were assigned to each of the individual nine dietary elements to establish the MED score. However, it is unknown whether specific food groups within a MedDiet pattern exert a greater influence. Lopez-Garcia et al. [35] previously reported that fruits and vegetables exhibited the strongest association, within a MedDiet pattern, for a reduced risk of physical frailty. In contrast, we showed that fish and seafood consumption was the most significant contributor to better gait speed, independent of age, physical activity and length of time since T2DM diagnosis. Similar findings have also been shown in a previous cross-sectional analysis of the InCHIANTI study [41] where plasma concentrations of n-3 fatty acids, a biological marker of fish and seafood consumption, was associated with greater protection against accelerated declines in physical performance [42]. Furthermore, in a recent randomized controlled trial Smith et al. [43] showed that 6 months of n-3 fatty acid supplementation, without exercise, had statistically and clinically significant benefits on increasing muscle thigh volume, handgrip strength, and upper/lower body 1-RM muscle strength. Similar findings were also reported by Rodacki et al. [44] whereby n-3 fatty acid supplementation was shown to augment exercise induced changes in muscle strength and physical performance in elderly women. Although long chain n-3 fatty acids, eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:3n-6) found in fatty fish, are recognized for their potent anti-inflammatory properties [45], it has previously been speculated that the anabolic effects of n-3 fatty acids are independent of any significant influence on inflammation. Rather, they likely involve alterations in both anabolic and catabolic pathways, improved mitochondrial functioning and biogenesis, neuroprotection and motor-neuron excitability properties [43,44].

In the present study, we observed significant associations between adherence to a MedDiet and gait speed when using either adherence tool; however, unlike the MEDAS tool, no association between adherence to a MedDiet and physical performance was observed when assessed using the MED tool. Although a number of diet quality indices, such as *a priori* scoring systems, have been used to quantify adherence to a MedDiet [11], differences in the present study are not surprising given that many of the scoring systems used to quantify adherence are not homogeneous, making comparisons difficult. In the present study, no agreement between the two adherence tools was observed. Nevertheless, despite these differences, previous studies [46,47] have reported agreement when using either the MEDAS adherence tool or a population-based MedDiet adherence score, such as the MED or MDS.

Although key findings from the present study are consistent with existing literature, there are some important considerations that should be applied toward the interpretation of these results. Firstly, although we achieved statistical power, relative to previous observational studies, the sample size of this cohort was small. Moreover, the cross-sectional nature of this study limits the establishment of causality. Furthermore, two different dietary adherence instruments were used, which yielded slightly differing

results. The majority of previous studies have assessed adherence to a MedDiet using the MDS developed by Trichopoulou et al. [20]. However, the MED adherence tool was selected in the present study as it has previously been validated to assess adherence to a MedDiet in non-Mediterranean populations [18]. Unlike the MEDAS tool, which is based on normative scores and reflective of a Mediterranean-style diet, adherence tools such as the MDS or MED are dependent on the habitual dietary characteristics of the studied population, and may not reflect true adherence to a MedDiet, particularly in non-Mediterranean populations [48]. Importantly, given that we did not control for glycaemia upon recruitment, our results may indeed be overstated and not generalizable to the wider population of older adults with T2DM due to the potential heterogeneity in glycaemic control of the study cohort. Akin to many observational studies, dietary intake and physical activity behaviours were self-reported. Despite all questionnaires being administered by a member of the research team, recall bias may still exist, leading to an underestimation of dietary intake and an overestimation of energy expenditure, which may impact the reported prevalence of physical frailty within the studied cohort; nevertheless, this did not preclude the observation of a clear association between greater adherence to a MedDiet and better gait speed. Lastly, although multiple regression analyses were adjusted, some residual confounding cannot be ruled out.

In conclusion, adherence to a MedDiet was associated with better lower extremity physical performance in community-dwelling older adults with T2DM. These results are of clinical importance because physical frailty has been identified as potential risk factor for loss of independence, physical disability and falls and fracture risk, especially in vulnerable populations such as older adults with T2DM. Further confirmation of these findings in larger longitudinal studies and clinical interventions is warranted. Future directions for research should focus on the examination of the efficacy of MedDiet interventions in attenuating characteristics of physical frailty in vulnerable older adults.

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Statement of authorship

RM and AV were responsible for the study conception and design. RM was responsible for data collection, statistical analysis, interpretation of the findings and drafting the final manuscript. AV was responsible for conducting and interpreting DXA scans, interpretation of the findings and drafting the final manuscript.

Conflicts of interest

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clnesp.2019.05.009.

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