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# Associations between Mediterranean lifestyle and its components with clinical outcomes among community-dwelling older adults

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The present study examined cross-sectional and longitudinal associations between adherence to Mediterranean lifestyle (MEDLS) and health outcomes in older adults in England. We analyzed data from 565 adults aged ≥65 years in the English Longitudinal Study of Ageing. MEDLS adherence (0–24) included diet quality, physical activity, hydration, sleep, social isolation, and cooking habits. Outcomes included mobility limitations, basic (ADL) and instrumental (IADL) activities of daily living disability, walking speed, cognition, depressive symptoms, and mortality. Results indicated that higher MEDLS adherence was associated with lower ADL/IADL disability and reduced risk of functional decline. It also correlated with better cognitive performance and maintenance of processing speed, fluency, and memory, alongside fewer depressive symptoms. No associations with mortality were found. Sensitivity analysis indicated that social isolation, cooking activities, and physical activity were key contributors. In conclusion, greater MEDLS adherence relates to better physical and cognitive aging in non-MED settings.

The Mediterranean (MED) diet is a traditionally defined dietary pattern that emerged from millenary cultural exchanges among populations inhabiting the regions surrounding the MED basin[1,2]. It is characterized by high consumption of fruits, vegetables, whole grains, legumes, nuts, and olive oil, moderate intake of fish, occasional consumption of alcohol usually during meals, mainly wine, and limited intake of red meat and processed foods[1,2]. The MED diet gained substantial scientific attention in the 1990s, when population-based cohort studies reported a reduced risk of mortality among individuals with higher adherence[3,4]. Since then, numerous investigations have confirmed and expanded these findings, extending the benefits of the MED diet to a wide range of health outcomes[5–10].

Beyond the MED basin, growing attention has been directed toward the potential role of the MED diet in promoting longevity, particularly in the context of the so-called "Blue Zones," geographic areas characterized by exceptional life expectancy[11]. Although some of these regions (e.g., Ikaria, Nicoya, Okinawa) differ culturally and geographically, their dietary patterns often share similarities with the traditional MED diet, especially in terms of high consumption of plant-based foods and limited intake of processed products[11].

A substantial body of research has shown that greater adherence to the MED diet is associated with attenuated age-related deterioration in both physical performance and cognitive function[10,12–17]. Specifically, greater adherence to the MED diet is associated with slower age-related decline in physical performance and cognitive function, as well as a lower likelihood of conditions related to functional impairment (e.g., frailty and sarcopenia)[10,12–16].

Physical performance is a multidimensional construct referring to the purposeful movements generated by muscle activity that enable individuals to interact with their environment[18,19]. It encompasses a wide range of actions, from simple tasks involving small muscle groups, such as grasping an object, to more complex activities, such as walking, which require the coordinated integration of multiple muscle groups and physiological systems[18,19]. Physical performance is a component of physical functioning—also called functionality—which refers to an individual's ability to use physical capacities (e.g., muscle strength and power) to perform fundamental physical tasks (e.g., rising from a chair, walking)[20]. Similarly, cognitive function is a broad construct encompassing the mental abilities that enable individuals to perceive, process, store, and use information to interact with and respond to their environment[21,22].

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**Table 1 | Main characteristics of study participants (*n* = 565)**

| Variables | Values |
|---|---|
| Age, *y* | 73.68 (5.95) |
| Female, % | 55.8 |
| Caloric intake, kcal/day | 2106.82 (715.94) |
| Hospitalized during COVID-19, % | 4.3 |
| Current smoking, % | 9.4 |
| Mobility aids, % | 2.2 |
| Age at completion of education, % | |
| Not yet finished | 1.0 |
| 14 or under | 3.8 |
| At 15 | 39.3 |
| At 16 | 23.4 |
| At 17 | 7.5 |
| At 18 | 7.1 |
| 19 or over | 16.3 |
| MEDLS, mean (SD) | 9.2 (2.7) |
| Dietary habits (0–18), mean (SD) | 9.3 (1.9) |
| Physical activity (≥600 MET·min/day), % | 190 (33.7) |
| Hydration status (≥5 glasses per day), % | 37 (6.5) |
| Presence of social isolation, % | 462 (81.8) |
| Sleeping patterns (6–8 h), % | 328 (95.6) |
| Cooking activities (yes), % | 321 (58.6) |
| Physical function | |
| ADL problems, % | 100 (17.7) |
| IADL problems, % | 117 (20.7) |
| Mobility problems, % | 328 (58.1) |
| Prefrailty, % | 496 (87.8) |
| Frailty, % | 188 (33.3) |
| Prior falls, % | 411 (72.7) |
| WS in seconds, mean (SD) | 2.8 (1.0) |
| Cognition | |
| MMSE, mean (SD) | 27.08 (3.2) |
| TICS, mean (SD) | 2.82 (0.48) |
| TMT-A, mean (SD) | 51.83 (31.83) |
| TMT-B, mean (SD) | 108.39 (53.58) |
| TMT-B – TMT-A, mean (SD) | 59.63 (43.64) |
| TMT-B/TMT-A, mean (SD) | 2.54 (2.32) |
| IR, mean (SD) | 19.09 (5.31) |
| DR, mean (SD) | 18.65 (2.38) |
| RM, mean (SD) | 19.24 (4.88) |
| Verbal fluency, mean (SD) | 5.67 (2.74) |
| Letter cancellation, mean (SD) | 19.88 (9.22) |
| Raven's Progressive Matrices, mean (SD) | 13.82 (3.57) |
| Logical Memory, mean (SD) | 4.11 (1.5) |
| Backward Counting, mean (SD) | 1.05 (1.42) |
| Constructional Praxis Recall, mean (SD) | 33.55 (12.07) |
| CES-D, mean (SD) | 7.55 (3.3) |

*ADL* activities of daily living, *CES-D* Center for Epidemiologic Studies Depression Scale, *DR* delayed recall, *IADL* Instrumental Activities of Daily Living, *IR* immediate recall, *MMSE* Mini-Mental State Examination, *RM* recognition memory, *SD* standard deviations, *TICS* Telephone Interview for Cognitive Status, *TMT-A* Trail Making Test Part A, *TMT-B* Trail Making Test Part B, *WS* walking speed.

These outcomes are particularly relevant in late life because maintenance of functionality and cognition are key determinants of healthy aging[23,24]. Their preservation has been consistently emphasized by the World Health Organization (WHO) as essential for sustaining quality of life in later years[25].

More recently, the concept of MED diet has been expanded in response to arguments that the functional benefits attributed to adequate nutritional habits may stem not only from dietary intake itself but also from its integration within a broader MED way of living[2,26]. This lifestyle is traditionally characterized by a combination of high levels of physical activity (PA), strong social engagement, and adequate sleep, among other behaviors that are strongly associated with better health outcomes[27–33]. Such reasoning led to the emergence of the term Mediterranean lifestyle (MEDLS)[2,26].

Since then, an increasing number of studies have examined the effects of the MEDLS framework[34–39]. Nonetheless, data regarding physical function and cognition are still scarce, with just a few evidence available[40,41]. Furthermore, available studies restricted the analysis to frailty status, examined older adults with advanced stages of cognitive decline (e.g., Alzheimer's disease), and are based on a cross-sectional design. As such, a comprehensive synthesis examining MEDLS is still lacking.

The applicability of the MED diet beyond its region of origin has been extensively investigated, with numerous studies evaluating its transferability to non-MED settings (e.g., United States of America, Sweden, Denmark, Germany)[42,43]. These efforts reflect a broader attempt to establish a globally adaptable dietary model capable of mitigating major risk factors in older populations. However, this growing interest has raised concerns, as some authors argue that adherence to the MED diet in non-MED contexts often represents only the consumption of foods with similar nutrient profiles to the traditional pattern[42,44]. In this scenario, the validity of applying the MED diet in non-MED countries may be compromised, which also raises questions about the potential effectiveness of MEDLS in these geographical locations.

Based on these premises, the present study examined data from the English Longitudinal Study of Ageing (ELSA) to provide a comprehensive assessment of the associations between MEDLS and its components with physical function, cognition, and death among community-dwelling older adults.

## Results

### Participants' characteristics

Main characteristics of the study participants are presented in Table 1 ($n = 565$). Characteristics of study participants according to MEDLS categories are shown in Tables S1 and S2. Participants were mostly female (55.8%). MEDLS scores ranged from 4 to 18, with the majority of participants scoring between 6 and 10. Adherence to the MED diet ranged from 4 to 14, with most participants exhibiting results between 8 and 10. Feeling of isolation (81.8%) was highly prevalent among participants. Additionally, 33.7% exhibited adherence to PA recommendations, 95.6% slept for 6–8 h, and 6.5% maintained adequate hydration levels. Mobility problems, disability in basic (ADL) and instrumental (IADL) activities of daily living were identified in 58.1%, 17.7%, and 20.7% of the study participants, respectively. Walking aids (i.e., cane, walking stick, Zimmer frame, and walker) were used by 2.2%. A high prevalence of prefrailty was observed (87.8%), whereas only 33.3% of the participants were identified as frail. Average Mini-Mental State Examination (MMSE) was $26.3 \pm 3.4$, with most participants (82.3%) scoring between 24 and 30 points. The majority of participants (84.1%) self-reported that they had not experienced significant changes in their mental abilities during the 2 years preceding data collection. Nearly 80% rated their mental abilities as good/very good. During follow-up, the incidence of mobility problems, falls, ADL disability, IADL disability, prefrailty, and frailty was 64.9%, 27.5%, 24.9%, 15.1%, 7.9%, and 5.6%, respectively. A total of 68 participants (2.7%) died during follow-up.

### Cross-sectional and longitudinal associations between MEDLS and physical function

Results of the cross-sectional and longitudinal unadjusted and adjusted associations between MEDLS and physical function are shown in Table S3

**Table 2 | Binary longitudinal regressions between MEDLS and physical function***

| | MEDLS (Total score) | | | | | | MEDLS (Quartiles) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unadjusted | | | Adjusted | | | Unadjusted | | | Adjusted | | |
| | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value |
| Variables | | | | | | | | | | | | |
| ADL problems | **0.715** | **0.628, 0.815** | **0.001** | **0.414** | **0.189, 0.908** | **0.028** | 0.510 | **0.393, 0.661** | **0.001** | **0.141** | **0.189, 0.908** | **0.028** |
| IADL problems | 0.947 | 0.832, 1.078 | 0.408 | **0.750** | **0.157, 1.343** | **0.013** | 0.954 | 0.686, 1.373 | 0.778 | 0.591 | 0.123, 2.581 | 0.513 |
| Self-reported mobility problems | **0.833** | **0.812, 0.960** | **0.003** | 0.280 | 0.453, 1.258 | 0.280 | **0.761** | **0.608, 0.953** | **0.017** | 0.569 | 0.154, 2.101 | 0.398 |
| Prefrailty | 0.912 | 0.743, 1.120 | 0.379 | 1.114 | 0.772, 1.606 | 0.565 | 0.886 | 0.547, 1.435 | 0.622 | 1.514 | 0.538, 4.258 | 0.432 |
| Frailty | 0.873 | 0.756, 1.007 | 0.062 | 0.628 | 0.265, 1.485 | 0.289 | 0.864 | 0.622, 1.199 | 0.382 | 0.371 | 0.073, 1.882 | 0.232 |
| Prior falls | 0.916 | 0.827, 1.014 | 0.090 | 1.167 | 0.882, 1.545 | 0.280 | 0.879 | 0.678, 1.141 | 0.333 | 2.413 | 0.865, 6.743 | 0.093 |
| | Beta | 95% CI | *P*-value | Beta | 95% CI | *P*-value | Beta | 95% CI | *P*-value | Beta | 95% CI | *P*-value |
| WS | 0.290 | −0.052, 0.111 | 0.481 | −0.141 | −0.490, 0.208 | 0.405 | 0.332 | −0.227, 0.892 | 0.244 | −0.187 | −1.257, 0.883 | 0.717 |

**Bold denotes significance**.
*ADL* Activities of daily living, *CI* confidence interval, *IADL* Instrumental activities of daily living, *OR* odds ratio, *WS* walking speed.
*MEDLS (Total score): entered as a continuous variable; MEDLS (Quartiles): ordinal quartile variable (1–4) used to test linear dose–response trend across adherence levels.

and Table 2, respectively. In the cross-sectional analysis, MEDLS (overall and quartiles) was significantly associated with ADL and IADL disability. We also observed significant associations between MEDLS—as quartiles—and self-reported mobility problems. In the longitudinal analysis, associations between MEDLS—overall, quartiles—and ADL disability, and overall MEDLS scores and IADL disability, remained significant. No other significant associations were found.

Sensitivity analysis was conducted to examine the associations between MEDLS and the incidence of self-reported mobility problems and both ADL and IADL disability (Table S4). After removing those individuals with self-reported mobility problems, ADL, and IADL disability at baseline, no significant associations were observed.

### Cross-sectional and longitudinal associations between MEDLS and cognitive function

Results of the cross-sectional and longitudinal unadjusted and adjusted associations between MEDLS and cognitive function are shown in Table S5 and Table 3, respectively. In the cross-sectional analysis, MEDLS (overall) was significantly associated with MMSE (overall, highest quartile), the time to complete the Trail Making Test Part B (TMT-B), Raven's Progressive Matrices (RV), Backward Counting (BC), and Constructional Praxis Recall (CPR) scores. MEDLS (quartiles) was also significantly associated with the time to complete the TMT-A, Immediate Recall (IR), and RV scores. In the longitudinal analysis, the association between increasing MEDLS adherence quartiles and TMT-A performance remained significant, with each one-quartile increase in MEDLS adherence associated with a shorter completion time and, therefore, better performance. Moreover, the associations between MEDLS adherence and BC and verbal fluency, as well as between increasing MEDLS quartiles and changes in Center for Epidemiologic Studies Depression Scale (CES-D) scores, became significant.

### Associations between MEDLS and mortality

Associations between adherence to MEDLS and mortality are shown in Table 4. No significant associations were observed.

### Associations between MEDLS components and clinical outcomes

A sensitivity analysis was conducted to examine the effects of individual MEDLS components on the observed associations. Significant results are shown in Table 5, while the complete results of the sensitivity analyses are shown in Tables S6–S9. Numerous cross-sectional associations were observed between MEDLS components and cognitive and functionality. MED diet was significantly associated with MMSE scores, while PA was significantly associated with verbal fluency and RV scores. Social isolation was significantly associated with ADL, IADL, and self-reported mobility problems and prior falls, as well as with MMSE, TMT-A, TMT-B, and RV scores. Adequate sleep patterns were significantly associated with verbal fluency, while cooking activity was significantly associated with CPR scores. In the longitudinal analysis, social isolation was significantly associated with ADL problems and changes in BC and CES-D scores. Cooking activity was significantly associated with frailty and changes in TICS scores.

## Discussion

The main findings of the present study indicate that high adherence to MEDLS was significantly associated with a lower risk of worsening physical function and cognitive performance among community-dwelling older adults. Specifically, MEDLS—as an overall score or examined according to those in the highest quartile—was significantly and negatively associated with ADL and IADL disability, and positively with animal fluency, after adjustment for many covariates. Furthermore, those with the highest adherence to MEDLS had a lower risk of decline in TMT-A and CES-D. Notably, significant differences were observed between the cross-sectional and longitudinal associations. Furthermore, the sensitivity analysis indicated that individual MEDLS components significantly contributed to its effects on cognition and functionality. In particular, social isolation, cooking activities, and PA levels were associated with a substantial number of these relationships.

Only a few studies have examined the associations between MEDLS and functionality or cognitive function[40,41]. Anastasiou et al.[41] analyzed data from the Hellenic Longitudinal Investigation of Ageing and Diet (HELIAD) study and observed better global cognitive function, memory, executive visual-spatial function, and verbal fluency among older adults with higher adherence to MEDLS. When each MEDLS aspect was examined individually, MED diet, PA, and sleep patterns emerged as significant determinants of the associations. Maroto-Rodriguez et al.[40] examined data from the Seniors-ENRICA-1 prospective study to test the associations between MEDLS and frailty. The analysis involved more than one thousand older adults and an average follow-up period of 3.3 years. Results indicated that each 2-point increment in MEDLS adherence was significantly associated with a 27% lower relative risk of frailty.

Despite these important findings, to the best of our knowledge, no comprehensive analysis has yet examined the relationships with MEDLS

**Table 3 | Binary longitudinal regressions between MEDLS and cognition***

| | MEDLS (Total score) | | | | | | MEDLS (Quartiles) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unadjusted | | | Adjusted | | | Unadjusted | | | Adjusted | | |
| | Beta | 95% CI | *P*-value | Beta | 95% CI | *P*-value | Beta | 95% CI | *P*-value | Beta | 95% CI | *P*-value |
| Variables | | | | | | | | | | | | |
| MMSE | **0.242** | **0.160, 0.323** | **<0.001** | 0.222 | −0.365, 0.808 | 0.436 | **0.844** | **0.610, 1.079** | **<0.001** | 0.096 | −4.294, 4.486 | 0.964 |
| TICS | **0.05** | **0.034, 0.067** | **<0.001** | 0.058 | −0.085, 0.201 | 0.406 | **0.174** | **0.127, 0.220** | **<0.001** | −0.056 | −1.128, 1.015 | 0.913 |
| TMT-A | **−1.349** | **−2.070, −0.627** | **<0.001** | −2.358 | −6.984, 2.267 | 0.297 | **−4.769** | – | **<0.001** | **−10.18** | **−17.358, −3.002** | **0.006** |
| TMT-B | −2.952 | −6.209, 0.305 | 0.075 | −0.397 | −21.053, 20.258 | 0.968 | 1.246 | −3.649, 6.140 | 0.617 | 56.529 | −92.492, 205.551 | 0.435 |
| TMT-B – TMT-A | −0.001 | −0.018, 0.015 | 0.871 | 0.112 | −10.660, 10.883 | 0.982 | **8.803** | **1.454, 16.152** | **0.019** | −7.458 | −25.364, 10.718 | 0.413 |
| TMT-B/TMT-A | 0.001 | −0.001, 0.004 | 0.241 | 0.07 | −0.279, 0.418 | 0.672 | 0.214 | −0.048, 0.475 | 0.108 | 0.144 | −0.244, 0.532 | 0.460 |
| IR | 0.182 | −0.003, 0.367 | 0.054 | 0.143 | −0.252, 0.539 | 0.454 | 0.268 | −0.021, 0.558 | 0.069 | 0.08 | −2.875, 3.034 | 0.955 |
| DR | **0.187** | **0.047, 0.327** | **0.009** | 0.1 | −0.268, 0.468 | 0.574 | **0.739** | **0.504, 0.974** | **<0.001** | 0.128 | −2.604, 2.861 | 0.922 |
| RM | 0.009 | −0.033, 0.052 | 0.651 | −0.027 | −0.291, 0.236 | 0.830 | **0.542** | **0.149, 0.935** | **0.007** | 0.218 | −1.720, 2.156 | 0.815 |
| Verbal fluency | **0.671** | **0.277, 1.066** | **0.001** | 1.458 | −0.412, 3.327 | 0.118 | **2.365** | **1.658, 3.073** | **<0.001** | **17.396** | **4.063, 30.729** | **0.014** |
| Letter cancellation | **0.034** | **0.005, 0.064** | **0.021** | 0.003 | −0.035, 0.040 | 0.887 | **0.096** | **0.011, 0.181** | **0.027** | 0.082 | −0.194, 0.357 | 0.539 |
| Raven's Progressive Matrices | **0.174** | **0.096, 0.252** | **<0.001** | 0.344 | −0.232, 0.920 | 0.224 | **1.181** | **0.900, 1.463** | **<0.001** | 1.374 | −2.995, 5.743 | 0.516 |
| Backward Counting | **1.219** | **0.340, 2.098** | **0.006** | **2.826** | **0.125, 5.527** | **0.041** | **2.13** | **1.269, 2.991** | **<0.001** | **13.808** | **1.647, 25.970** | **0.028** |
| Constructional Praxis Recall | 0.068 | −0.003, 0.140 | 0.062 | 0.224 | −0.367, 0.815 | 0.435 | **0.542** | **0.149, 0.935** | **0.007** | 1.600 | −2.751, 5.951 | 0.449 |
| CES-D | −0.059 | −0.127, 0.010 | 0.093 | −0.041 | −0.581, 0.500 | 0.876 | −0.002 | −0.269, 0.265 | 0.989 | **−3.656** | **−6.935, −0.377** | **0.031** |

**Bold denotes significance**.

*BC* backward counting, *CES-D* Center for Epidemiologic Studies Depression Scale, *CI* confidence interval, *CPR* Constructional Praxis Recall, *DR* delayed recall, *IR* immediate recall, *LC* letter cancellation, *MMSE* Mini-Mental State Examination, *OR* odds ratio, *RM* recognition memory, TICS Telephone Interview for Cognitive Status, *TMT-A* Trail Making Test Part A, *TMT-B* Trail Making Test Part B, *VF* verbal fluency.

*MEDLS (Total score): entered as a continuous variable; MEDLS (Quartiles): ordinal quartile variable (1–4) used to test linear dose–response trend across adherence levels.

across various measures, clinical conditions (e.g., functionality, cognitive function, mortality), and different time points (e.g., baseline and follow-up) in community-dwelling older adults. Our findings add to the current knowledge by providing such data and to emphasize the importance of MEDLS as an effective strategy to reduce the risk of physical and cognitive impairments in people with advanced age.

Particularly, individuals with high adherence to MEDLS had a lower risk of experiencing worsening disability, impairments in semantic fluency (i.e., animal fluency), processing speed, visual attention, and psychomotor speed (i.e., TMT-A), and depressive symptomatology. These results have important clinical implications because maintaining physical functioning and cognition is central to the concept of successful aging, which focuses on experiencing senescence with quality of life and dignity[23,24]. Furthermore, preserving these health parameters might significantly reduce the risk of burden of major clinical events, including falls and fractures, hospitalization, comorbidities, polypharmacy, nursing-home placement, and mortality[27,45–52].

Differences between cross-sectional and longitudinal findings on cognitive function are notable and warrant further exploration. Along with the intrinsic factors that may individually impact each cognitive domain[53–55], and the cross-sectional design that does not establish cause-and-effect relationships, our results might reflect the difficulty of adhering to MEDLS over long periods. Indeed, adherence to MEDLS is influenced by a complex interplay of numerous parameters[56,57].

For instance, moderate adherence to MEDLS is often observed among older adults[58]. Perceived barriers include, among others, the difficulty of acquiring and seasonality of MED foods, lack of knowledge of how to incorporate MED diet components, high costs associated with specific adapted gyms, lack of motivation to cook, resistance to dietary changes, diminished sensory response to MED diet, fear of falling, fractures, and pain, fatigue, monotonous exercise sessions, cultural believes, poor environment, institutional ageism, physical limitations, and presence of comorbidities[59–61].

Furthermore, the limited data available from the ELSA study prevented us from adjusting for intermediate conditions, such as sarcopenia and malnutrition, or from conducting more in-depth analyses to investigate their potential role in the pathway between relatively good health and the study outcomes.

**Table 4 | Binary regressions between MEDLS and mortality***

| | MEDLS | | | | | |
|---|---|---|---|---|---|---|
| | Unadjusted | | | Adjusted | | |
| | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value |
| **MEDLS (Total score)** | **0.729** | **0.644, 0.825** | **0.001** | 0.965 | 0.779, 1.194 | 0.741 |
| **MEDLS (Quartiles)** | **0.46** | **0.352, 0.600** | **0.001** | 0.906 | 0.535, 1.533 | 0.713 |

**Bold denotes significance**.
*CI* confidence interval, *OR* odds ratio.
*MEDLS (Total score): entered as a continuous variable; MEDLS (Quartiles): ordinal quartile variable (1–4) used to test linear dose–response trend across adherence levels.

**Table 5 | Regressions between MEDLS components and both physical function and cognition**

| Variables | Outcome domain | OR/B | 95% CI | *P*-value |
|---|---|---|---|---|
| Cross-sectional analyses | | | | |
| MED diet | | | | |
| MMSE | Cognitive function | 0.538 | 0.047 to 1.029 | **0.040** |
| Physical activity | | | | |
| Verbal fluency | | **2.456** | **0.223, 4.689** | **0.031** |
| Raven's Progressive Matrices | | **0.686** | **0.160, 1.213** | **0.011** |
| Social isolation | | | | |
| ADL problems | Physical function | 0.672 | 0.575–0.786 | **<0.001** |
| IADL problems | Physical function | 0.67 | 0.582–0.770 | **<0.001** |
| Self-reported mobility problems | Physical function | 0.877 | 0.781–0.985 | **0.026** |
| Prior falls | Physical function | 0.836 | 0.745–0.939 | **0.002** |
| MMSE | Cognitive function | 0.285 | 0.011 to 0.559 | **0.041** |
| TMT-A | Cognitive function | −4.124 | −6.828 to −1.600 | **0.002** |
| TMT-B | Cognitive function | −7.476 | −12.734 to −2.218 | **0.005** |
| Raven's Progressive Matrices | Cognitive function | 0.442 | 0.142 to 0.741 | **0.004** |
| Sleep patterns | | | | |
| Verbal fluency | Cognitive function | −9.077 | −17.393 to −0.761 | **0.033** |
| Cooking activity | | | | |
| Constructional Praxis Recall | Cognitive function | 0.446 | 0.165 to 0.728 | **0.002** |
| Longitudinal analyses | | | | |
| Social isolation | | | | |
| ADL problems | Physical function | 0.554 | 0.396–0.774 | **<0.001** |
| Backward Counting | Cognitive function | 2.838 | 0.410 to 5.266 | **0.023** |
| CES-D | Cognitive function | −1.154 | −2.204 to −0.105 | **0.033** |
| Cooking activity | | | | |
| Frailty | Physical function | 0.145 | 0.049–0.430 | **<0.001** |
| TICS | Cognitive function | −0.451 | −0.885 to −0.017 | **0.043** |

Another possible explanation is that MEDLS was assessed only at baseline. Lifestyle behaviors are dynamic and may change over time, particularly in older adults as a consequence of changes in health status, functional capacity, social circumstances, or life events. Consequently, baseline MEDLS may not accurately reflect long-term lifestyle exposure throughout follow-up, potentially attenuating longitudinal associations.

Finally, the possibility that high adherence to MEDLS is not sufficient to counteract the development of age-related disorders might not be ruled out. With advancing age, the human body undergoes progressive physiological dysregulation across multiple systems[62–65]. This dysregulation is characterized, among other changes, by increased markers of cellular senescence (e.g., DNA damage), metabolic imbalance, and systemic inflammation[64,65] leading to declining homeostatic control, greater vulnerability to external stressors, and contributing to the development of numerous chronic conditions [65,66]. In this context, more specific intervention strategies, such as individualized nutritional interventions[67] (e.g., oral protein supplementation when indicated) and structured exercise training[68] (e.g., progressive resistance training), may be required to optimize the preservation of physical function and cognition in older adults.

These explanations remain speculative and should be interpreted with caution. Future longitudinal studies with repeated assessments of lifestyle behaviors and potential mediators are needed to determine the mechanisms underlying the differences observed between cross-sectional and longitudinal associations.

We observed that specific MEDLS components, with special emphasis on social isolation, cooking activities, and PA levels, played a key role in some of the observed associations. Numerous studies have found significant and independent associations between low engagement in social activities and cognitive impairments[29,30,69]. Candidate explanations for these observations rely on the fact that poor social engagement limits cognitive stimulation, reducing reserve accumulation, while loneliness may be associated with increased psychological distress and long-term activation of stressful pathways (e.g., inflammation, hypothalamic-pituitary-adrenal axis), which might make the brain more susceptible to damage[30,69].

Furthermore, social isolation may contribute to disability through several pathways[70]. Reduced social engagement can increase inflammation and stress-related responses, which may accelerate physical decline and increase the risk of frailty[70]. In addition, socially isolated individuals may be less physically active and have fewer opportunities for social participation, leading to declines in mobility, muscle function, and independence[70].

PA is widely recognized as a protective modifiable factor against cognitive impairment. Higher PA levels are associated with slower cognitive decline among non-demented older adults[28,71]. Moreover, results from randomized clinical trials have shown that older adults engaged in PA programs experience significant improvements in many cognitive domains[72–76]. Numerous mechanisms have been proposed to explain these results, including improvements in cerebral blood flow, increased synthesis of myokines and neurotrophins, as well as reductions in inflammation and tau deposition[28,71,72,77].

Cooking activities represent an important aspect of daily living, reflecting not only dietary behaviors but also culinary traditions, autonomy, and engagement in meaningful activities. Participation in cooking may contribute to the maintenance of physical and cognitive function, as meal preparation requires planning, organization, attention, and motor skills. Previous studies have shown that cooking practices and methods are associated with frailty[78] and cognitive outcomes[79], suggesting that dietary preparation behaviors may reflect broader aspects of health status and functional capacity.

Notably, adherence to these lifestyle factors appears to be interdependent, as some studies suggest that higher adherence to one factor is often associated with greater adherence to others[80]. Taken as a whole, these findings indicate that preventive and treatment strategies based on the adoption of MEDLS could be implemented holistically, integrating all components, as their effects are interrelated.

Higher adherence to MEDLS was not associated with mortality in the present study. These findings are contrary to a comprehensive body of literature that supports lower mortality among older adults who adhere to MEDLS and its components[81–85]. These distinct results might be explained according to participants' characteristics, follow-up length, MEDLS index components[86], and mortality rate.

A final finding that warrants attention is that, among all MEDLS components, adherence to the MED diet was only significantly associated with global cognitive function. Although this finding is noteworthy, numerous studies have demonstrated that adherence to the MED diet is associated with a wide range of clinical outcomes, including physical function, cognitive domains, and mortality[10,12–17]. The transferability of the MED diet to non-MED countries has been a theme of debate[42,43]. Although traditional MED diet indexes might be adapted to other geographical locations distinct from those where they were developed[42,43], food composition and the way it is produced and prepared might differ significantly between MED and non-MED countries, impacting the possible benefits of this diet pattern on health aspects[42,44].

An alternative or complementary explanation is based on the average adherence to the MED diet observed in the present study, which is relatively lower than that found among older adults from MED countries[87]. In fact, pooled analyses have shown lower adherence to the MED diet in non-MED countries[56,85,88,89]. Hence, the possibility that different results might be obtained in MED populations with higher adherence levels cannot be ruled out.

The present study has several limitations that should be acknowledged. First, participants in the ELSA represent a cohort of relatively healthy individuals, with a notably low prevalence of mobility limitations, frailty, and moderately adequate nutritional intake. While this population provides valuable insights into a reasonably healthy segment of older adults, findings may not fully apply to individuals with more severe clinical conditions, such as sarcopenia and malnutrition. Therefore, further research including those with worse clinical profiles or more advanced frailty status is needed to broaden and complement our findings, offering a fuller understanding of how nutrition influences health aspects in older adults. Second, the ELSA study does not include variables indicating the number of years of education completed or the highest level of formal education attained. Therefore, we used age at completion of education as a proxy for educational attainment to adjust the model. This approach may have limitations and should be considered when interpreting the findings. Third, participants in ELSA Wave 11 (2023–2024) are survivors of the COVID-19 pandemic. Despite our efforts to control for this scenario by adjusting the analysis for those hospitalized due to the virus, the possibility that it could still affect our results cannot be ruled out. Fourth, mortality data were based on Wave 10 (2021–2023), as more recent data are not yet available. Fifth, the incidence of dementia was relatively low, which limited our ability to conduct further analysis on this condition. Sixth, MEDLS was based on self-reported measures, which increases the risk of recall bias, particularly in this population. Regarding MEDLS, thresholds for sleep patterns were determined using an instrument validated for the Spanish population and were based solely on a single night of sleep. Another aspect that warrants attention is hydration status. In the present study, only water intake was analyzed, as detailed information on total fluid consumption is not available in the ELSA study. Finally, although the overall sample included a relatively balanced distribution of males and females, the number of incident cases and deaths was insufficient to support adequately powered sex-stratified analyses. Dividing the sample by sex substantially reduced the number of events within each subgroup, limiting the robustness and reliability of these analyses. Future studies with larger samples and a greater number of outcome events are necessary to confirm and expand findings of the present study.

In conclusion, our findings suggest that higher adherence to the MEDLS is associated with a lower risk of decline in physical function and cognitive performance among community-dwelling older adults living in England. Additionally, we found that cognitive function was most strongly linked to the social isolation, cooking activities, and PA domains of the

MEDLS. These findings underscore the potential of MEDLS as an effective strategy to mitigate the negative effects of aging on physical function and cognition. Furthermore, these data provide a foundation for developing tailored interventions aimed at non-MED populations.

## Methods

### Study design and population

This prospective study examined both the cross-sectional and longitudinal associations between adherence to the MEDLS and health outcomes in older adults in England.

The ELSA is a longitudinal cohort of adults aged ≥50 years in England, with repeated assessments of physical performance, cognition, health behaviours, chronic conditions, and biological markers[90]. The study began in 2002–2003, and the most recent data collection occurred in Wave 11 (2023–2024). Nutritional information, including detailed dietary intake assessed through the FFQ, was collected only at Wave 9 (2018–2019). Therefore, Wave 9 was considered the baseline for the present analysis. Cognitive function data were recovered from the ELSA: Harmonised Cognitive Assessment Protocol, 2018-2023 database. Wave 11 (2023–2024) was used as the follow-up point, providing approximately 6 years of longitudinal observation. Mortality data were retrieved from Wave 10 (2020–2023), which captures deaths occurring between the baseline and the most recent wave available.

For this study, we restricted the analytical sample to participants aged ≥65 years at baseline. Individuals using mobility aids (i.e., a manual or electric wheelchair, buggy, or scooter) were excluded because they were unable to perform the physical performance tests and were, by definition, dependent, with disability and a high likelihood of frailty. We also excluded participants with major chronic conditions at baseline (i.e., cancer, Parkinson's disease, psychiatric disorders, Alzheimer's disease, multiple sclerosis, or motor neurone disease), as these conditions are strongly associated with cognitive and/or physical impairments and could substantially influence the associations between MEDLIFE adherence and the outcomes under investigation. Participants who developed any of these conditions during follow-up were also excluded from the longitudinal analyses to minimize potential bias arising from incident diseases that could affect physical or cognitive function.

Regarding nutritional information, 6730 participants were excluded due to missing Food Frequency Questionnaire (FFQ) data. Among those with available FFQ data, 1880 were further excluded because of insufficient information to compute the Medi-Lite score. Participants lacking sufficient data to construct the overall MEDLS score were also excluded, except for sleep duration, which was retained despite 222 missing values.

The final analytical cohort is depicted in Fig. S10. The ELSA study adhered to the ethical principles outlined in the Declaration of Helsinki and received ethical approval for the National Research Ethics Service (MREC/01/2/91). Informed consent was obtained from each participant before data collection. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (Table S11)[91].

**Mediterranean lifestyle**. Adherence to MEDLS was estimated using an adapted version of the index proposed by the Department of Preventive Medicine and Public Health of the School of Medicine of the *Universidad Autónoma de Madrid*, Madrid, Spain[34]. The MEDLS index used in the present study comprises a combination of 17 variables — 9 MED diet components and 8 lifestyle or social behavior items[2,26]. The nine dietary variables were scored according to the Medi-Lite system, with each component receiving 0–2 points and contributing up to 18 points to the total score. The eight lifestyle and social behavior items were used to derive five components: (i) PA levels, (ii) water intake, (iii) social isolation, (iv) sleeping patterns, and (v) cooking and food-preparation activities. PA, water intake, sleeping patterns, and cooking and food-preparation activities were scored dichotomously from 0 to 1, whereas social isolation was scored from 0 to 2. Together, the lifestyle and social components contributed up to six additional points. Individual component scores were summed to generate the total MEDLS score, ranging from 0 to 24, with higher scores indicating greater adherence to the Mediterranean lifestyle.

Adherence to the MED diet was assessed using the Medi-Lite score (0–18)[16,87], calculated across nine food categories. A score from 0 (lowest intake) to 2 (highest consumption) was assigned to food items usually included in a Medi-Diet (i.e., cereals, fruits, legumes, fish, and vegetables). For dietary categories not included in a typical Medi-Diet (e.g., meat and dairy products), 2 points were allocated to the lowest intake, 1 point to an intermediate consumption, and 0 points to the highest consumption. In the case of olive oil, 2 points were assigned for daily usage, 1 point for regular use, and 0 points for occasional consumption. For alcohol intake, 1 and 2 points were assigned to participants with near-to-moderate and moderate consumption, respectively, while non-consumers received 0 points. Overall scores ranged from 0 to 18, with higher scores indicating greater adherence to the MED diet.

Dietary data in ELSA are collected using a food-frequency questionnaire rather than quantitative gram/day intake. Accordingly, Medi-Lite scoring was operationalized using reported frequency of consumption for each food group following the validated approach commonly applied in population-based cohort studies using FFQ data.

Dietary intake was assessed using the FFQ administered in Wave 9 of the ELSA via the Oxford web questionnaire. The FFQ captures usual dietary intake over the previous 12 months by recording the frequency of consumption for a comprehensive list of foods and beverages. The score is based on FFQ-derived intake of key food groups, with higher values indicating greater adherence. Beneficial components (vegetables, fruits, legumes, cereals, fish, olive oil, and moderate alcohol) were scored positively according to consumption frequency, while detrimental components (red and processed meat, and high-fat dairy) were reverse-scored.

PA levels, expressed as metabolic equivalent task (MET)·min/day, were obtained from the derived MET variable available in the ELSA Wave 9 Nutrition Dataset. According to the ELSA Wave 9 Nutrition Data User Guide, MET·min/day on the day of the questionnaire was calculated based on participants' responses to the physical activity questions. These questions assessed the frequency of vigorous-, moderate-, and light-intensity physical activities using four response categories: more than once per week, once per week, one to three times per month, or hardly ever. PA levels were dichotomized as high (≥600 MET·min/day) or low (<600 MET·min/day). Participants classified as having high PA levels received 1 point in the MEDLS score[92].

Hydration status was assessed based on participants' reported intake of water consumed from a glass or beaker (e.g., still, sparkling, or tap water). The original MEDLIFE index[93] defines adequate hydration as ≥6 glasses of water per day. However, because only 3.4% of ELSA participants met this criterion, the threshold was adapted to ≥5 glasses/day to improve the distribution of the variable in this cohort. Participants meeting this criterion received 1 point in the MEDLS score.

Social isolation was assessed using items evaluating feelings of lacking companionship and perceived isolation from others. Response options included: *hardly ever or never*, *some of the time*, and *often*. Participants who reported feeling a lack of companionship or social isolation often were classified as having high social isolation (0 points), those reporting these feelings some of the time as moderate social isolation (1 point), and those reporting them hardly ever or never as having low social isolation (2 points). Higher scores indicated lower levels of social isolation and contributed positively to the MEDLS score. These parameters represent complementary social constructs, as social isolation refers to structural social deprivation, while loneliness is linked to subjective emotional distress[30].

Sleep patterns were assessed by calculating the total hours slept during the 24-h period preceding data collection. Participants who reported sleeping between 6 and 8 h were classified as having adequate sleep duration and received 1 point in the MEDLS score[34].

Cooking activity was assessed using a questionnaire item asking participants how often they prepared and cooked meals at home. Participants who reported cooking at home regularly received 1 point in the MEDLS score.

### Clinical outcomes and death

Physical functioning. Mobility problems were defined as the presence of difficulty in any of following tasks: (i) walking 100 yards, (ii) sitting for 2 h, (iii) getting up from a chair after sitting for long periods, (iv) climbing several flights of stairs without resting, (v) climbing a single flight of stairs without resting, (vi) stooping, kneeling, or crouching, (vii) reaching or extending the arms above shoulder level, (viii) pulling or pushing large objects, (ix) lifting or carrying weights over 10 pounds, and (x) picking up a 5-pence coin from a table.

ADL disability was defined as reporting difficulty in at least one ADL item: (i) dressing (including putting on shoes and socks), (ii) walking across a room, (iii) bathing or showering, (iv) eating (such as cutting up food), (v) getting in or out of bed, and (vi) using the toilet, while IADL disability included difficulties in at least one of the following variables: (i) using a map to navigate in an unfamiliar place, (ii) recognizing situations of physical danger, (iii) preparing a hot meal, (iv) shopping for groceries, (v) making telephone calls, (vi) communicating because of speech, hearing, or eyesight limitations, (vii) taking medications, (viii) doing work around the house or garden, and (ix) managing money (e.g., paying bills or keeping track of expenses)[94,95].

Frailty status was assessed using an adapted FRAIL scale[96]. Fatigue was assessed using the CASP-19 item "How often do you feel full of energy these days?", with responses coded as 1 for *always* or *sometimes* and 0 for *not often* or *never*. Resistance was defined as reporting difficulty climbing several flights of stairs without resting. Ambulation was defined as difficulty walking 100 yards. Illness was computed as the sum of chronic conditions. Only ten conditions are available in ELSA (chronic kidney disease was not assessed). Loss of weight was based on self-reported current body weight and weight 1 year earlier, with percent change calculated as $[(weight_{1year ago} - current\ weight)/weight_{1year ago}] \times 100$. A reduction greater than 5% was coded as 1 and less than or equal to 5% as 0. Participants reporting extreme weight change (>20 kg; $n = 64$) were excluded from the weight-loss component due to implausibility. Possible scores range from 0 to 5 points, and individuals are classified as robust (0 points), pre-frail (1–2 points), and frail (≥3 points).

Prior falls were assessed through self-report. Participants were classified as positive for prior falls if they answered "yes" to the question asking whether they had fallen since the previous interview.

Walking speed was derived from the timed 8-foot walk test. Participants completed two walking trials at their usual pace, and the time (in seconds) required to complete each walk was recorded. WS was calculated as the mean of the two trials, with lower values indicating faster performance.

### Cognition

Global cognitive function. Global cognitive function was assessed using the MMSE, a widely used 30-point screening tool evaluating orientation, registration, attention, recall, language, and visuospatial skills. Higher scores indicate better global cognition. The Telephone Interview for Cognitive Status is an 11-item cognitive screening instrument used to assess global cognition via telephone. It evaluates orientation, immediate and delayed recall, attention, and language. Higher scores reflect better cognitive status[97].

Executive function, attention, and processing speed. The TMT assesses multiple cognitive processes using two complementary parts. TMT-A measures visual search, psychomotor speed, and attention by requiring participants to connect numbered circles in ascending order as quickly as possible. TMT-B evaluates set shifting and cognitive flexibility, with participants alternating between numbers and letters in ascending sequence (1–A–2–B…). For both parts, total completion time (in seconds) is recorded, with longer times indicating poorer performance. Two additional indices were derived to contextualize executive functioning: a difference score (TMT-B – TMT-A) and a ratio score (TMT-B / TMT-A)[98]. Attention and visual scanning were assessed using a Letter Cancellation task that required identifying target letters within a structured array. Higher scores reflected better attentional control and processing speed[99].

Verbal memory. Verbal memory was assessed using the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) Word List Learning task, comprising immediate recall, delayed recall, and recognition memory. Immediate recall assessed the learning and recall of newly presented verbal information across three trials, whereas delayed recall assessed retention and retrieval following a delay. Recognition memory required participants to identify previously presented words among distractors, providing a measure of recognition and discrimination accuracy[100].

Language and verbal fluency. Language and semantic retrieval were evaluated with an animal naming verbal fluency task in which participants generated as many animal names as possible within 60 s. Higher scores indicated more efficient lexical retrieval and semantic organization.

Fluid reasoning. Nonverbal reasoning was assessed using Raven's Progressive Matrices (RV). This measure required participants to identify patterns and complete abstract visual analogies, providing an established index of fluid intelligence. Higher scores reflected stronger abstract reasoning. Baseline and follow-up scores were used to calculate reasoning change over time[99].

Working memory. Working memory and attention were measured using a Backward Counting (BC) task, in which participants counted backward from a specified starting point. Higher scores reflected stronger attentional control, working memory capacity, and mental sequencing. Change scores were computed to capture performance shifts across time [99].

Visuospatial memory. Visuospatial recall was assessed through Constructional Praxis Recall (CPR), which required reproducing previously viewed geometric designs from memory. Higher CPR scores indicated better visuospatial memory and constructional ability. Longitudinal comparisons were used to evaluate change in visuospatial recall[101].

Depressive symptomatology. Depressive symptoms were assessed using the Center for Epidemiologic Studies Depression Scale (CES-D), a 20-item measure evaluating mood, somatic complaints, and interpersonal difficulties. Higher scores indicate greater depressive symptomatology and are frequently used to adjust cognitive models[102].

Death. Survival status was obtained from the End-of-Life interviews (elsa_endoflife_hcap2_w10; wave 10). Time to death was calculated from the date of the baseline visit to that of death. All events were included in the analysis.

Covariates. Age was recorded in years, and sex was documented as male or female. Because severe COVID-19 infection may influence subsequent health trajectories, we also included an indicator of whether the participant had been hospitalized due to COVID-19 during the study period. Additional covariates were smoking status (yes/no), number of comorbidities, use of mobility aids, and age at completion of education (consolidated).

Statistical analysis. Sample sizes for each variable are provided in Table S12. Continuous variables were expressed as means ± standard deviations, and categorical variables as %. Comparisons between included and excluded participants are provided in Table S13. MEDLS was examined both as a total adherence score (ranging from 4 to 18) and by quartiles (1–4). Quartiles were entered as an ordinal variable to evaluate linear dose–response trends across increasing levels of adherence rather than as separate categorical comparisons. Logistic regression models were used to examine associations between MEDLS and history of falls, frailty status, mobility limitations, ADL and IADL disability, and mortality. Linear regression analyses were applied to investigate associations with cognitive domains. The final model was adjusted for age, sex, whether participants had been hospitalized due to COVID-19 during the study period, smoking status (yes/no), number of comorbidities, age at completion of education (for cognition variables), and, for physical function variables, use of mobility aids, including cane, walking stick, Zimmer frame, and walker. For longitudinal analyses, outcome-specific approaches were used: for categorical outcomes (e.g., disability, mobility problems, and frailty), models evaluated both worsening cases or incident cases by excluding participants presenting the condition at baseline, whereas for continuous variables (e.g., walking speed and cognitive tests), change scores between baseline and follow-up were analyzed. To identify which MEDLS components contributed to the observed significant associations, each aspect was analyzed individually. In these cases, models were composed of age, sex, number of comorbidities, and either age at completion of education or use of mobility aids. Effect sizes and 95% confidence intervals were calculated for all analyses, and significance was set at $p < 0{\cdot}05$. Analyses were conducted using SPSS version 23 (IBM, New York, NY, USA).

## Data availability

The datasets analyzed in this study can be accessed under subscription via the English Longitudinal Study of Ageing (ELSA) website. Researchers interested in using these data are required to register and comply with ELSA's data access policies.

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## References

1. Bach-Faig, A. et al. Mediterranean diet pyramid today. Science and cultural updates. *Public Health Nutr.* **14**, 2274–2284 (2011).
2. Diolintzi, A., Panagiotakos, D. B. & Sidossis, L. S. From Mediterranean diet to Mediterranean lifestyle: a narrative review. *Public Health Nutr.* **22**, 2703–2713 https://doi.org/10.1017/S1368980019000612 (2019).
3. Trichopoulou, A. et al. Diet and overall survival in elderly people. *BMJ* **311**, 1457 (1995).
4. Verschuren, W. M. M. et al. Serum total cholesterol and long-term coronary heart disease mortality in different cultures: twenty-five-year follow-up of the Seven Countries Study. *J. Am. Med. Assoc.* **274**, 131–136 (1995).
5. Martín-Peláez, S., Fito, M. & Castaner, O. Mediterranean diet effects on type 2 diabetes prevention, disease progression, and related mechanisms. A review. *Nutrients* **12**, (2020).
6. Martinez-Lacoba, R., Pardo-Garcia, I., Amo-Saus, E. & Escribano-Sotos, F. Mediterranean diet and health outcomes: a systematic meta-review. *Eur. J. Public Health* **28**, 955–961 (2018).
7. Sánchez-Sánchez, M. L. et al. Mediterranean diet and health: a systematic review of epidemiological studies and intervention trials. *Maturitas* **136**, 25–37, https://doi.org/10.1016/j.maturitas.2020.03.008 (2020).
8. Torres-Peña, J. D., Rangel-Zuñiga, O. A., Alcala-Diaz, J. F., Lopez-Miranda, J. & Delgado-Lista, J. Mediterranean diet and endothelial function: a review of its effects at different vascular bed levels. *Nutrients* **12**, 1–22, https://doi.org/10.3390/nu12082212 (2020).
9. Mamalaki, E., Balomenos, V., Scarmeas, N. & Yannakoulia, M. Type 2 diabetes and Mediterranean diet in older adults: a brief review of the evidence. *Curr. Geriatr. Rep.* **9**, 237–241 (2020).
10. Coelho-Júnior, H. J., Trichopoulou, A. & Panza, F. Cross-sectional and longitudinal associations between adherence to Mediterranean diet with physical performance and cognitive function in older adults: a systematic review and meta-analysis. *Ageing Res. Rev.* **70**, 101395 (2021).
11. Santacroce, L. et al. Healthy diets and lifestyles in the world: Mediterranean and Blue Zone people live longer. special focus on gut microbiota and some food components. *Endocr. Metab. Immune Disord. Drug Targets* **24**, 1774–1784 (2024).
12. Hardman, R. J. et al. The association between adherence to a Mediterranean style diet and cognition in older people: the impact of medication. *Clin. Nutr.* **37**, 2156–2165 (2018).
13. Fougère, B. et al. Association between the Mediterranean-style dietary pattern score and physical performance: results from TRELONG study. *J. Nutr., Health Aging* **20**, 415–419 (2016).
14. Struijk, E. A., Guallar-Castillón, P., Rodríguez-Artalejo, F. & López-García, E. Mediterranean dietary patterns and impaired physical function in older adults. *J. Gerontol. Ser. A Biol. Sci. Med. Sci.* **73**, 333–339 (2018).
15. Sotos-Prieto, M., Ortolá, R., López-García, E., Rodríguez-Artalejo, F. & García-Esquinas, E. Adherence to the Mediterranean diet and physical resilience in older adults: the Seniors-enrica cohort. *J. Gerontol. Ser. A Biol. Sci. Med. Sci.* **76**, 505–512 (2021).
16. Cacciatore, S. et al. Low adherence to Mediterranean diet is associated with probable sarcopenia in community-dwelling older adults: results from the longevity check-up (Lookup) 7+ project. *Nutrients* **15**, 1026 (2023).
17. McClure, R. & Villani, A. Mediterranean diet attenuates risk of frailty and sarcopenia: new insights and future directions. *JCSM Clin. Rep.* **2**, 1–17 (2017).
18. Coelho-Junior, H. J. et al. Age- and gender-related changes in physical function in community-dwelling brazilian adults aged 50 to 102 years. *J. Geriatr. Phys. Ther.* **44**, E123–E131 (2021).
19. Coelho-Júnior, H. J. & Marzetti, E. Protein intake and its interaction with dietary patterns on clinical outcomes among older adults. *npj Aging 2026 12:1* **12**, 68 (2026).
20. International Classification of Functioning, Disability and Health (ICF) — World Health Organization. in (2001).
21. Association, A. P. A. Dictionary of psychology. https://dictionary.apa.org/cognition (2019).
22. Machado, L. Understanding cognition and how it changes with aging, brain disease, and lifestyle choices. *J. R. Soc. N. Z.* **51**, 128–142 (2021).
23. Anton, S. D. et al. Successful aging: advancing the science of physical independence in older adults. *Ageing Res. Rev.* **24**, 304–327 (2015).
24. Liffiton, J. A., Horton, S., Baker, J. & Weir, P. L. Successful aging: how does physical activity influence engagement with life? *Eur. Rev. Aging Phys. Act.* **9**, 103–108, https://doi.org/10.1007/s11556-012-0098-0 (2012).
25. Beard, J. R. et al. The World report on ageing and health: a policy framework for healthy ageing. *Lancet* **387**, 2145–2154 (2016).
26. Kushkestani, M., Moghadassi, M. & Sidossis, L. Mediterranean lifestyle: more than a diet, a way of living (and thriving). *Endocr. Metab. Immune Disord. Drug Targets* **24**, 1785–1793 (2024).
27. Sanchez-Sanchez, J. L., Izquierdo, M., Carnicero-Carreño, J. A., García-García, F. J. & Rodríguez-Mañas, L. Physical activity trajectories, mortality, hospitalization, and disability in the Toledo Study of Healthy Aging. *J. Cachexia Sarcopenia Muscle* **11**, 1007–1017 (2020).
28. Yau, W.-Y. W. et al. Physical activity as a modifiable risk factor in preclinical Alzheimer's disease. *Nat. Med*. https://doi.org/10.1038/S41591-025-03955-6 (2025).
29. Pan, C. & Cao, N. Bidirectional associations between social isolation, loneliness, and cognitive function among Chinese older adults. *J. Glob. Health* **15**, (2025).
30. Li, L. et al. The independent association of social isolation and loneliness with cognitive frailty in Chinese older adults: a cross-sectional study. *BMC Public Health* **25**, 3860 (2025).
31. Gale, C. R., Westbury, L. & Cooper, C. Social isolation and loneliness as risk factors for the progression of frailty: the English Longitudinal Study of Ageing. *Age Ageing* **47**, 392–397 (2018).
32. Peppard, P. et al. The association of sleep-disordered breathing with objectively-assessed risk of falls. *Sleep Med.* **14**, e27–e27 (2013).

33. Nóbrega, P. V. et al. Sleep and frailty syndrome in elderly residents of long-stay institutions: a cross-sectional study. *Geriatr. Gerontol. Int.* **14**, 605–612 (2014).
34. Maroto-Rodriguez, J. et al. Association between a Mediterranean lifestyle and Type 2 diabetes incidence: a prospective UK biobank study. *Cardiovasc. Diabetol*. **22**, (2023).
35. Talavera-Rodríguez, I. et al. Mediterranean lifestyle index and 24-h systolic blood pressure and heart rate in community-dwelling older adults. *Geroscience* **46**, 1357–1369 (2024).
36. Georgousopoulou, E. N. et al. Mediterranean lifestyle and cardiovascular disease prevention. *Cardiovasc. Diagn. Ther.* **7**, S39–S47 (2017).
37. Hershey, M. S. et al. The Mediterranean lifestyle and the risk of depression in middle-aged adults. *J. Nutr.* **152**, 227–234 (2022).
38. Chatzianagnostou, K., Del Turco, S., Pingitore, A., Sabatino, L. & Vassalle, C. The Mediterranean lifestyle as a non-pharmacological and natural antioxidant for healthy aging. *Antioxidants* **4**, 719–736 (2015).
39. Mascaró, C. M., Bouzas, C. & Tur, J. A. Association between non-alcoholic fatty liver disease and Mediterranean lifestyle: a systematic review. *Nutrients* **14**, (2021).
40. Maroto-Rodriguez, J. et al. A Mediterranean lifestyle and frailty incidence in older adults: the seniors-ENRICA-1 cohort. *J. Gerontol. A Biol. Sci. Med. Sci.* **77**, 1845–1852 (2022).
41. Anastasiou, C. A. et al. Mediterranean lifestyle in relation to cognitive health: results from the HELIAD study. *Nutrients* **10**, (2018).
42. Hoffman, R. & Gerber, M. Evaluating and adapting the Mediterranean diet for non-Mediterranean populations: a critical appraisal. *Nutr. Rev.* **71**, 573–584 (2013).
43. Martínez-González, M. Á., Hershey, M. S., Zazpe, I. & Trichopoulou, A. Transferability of the Mediterranean diet to Non-Mediterranean Countries. What is and what is not the Mediterranean Diet. *Nutrients* **9**, (2017).
44. Bere, E. & Brug, J. Is the term 'Mediterranean diet' a misnomer? *Public Health Nutr.* **13**, 2127–2129 (2010).
45. Cöster, M. E. et al. Physical function tests predict incident falls: A prospective study of 2969 men in the Swedish Osteoporotic Fractures in Men study. *Scand. J. Public Health* 140349481880162 https://doi.org/10.1177/1403494818801628 (2018).
46. Studenski, S. et al. Gait speed and survival in older adults. *JAMA* **305**, 50 (2011).
47. Lohman, M. C., Scherer, E. A., Whiteman, K. L., Greenberg, R. L. & Bruce, M. L. Factors Associated with accelerated hospitalization and re-hospitalization among medicare home health patients. *J. Gerontol. A Biol. Sci. Med. Sci.* **73**, 1280 (2017).
48. Fried, L. P. et al. Frailty in older adults: evidence for a phenotype. *J. Gerontol. Ser. A Biol. Sci. Med. Sci.* **56**, M146–M156 (2001).
49. Lee, M. T., Jang, Y. & Chang, W. Y. How do impairments in cognitive functions affect activities of daily living functions in older adults? *PLoS ONE* **14**, (2019).
50. STURNIEKS, D. L. et al. Cognitive functioning and falls in older people: A systematic review and meta-analysis. *Arch. Gerontol. Geriatr*. **128**, (2025).
51. De Zoysa, W. et al. Multimorbidity, medications, and their association with falls, physical activity, and cognitive functions in older adults: multicenter study in Sri Lanka. *Sci. Rep*. **15**, (2025).
52. Lindbergh, C. A., Dishman, R. K. & Miller, L. S. Functional disability in mild cognitive impairment: a systematic review and meta-analysis. *Neuropsychol. Rev.* **26**, 129–159 (2016).
53. Diamond, A. Executive functions. *Annu. Rev. Psychol.* **64**, 135–168 (2013).
54. Glisky, E. L. Changes in cognitive function in human aging. *Brain Aging* 3–20 https://doi.org/10.1201/9781420005523-1. (2007).
55. Cox, S. R. Neurocognitive aging. *Annu. Rev. Dev. Psychol.* **6**, 505–527 (2024).
56. Ammar, A. et al. Exploring determinants of Mediterranean lifestyle adherence: findings from the Multinational MEDIET4ALL e-Survey Across Ten Mediterranean and neighboring countries. *Nutrients* **17**, (2025).
57. Dinu, M. et al. Adherence to the Mediterranean diet among Italian adults: results from the web-based Medi-Lite questionnaire. *Int. J. Food Sci. Nutr.* **72**, 1–9 (2021).
58. Obeid, C. A., Gubbels, J. S., Jaalouk, D., Kremers, S. P. J. & Oenema, A. Adherence to the Mediterranean diet among adults in Mediterranean countries: a systematic literature review. *Eur. J. Nutr.* **61**, 3327–3344 (2022).
59. Tsofliou, F., Vlachos, D., Hughes, C. & Appleton, K. M. Barriers and facilitators associated with the adoption of and adherence to a Mediterranean style diet in adults: a systematic review of published observational and qualitative studies. *Nutrients* **14**, 4314 (2022).
60. Chen, Y. et al. Barriers to and facilitators of physical activity among community-dwelling older adults: a systematic review. *BMJ Open* **15**, e095260 (2025).
61. Li, J., Cai, X. & Wamsiedel, M. Perceptions, opportunities and barriers of social engagement among the Chinese older adults: a qualitative study. *BMC Geriatr.* **24**, 1033 (2024).
62. Fried, L. P. et al. Nonlinear multisystem physiological dysregulation associated with frailty in older women: implications for etiology and treatment. *J. Gerontol. A Biol. Sci. Med. Sci.* **64**, 1049–1057 (2009).
63. Barajas-Martínez, A. et al. Metabolic physiological networks: the impact of age. *Front. Physiol.* **11**, 587994 (2020).
64. Hamilton, M. L. et al. Does oxidative damage to DNA increase with age? *Proc. Natl. Acad. Sci. USA* **98**, 10469–10474 (2001).
65. Zhang, S. et al. A metabolomic profile of biological aging in 250,341 individuals from the UK Biobank. *Nat. Commun*. **15**, (2024).
66. Franceschi, C., Garagnani, P., Parini, P., Giuliani, C. & Santoro, A. Inflammaging: a new immune–metabolic viewpoint for age-related diseases. *Nat. Rev. Endocrinol.* **14**, 576–590 https://doi.org/10.1038/s41574-018-0059-4 (2018).
67. Volkert, D. et al. ESPEN guideline on clinical nutrition and hydration in geriatrics. *Clin. Nutr.* **38**, 10–47 (2019).
68. Izquierdo, M. et al. Global consensus on optimal exercise recommendations for enhancing healthy longevity in older adults (ICFSR). *J. Nutr. Health Aging* **29**, 100401 (2025).
69. Zhang, W., Zhang, J. & Gao, N. Social isolation and cognitive decline in older adults: a longitudinal study across 24 countries. *BMC Geriatr.* **25**, 775 (2025).
70. Lyu, C., Siu, K., Xu, I., Osman, I. & Zhong, J. Social isolation changes and long-term outcomes among older adults. *JAMA Netw. Open* **7**, e2424519 (2024).
71. Kim, S. A. et al. Physical activity, Alzheimer plasma biomarkers, and cognition. *JAMA Netw. Open* **8**, (2025).
72. Coelho-Junior, H. et al. Resistance training improves cognitive function in older adults with different cognitive status: a systematic review and Meta-analysis. *Aging Mental Health*. https://doi.org/10.1080/13607863.2020.1857691 (2020).
73. Nagamatsu, L. S., Handy, T. C., Hsu, C. L., Voss, M. & Liu-Ambrose, T. Resistance training promotes cognitive and functional brain plasticity in seniors with probable mild cognitive impairment. *Arch. Intern. Med.* **172**, 666–668 (2012).
74. Yoon, D. H., Lee, J. Y. & Song, W. Effects of resistance exercise training on cognitive function and physical performance in cognitive frailty: a randomized controlled trial. *J. Nutr. Health Aging* **22**, 944–951 (2018).
75. Coelho-Júnior, H. J. et al. Effects of combined resistance and power training on cognitive function in older women: a randomized controlled trial. *Int. J. Environ. Res. Public Health* **17**, 3435 (2020).
76. Coelho-Júnior, H. J. & Uchida, M. C. Effects of low-speed and high-speed resistance training programs on frailty status, physical performance, cognitive function, and blood pressure in prefrail and frail older adults. *Front. Med.* **8**, 702436 (2021).

77. Castaño, L. A. A. et al. Resistance training combined with cognitive training increases brain derived neurotrophic factor and improves cognitive function in healthy older adults. *Front. Psychol*. **13**, (2022).
78. Dai, M., Xin, H., Dai, W., Huang, X. & Wang, X. Association of cooking oil and incident of frailty in older adults: a cohort study. *BMC Geriatr.* **24**, 424 (2024).
79. Saenz, J. L. Solid cooking fuel use and cognitive decline among older Mexican adults. *Indoor Air* **31**, 1522–1532 (2021).
80. Bloom, I. et al. Influences on diet quality in older age: the importance of social factors. *Age Ageing* **46**, 277–283 (2017).
81. Karam, G. et al. Comparison of seven popular structured dietary programmes and risk of mortality and major cardiovascular events in patients at increased cardiovascular risk: systematic review and network meta-analysis. *BMJ* **380**, (2023).
82. Sofi, F., Cesari, F., Abbate, R., Gensini, G. F. & Casini, A. Adherence to Mediterranean diet and health status: meta-analysis. *BMJ* **337**, 673–675 (2008).
83. Becerra-Tomás, N. et al. Mediterranean diet, cardiovascular disease and mortality in diabetes: a systematic review and meta-analysis of prospective cohort studies and randomized clinical trials. *Crit. Rev. Food Sci. Nutr.* **60**, 1207–1227 (2020).
84. Morales, G., Martínez-González, M. A., Barbería-Latasa, M., Bes-Rastrollo, M. & Gea, A. Mediterranean diet, alcohol-drinking pattern and their combined effect on all-cause mortality: the Seguimiento Universidad de Navarra (SUN) cohort. *Eur. J. Nutr.* **60**, 1489–1498 (2021).
85. Bonaccio, M. et al. Adherence to the traditional Mediterranean diet and mortality in subjects with diabetes. Prospective results from the MOLI-SANI study. *Eur. J. Prev. Cardiol.* **23**, 400–407 (2016).
86. Montero-Sandiego, E. et al. Assessment strategies to evaluate the Mediterranean lifestyle: a systematic review. *Nutrients* **14**, (2022).
87. Cacciatore, S. et al. Lower adherence to a Mediterranean diet is associated with high adiposity in community-dwelling older adults: results from the longevity check-up (Lookup) 7+ project. *Nutrients* **15**, 4892 (2023).
88. Apostolaki, I., Pepa, A., Vlassopoulos, A. & Kapsokefalou, M. Social capital and self-perceived quality of life-interrelated predictors of Mediterranean diet adherence in older adults. *Nutrients* **13**, (2021).
89. Pavlidou, E. et al. Evaluating the sociodemographic, anthropometric and lifestyle parameters, depression, quality of life, cognitive status, physical activity, and Mediterranean diet adherence of older adults in pre- and post-Covid-19 periods: a comparative cross-sectional *Psychol. Health* **39**, 2013–2038 (2024).
90. Maniscalco, L. et al. Sarcopenia using muscle mass prediction model and cognitive impairment: a longitudinal analysis from the English longitudinal study on ageing. *Arch. Gerontol. Geriatr*. **117**, (2024).
91. von Elm, E. et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Ann. Intern. Med.* **147**, 573–577 (2007).
92. Global physical activity questionnaire (GPAQ). https://www.who.int/publications/m/item/global-physical-activity-questionnaire.
93. Sotos-Prieto, M. et al. Validation of a questionnaire to measure overall Mediterranean lifestyle habits for research application: the Mediterranean lifestyle index (MEDLIFE). *Nutr. Hosp.* **32**, 1153–1163 (2015).
94. Manini, T. Development of physical disability in older adults. *Curr. Aging Sci.* **4**, 184 (2011).
95. Graf, C. The lawton instrumental activities of daily living scale. *Am. J. Nurs.* **108**, 52–62 (2008).
96. Morley, J. E., Malmstrom, T. K. & Miller, D. K. A simple frailty questionnaire (FRAIL) predicts outcomes in middle aged African Americans. *J. Nutr. Health Aging* **16**, 601–608 (2012).
97. Mitchell, A. J., Shukla, D., Ajumal, H. A., Stubbs, B. & Tahir, T. A. The Mini-Mental State Examination as a diagnostic and screening test for delirium: Systematic review and meta-analysis. *Gen. Hosp. Psychiatry* **36**, 627–633 (2014).
98. Llinàs-Reglà, J. et al. The trail making test. *Assessment* **24**, 183–196 (2017).
99. Lilienthal, L., Tamez, E., Myerson, J. & Hale, S. Predicting performance on the Raven's Matrices: the roles of associative learning and retrieval efficiency. *J. Cogn. Psychol.* **25**, https://doi.org/10.1080/20445911.2013.791299 (2013).
100. Neuropsychological assessment 5th edn. https://psycnet.apa.org/record/2012-02043-000.
101. Morris, J. C. et al. The Consortium to Establish a Registry for Alzheimer's Disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimer's disease. *Neurology* **39**, 1159–1165 (1989).
102. Andresen, E. M., Malmgren, J. A., Carter, W. B. & Patrick, D. L. Screening for depression in well older adults: evaluation of a short form of the CES-D. *Am. J. Prev. Med.* **10**, 77–84 (1994).



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