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Blue Zones: Centenarian Modes of Physical Activity: A Scoping Review

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Abstract

The primary aim of this scoping review was to identify the predominant modes of physical activity (PA) in each Blue Zone and to explore the influences that environment and culture have on PA. A research team of three Doctor of Physiotherapy students completed a systematic search using five online databases and cross referenced each reviewer in the study selection process. The study selection was based on eligibility criteria comprised of population autonomy/independence, > 80 years, Blue Zone resident, specified mode of physical activity, and utilized all research designs except for case studies and literature reviews. The databases retrieved a total of 236 articles, and 18 of which, met the inclusion criteria. Data synthesis revealed that 81% of the activities engaged by Blue Zone centenarians are moderate intensity activities. Blue Zone centenarians represent a significantly high physical functioning and high levels of activity through labouring occupations, outdoor hobbies and in-home activities. The most predominant mode represented through the included studies was agricultural activities. Overall, Blue Zones Centenarians are highly active, perform continuous and consistent movements daily, maintain daily hobbies, and work beyond the expected age of retirement. The key findings represent a significant effect on PA by environmental and cultural influences of each region.

Keywords Blue Zones · Centenarian · Physical activity · Activities of daily living · Longevity · Environment

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Introduction

The worldwide interest in aging science continues to grow due to the increasing numbers of Baby Boomers entering retirement. The implementation of health research into longevity and health span is extending the capabilities of older adult populations by promoting physical, social, spiritual and cognitive activity, allowing them to maintain autonomy, independence and in some cases, restore physical functioning and robustness (Cochrane et al., 2016; Marzetti et al., 2017).

Society's understanding of life-long physical activity to combat disease, disability and dependence weighs heavily as researchers continue to divulge the implications of physical activity (PA) and old age (Marzetti et al., 2017; Vaughan et al., 2016). Regular PA distances the process of requiring institutionalization in old aged-care facilities, lengthening the time as community-dwellers and/or ambulators (Bauman et al., 2016; Vaughan et al., 2016). As a result, the social implications offered to older adults and family support reduce the impact of depression and loneliness, producing significantly fewer functional limitations in daily movement (Prieto-Flores et al., 2011; Vaughan et al., 2016). Unfortunately, the ability for an older adult or "oldest old" (> 80 years) to live independently is becoming an unreachable notion (Cochrane et al., 2016), as worldwide trends demonstrate that PA was reduced in more than a quarter of the world's population in 2016 (Guthold et al., 2018). Referrals to old age-care facilities are becoming utilized as our society's new 'normal' process of aging. The United States has seen a 35% increase in prevalence of disability of ages 65 and older associated with overall decreases of PA (Vaughan et al., 2016). Consequently, these statistics represent a growing health burden in the aging population, highlighting the importance of PA for society. On the contrary, associated benefits of PA are known to improve self-efficacy, motor control, balance, cognitive health, psychological health, quality of life (QOL) (Awick et al., 2017; Bauman et al., 2016) and mitigate the onset of sarcopenia, frailty, cognitive decline, mental health illnesses, and incidences of falls and delayed mortality (Awick et al., 2017; Elavsky et al., 2005; Marzetti et al., 2017). These findings establish a demand for research into regions of the world that have adapted to life-long PA, potentially serving as a contributing factor to extreme longevity (Deiana et al., 1999; Pes et al., 2013; Poulain et al., 2021).

To date, there has been no research investigating the modes and frequencies of PA engaged by the "oldest old" (> 80 years), nonagenarians (> 90 years), centenarians (> 100 years) and supercentenarians (> 110 + years) populations in Blue Zone regions that are living longevous and independent lives. However, emergence of anecdotal, observational evidence and more recent studies examining culture, environment, and lifestyle have fascinated world leaders in longevity sciences. There are five geographical regions that surpass general civilization's expectations of old age and do so remarkably by delaying the appearance and effect of disease and disability (Poulain et al., 2021). These regions termed "Blue Zones" include Loma Linda, CA, USA; Nicoya, Costa Rica; Sardinia, Italy; Ikaria, Greece; and Okinawa, Japan (Beuttner & Skemp, 2016; Poulain et al., 2021). How these centenarian populations are thriving in a world marred by chronic

disease and age-related decline have been investigated. In these investigations, the Blue Zones have been categorized by their unique commonalities of the impacts that geographic isolation of the land, terrain, environment, and culture have on their lifestyles and health status (Poulain et al., 2021).

Although studies have been conducted with a primary focus on the following domains: sociodemographic, anthropology, psychology, epidemiology, nutrition, and genetics, there remains a paucity of literature investigating the types of PA, movement and hobbies participated in by centenarians (Pes et al., 2018; Poulain et al., 2021). Amongst the extant literature, it is suggested that centenarians engage in continuous movement throughout the day, which could cause challenges for extracting all modes, durations, and frequencies of activities in a 24-h period (Pes et al., 2018). These are the limitations of the several observational study methods utilized to analyze Blue Zone populations resulting in literature gaps amongst the modes and influences of PA. To advance the knowledge on this topic, more research is deemed necessary to explore the activity engagement of the oldest old demographic including the geographical and cultural influences of movement within each Blue Zone.

Insight into types of physical activities may help researchers develop optimal movement sequences and models that can be easily undertaken by aging adults. Furthering this knowledge could be used as advice from health practitioners to their patients to improve overall health and quality of life. This review may prompt researchers to expand their investigation regarding robust centenarians and their forms of physical activity in each Blue Zone. This could result in fostering a mastery of longevity and advancing preventative frameworks of early morbidity and disability of older adults. Therefore, this review was guided by the following research questions: 1) What are the modes of PA that predominate the Blue Zone? 2) How does geography and culture influence PA within the Blue Zones?

Objective

To the author's knowledge, there are no current publications being explored or conducted, specifically regarding the types of PA engaged in by centenarians in each Blue Zone, including the different influences such as environment, culture, social community, work, and agriculture. The objectives of this investigation are to: 1) explore modes of PA that predominate the Blue Zones and 2) determine the environmental and cultural influences on physical activity in the Blue Zones.

Methods

Protocol and Registration

A protocol was developed based on the PRISMA Extension for Scoping Reviews (PRSMA-ScR): Checklist and Expansion (Tricco et al., 2018). Protocol registration was submitted to Open Science Framework (OSF) on 08/12/2021, where the

registration information can be accessed via the OSF website (https://doi.org/10.17605/OSF.IO/RA5M8).

Eligibility Criteria

The Population-Concept-Context (PCC) framework from the Joanna Briggs Institute (JBI) Reviewers manual, were the building blocks for the eligibility criteria (Peters et al., 2020). These included studies containing categorized values between age of population, the geographical region and data for > 80 years of age groups relating to physical activity or environment. If a study examined different regions, it had to include categories specifying values for an individual Blue Zone or signified data separate from the other regions to be an eligible study.

Exclusion criteria were agreed upon on the premise of maintaining integrity of the scoping review by excluding case study papers, and all literature reviews. To maintain literature with an independent and ambulatory demographic, exclusion of old age-care facility settings was applied. Articles that were written in other languages than English or did not have accessible full text were automatically excluded.

Population

Population demographics included any individual that are amongst the oldest old and/or octogenarians (> 80 years), nonagenarians (> 90 years), centenarians (> 100 years), and super centenarians (> 110 + years) that are living independently in the defined Blue Zones.

Concept

There were four main concepts studied in the regions of the five Blue Zones: 1) physical activity, 2) environment, 3) centenarians and 4) longevity. Blue Zones were defined as geographically identified areas with high concentrations of centenarians that have reached the age of 100 years at a rate 10 times greater than the United States (Beuttner & Skemp, 2016). Each region had commonalities that promoted physical activity, which included landscape, community, social, and occupational environments (Beuttner & Skemp, 2016; Panagiotakos et al., 2011; Poulain et al., 2021).

Physical activity was coined as an umbrella term defined as any voluntary movement elicited by the musculoskeletal system that required energy expenditure (Dasso, 2019). Blue Zone centenarians were defined as being 100 years and older, studies pertaining to Blue Zones have examined octogenarians or oldest old (80 and over) and nonagenarians (90 and over), while longevity included long-lived persons starting at the age of 90 years (Legrand et al., 2019; Panagiotakos et al., 2011; Poulain et al., 2021). Considering the following, this review explored the 80 and over demographic in Blue Zones due to the delay of age-related chronic disease commencing with the oldest old (Willcox et al., 2006).

Context

Contextual factors of the study included all periods of time and geographical locations inclusive of the five defined Blue Zones; Ikaria, Greece; Okinawa, Japan; Sardinia, Italy; Nicoya Peninsula, Costa Rica; and Loma Linda, California. Additionally, centenarians within the Blue Zones, both male and female who have maintained independence, autonomy, and were active participants in their community were included in the current study. Studies including populations of centenarians that were cared for in an age care facility were excluded.

Information Sources & Search Strategy

An initial rapid search was completed by three researchers (CH, RD and MH) on the date of 03/11/2021, through PubMed to conceptualize and develop key terms, research questions, population, concepts, and context of this review. The preliminary search through five selected databases (PubMed, Web of Science, CINAHL, ProQuest Dissertation & Theses Global, and Google Scholar) was completed to capture 10 data-rich articles to correspondingly develop a search strategy that would result in inclusion of these specific references. Multiple search strategies were designed before the research team decided on the final strategy, which included three out of the four main concepts. 'Environment' was not inserted into the search strategy as the search results produced irrelevant references in the databases, so exclusion of the term was deemed appropriate (see Table 1). The Bond University Librarian was consulted to refine the search strategy and provided guidance on formatting to translate the search strategy into the databases. The use of Yale MeSH Analyzer improved the search precision to pull key terms from relevant articles to insert into the search strategy (Hocking, 2017). Following the consultation and a meeting with the research team, the following terms were added: "longest lived" and "motor activity," as both terms associated with the aims of the study and made the search strategy more concise. Guidance with modified search strategies for ProQuest Dissertations and Theses Global, and Google Scholar databases was also provided to exclude the "MeSH terms" function and to use the "Title/Abstracts" instead. The following search strategy for ProQuest Dissertations & Theses Global and Google Scholar were entered directly into the databases and are included in the appendices (Appendix A) along with the search strategies for each database. The most recent search strategy was conducted on Dec 1, 2021, identifying references in each database and screening for new publications. The sum of articles identified did not change (see Table 1, and sum of articles in Table (7) included in the Appendix).

Study Selection

The final search results were exported into EndNote (Clarivate Analytics, version 20, 2020) to create a reference library that was exported to Systematic Review Accelerator (SRA) for removal of duplicate articles by one reviewer (RD) (Clarke

Table 1 Search terms used to develop the search strategies with the list of databases used

Concepts	Terms	Databases
Physical Activity	Exercise Leisure Activities Activities of Daily Living Movement Motor Activity	PubMed CINAHL Web of Science Google Scholar ProQuest Dissertation & Theses Global
Centenarians	80 years and older 90 years and older Octogenarian Nonagenarian Oldest Old Longest Lived	
Environment[a]	Blue Zones Sardinia Ikaria Nicoya Loma Linda Okinawa	
Longevity		

[a]Concept not included in search terms due to irrelevant search results.

et al., 2020). Screening of articles was completed by two reviewers (CH and MH) independently, reviewing the title and abstracts against the eligibility criteria. The screening process was finalized in Disputatron (SRA) to settle differences in results with a third reviewer for consolidation (RD) (Clarke et al., 2020). Full texts were obtained by one reviewer (CH) and additional exclusion between each reviewer was completed based on the agreed methods during screening to maintain consistency. Any uncertainty was referred to the research partners (MH and RD), including a collective decision made on the excluded articles. The complete study selection process was documented in the PRISMA-ScR flow diagram.

Data Extraction

Following inclusion by the eligibility criteria, categories entailing concepts and themes were created in tables on Excel by the research team. The initial data extraction table items were formed by the research team (MH, RD, and CH). A piloted data extraction process took place with a research supervisor (KKS) for guidance and refinement of categorization, themes, and main findings. Data extraction was processed by two reviewers (MH and RD) with extraction into individual Excel spreadsheets. The research team cross-checked the results to consolidate the findings. A third reviewer (CH) was referred to, to warrant consensus and contribute to data collection of missing data.

The key items for data extraction consisted of study characteristics (e.g., author/year of publication, study design, study aims/objectives, level of evidence and setting), participant characteristics (e.g., location/country, sample size, age, and sex) and PA data characteristics (e.g., outcome measures, outcome values, types of physical activity, environment/location of the PA, frequencies of PA, and activity participation sample size), and the main findings. Additional items were documented for qualitative studies, excluding outcome measures and outcome values. The items included phenomena of interest, methods, methodological frameworks, themes, descriptions, illustrations, and main findings.

The current scoping review identified knowledge gaps through conceptualization and mapping of relevant research. Determining the quality of the research included did not align with the current aims of the review, so a critical appraisal was not required. While a formal evaluation of the quality of individual study types was not necessary, each study's level of evidence was determined based on the National Health and Medical Research Council (NHMRC, 2009) evidence hierarchy consistent with the study type and methodology employed. Levels of evidence for prognosis were selected, as the aim of this study entailed analyzing the forecast of achieved benefits over time while the "oldest old" implemented active lifestyles (Hoffman et al., 2013). Level IV in the hierarchy table was modified to include cross-sectional study designs, consistent with the levels of evidence for aetiology, as it was included in the lowest level along with case series (McNair & Lewis, 2012). The addition was considered to draw strengths in relevant studies involving 'prevalence' of factors that were concluded in cross sectional study designs (Hoffman et al., 2013).

Data Synthesis

Once data was extracted, the collected data was divided in terms of general study characteristics, study design characteristics, quantitative data, qualitative data, and prevalent modes of PA within the studies. Study design characteristics included the total number of studies examined per Blue Zone, the levels of evidence, study designs utilized, settings/context, author and year. Additionally, general study characteristics categorized year of publication, country of publication, study design, and population studied.

Themes were quantitatively categorized by: 1) outcome measures, 2) outcome values, 3) modes of PA, 4) frequencies of activity and 5) the main findings. When extracting the outcome measures and values, it is important to note that some authors administered various measurement tools resulting in heterogeneous outcome values. Therefore, the individual measurement tools were not categorized, rather, they were broadly categorized as "outcome measures" and are contained within the appendices (Appendix B). The two qualitative studies presented the following: 1) descriptions of themes and/or participants, 2) illustrations of cultural and environmental influences, 3) main findings of modes and/or frequencies of PA.

To represent the prevalence of modes of PA that were reported, activities were categorized into the following groups: 1) agricultural activities (e.g. gardening, farming, shepherd work), 2) in-home activities (e.g. house-keeping, basho-fu weaving), 3) outdoor hobbies (e.g. sports, social/cultural activities, nature engagement, swimming, horseback riding, and dancing), 4) walking (e.g. hiking in the mountains), 5) other labour occupations (e.g. sailors, fishermen, craftsmen, tradesmen, and coalminers), and 6) n/a (e.g. no modes of PA identified in reference). These themes were included in a visual portrayal per individual activity to provide an understanding of prevalent modes reported in studies. Sample sizes of specific activity engagement by participants were extracted from all studies, but only obtained by eight studies in total. In cases where sample sizes were not reported, two processes were followed: 1) if sample size percentages of activity participation were reported, the activity sample size (n) was calculated by multiplying the percentage (%) by the overall sample size (N) in the study, 2) if the percentages for participation of individual activities were not reported, sample sizes of that that study were not included in the synthesis of percentages of activities engaged in low, moderate and high intensity activities. Considering this, there were limitations in summarizing the sample size population percentages and identifying the most prevalent mode of PA relative to the sample sizes due to each study not consistently reporting the same activities throughout. As an alternative, each activity was categorized into three levels of intensities: low, moderate, and high.

The following activity was categorized as low intensity: Basho-fu weaving which was described as the most labour-intensive activity as it was a continuous task completed throughout 20 days, however, it involved hand dexterity, fine gross motor skills and precision (Willcox et al., 2007b). Moderate intensity activities were categorized in studies as the following: swimming, dancing and walking that were identified as modes of aerobic moderate intensity (Legrand et al., 2021); shepherd work had been labeled as constant and continuous energy expenditure walking long distances in the mountainous terrain (Pes et al., 2013); outdoor hobbies and nature engagement are broader terms that have been categorized as moderate intensity activities relating to swimming and gardening outdoor tasks using both upper and lower limbs which were identified as such by Legrand et al. (2019) and Nicklett et al. (2016); housekeeping pertaining to household chores that involve vacuuming, mopping, washing windows, etc., have met the metabolic equivalent value of 3.0 equating to moderate intensity activities (Manini et al., 2006). High intensity was categorized between the remaining activities, farming, and other labour occupations. Pes et al. (2013) suggested farming to be labouring in concentrated periods and described other labour occupational demands in similar terms as farming.

Results

Selection of Sources of Evidence

Reference identification, screening, and eligibility processes enforced in this scoping review can be viewed in the PRISMA flow diagram (Fig. 1). Through a

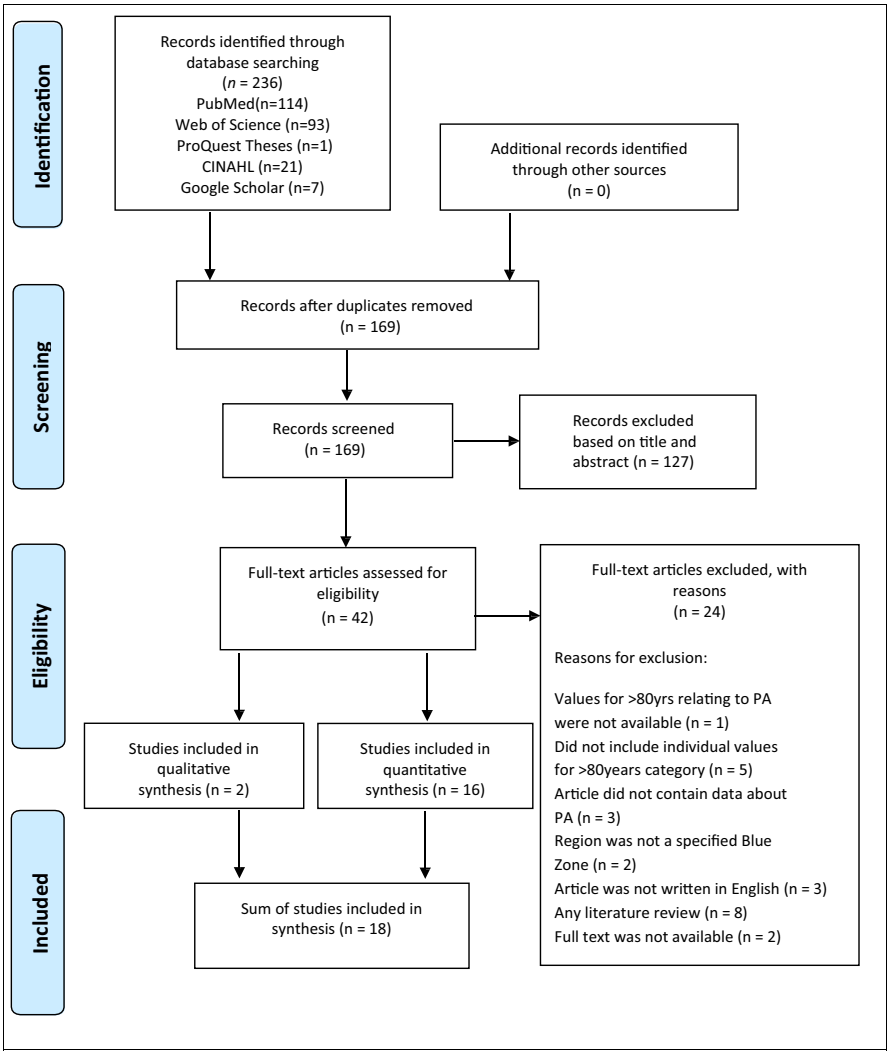


Fig. 1 PRISMA-ScR flow chart. *Source*: Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D., Horsley, T., Weeks, L., & Hemple, S. (2018). PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Annals of Internal Medicine, 169*(7), 467–473. doi:10.7326/M18-0850

multi-database search, a total of 236 articles were identified through PubMed, Web of Science, ProQuest Dissertations & Theses Global, CINAHL, and Google Scholar. There were no other articles identified through additional sources. Following the removal of duplicates, 169 articles were screened by two reviewers. After viewing titles and abstracts against the eligibility criteria, consensus was made to exclude 127 articles. Exclusion was made on the grounds of articles not including PA values categorized for participants > 80 years old, not extracting PA data, areas not in Blue

Zone regions, not written in English, and any study designs (literature review and full text) not available. Retrieval of full texts were conducted for 42 articles, with 24 articles being further excluded due to their inaccessibility or lack of eligibility, leaving 18 articles in total to be studied in this review. This comprised 16 quantitative and two qualitative studies. Exact sum and process of selection can be found in the PRISMA flow diagram (Fig. 1).

Study Characteristics

Of the 18 articles that were included, all were reviewed for data extraction and synthesis. A summary of the study design characteristics can be found in Table 2, displaying the number of studies explored for each Blue Zone, the methods utilized and the levels of evidence according to the study type.

General study characteristics were extracted to provide a synthesized understanding of periods of publication, countries of publication, study designs and populations studied (Table 3). Analysis of these themes was drawn from the increased number of studies in certain categories, with a significant portion of studies conducted in the last five years (Fastame et al., 2018; Legrand et al., 2019, 2021; Madrigal-Leer et al., 2020; Nieddu et al., 2020; Pes et al., 2018, 2020, 2021; Spencer-Hwang et al., 2018) and being primarily of a cross sectional design and published in the United States (Chan et al., 1997; Legrand et al., 2019; Panagiotokos et al., 2011; Pes et al., 2018, 2020; Spencer-Hwang et al., 2018; Willcox et al., 2007b, 2008) with cross-sectional study designs (11 out of 18, level IV evidence) utilizing questionnaires were the most common research tool (Akisaka et al., 1996; Chan et al., 1997; Deiana et al., 1999; Fastame et al., 2018; Legrand et al., 2019; Legrand et al., 2021; Madrigal-Leer et al., 2020; Nieddu et al., 2020; Panagiotakos et al., 2011; Pes et al., 2013, 2018). Populations that were investigated most commonly were Okinawan resident centenarians (Akisaka et al., 1996; Chan et al., 1997; Willcox et al., (2007a)) and centenarian residents of municipalities in Sardinia (Deiana et al., 1999; Pes et al., 2013; Poulain et al., 2004).

Summary of Outcome Measures and Findings Across Study Themes

Assessment measures of Blue Zone participants found in the Appendix B reveal the level of function of the "oldest old" (i.e., those over 80 years of age) in Ikaria, Sardinia, Okinawa, Nicoya through outcome measures and values (Akisaka et al., 1996; Chan et al., 1997; Deiana et al., 1999; Legrand et al. 2019, 2021; Madrigal-Leer et al., 2020; Nieddu et al., 2020; Panagiotakos et al., 2011; Pes et al., 2018, 2020, 2021; Willcox et al., (2007a, 2008). The outcome values include the following: Activities of Daily Living (ADL) scores, Instrumental Activities of Daily Living (IADL) scores, Basic Activities of Daily Living (BADL) scores, International Physical Activity Questionnaire (IPAQ) results, and grip strength. Whereas frequencies values in Table 4 represent a summarization of motor activity index values, MET measurements, durations, intensities, volumes, and levels of physical activity engaged in by the oldest old. The main findings indicate that

Table 2 Study Design Characteristics

Blue Zone/Country	Number of Studies Per Zone	Level of Evidence*	Study Design	Setting/Context	Author & Year
Ikaria, Greece	3	IV	Cross-sectional Study	Questionnaire administration	Legrand et al. (2019)
		IV	Cross-sectional Study	Questionnaire administration	Legrand et al. (2021)
		IV	Cross-sectional Study	Structured, quantitative questionnaire	Panagiotakos et al. (2011)
Loma Linda, USA	1	III-3	Retrospective cohort study	Interview	Spencer-Hwang et al. (2018)
Nicoya Peninsula, Costa Rica	2	IV	Cross-sectional Study	In-home interview	Madrigal-Leer et al., 2020; Nieddu et al. (2020)
Okinawa, Japan	5	IV	Cross-sectional Study	In-home Survey	Akisaka et al. (1996)
		IV	Cross-sectional Study	Survey	Chan et al. (1997)
		III-3	Retrospective Cohort Study	Mailed questionnaire, interview, assessment	Willcox et al. (2007a)
		II	Prospective Cohort Study	Field study, Interview	Willcox et al. (2007b)
		II	Prospective Cohort Study	Field study, Interview	Willcox et al. (2008)
Sardinia, Italy	8	IV	Cross-Sectional Study	In-home interview, assessment	Deiana et al. (1999)
		IV	Cross-Sectional Study	Questionnaire, interview, assessment	Fastame et al. (2018)
		IV	Cross-sectional Study	In-home interview	Nieddu et al. (2020)
		IV	Cross-sectional Study	Database analysis	Pes et al. (2013)
		IV	Cross Sectional Study	Questionnaire administration	Pes et al. (2018)
		III-3	Retrospective Cohort Study	Interview, questionnaire, examination by physicians	Pes et al. (2020)
		III-3	Retrospective Cohort Study	In-home interview by physician	Pes et al. (2021)
		III-3	Retrospective Cohort Study	Registry Office Data extraction of 40 municipalities	Poulain et al. (2004)

Table 3 General Study Characteristics

Characteristics	Number of Studies	References
Years of Publication		
1999 and before	3	Akisaka et al. (1996); Chan et al. (1997); Deiana et al. (1999)
2000–2004	1	Poulain et al. (2004)
2005–2009	3	Willcox et al. (2007a, b, 2008)
2010–2014	2	Panagiotokos et al. (2011); Pes et al. (2013)
2015–2019	4	Fastame et al. (2018); Legrand et al. (2019); Pes et al. (2018); Spencer-Hwang et al. (2018)
2020 and after	5	Legrand et al. (2021); Madrigal-Leer et al. (2020); Nieddu et al. (2020); Pes et al. (2020, 2021)
Country of Publication		
England	2	Poulain et al. (2004); Willcox et al. (2007a)
Italy	1	Deiana et al. (1999)
Japan	1	Akisaka et al. (1996)
Netherlands	1	Pes et al. (2013)
Switzerland	5	Fastame et al. (2018); Legrand et al. (2021); Madrigal-Leer et al. (2020); Nieddu et al. (2020); Pes et al. (2021)
United States	8	Chan et al. (1997); Legrand et al. (2019); Panagiotokos et al. (2011); Pes et al. (2018, 2020); Spencer-Hwang et al. (2018); Willcox et al. (2007b, 2008)
Study Design		
Prospective Cohort Study	2	Willcox et al. (2007b, 2008)
Retrospective Cohort Study	5	Pes et al. (2020, 2021); Poulain et al. (2004); Spencer-Hwang et al. (2018); Willcox et al. (2007a)
Cross sectional Study	11	Akisaka et al. (1996); Chan et al. (1997); Deiana et al. (1999); Fastame et al. (2018); Legrand et al. (2019, 2021); Madrigal-Leer et al. (2020); Nieddu et al. (2020); Panagiotakos et al. (2011); Pes et al. (2013, 2018);

Table 3 (continued)

Characteristics	Number of Studies	References
Population Studied		
Elderly Women in Ogimi Village (Okinawa)	1	Willcox et al. (2007b)
Okinawan Resident Centenarians	3	Akisaka et al. (1996); Chan et al. (1997); Willcox et al. (2007a)
Supercentenarians (110 + yrs of age) individuals in Okinawa	1	Willcox et al. (2008)
Centenarians and Seniors of Loma Linda	1	Spencer-Hwang et al. (2018)
Individuals aged 90 years and older from Evdilos and Raches (Northwest Ikaria)	2	Legrand et al. (2019); Legrand et al. (2021)
Adult population of Ikaria Island	1	Pangiotakos et al. (2011)
Centenarians of the Nicoya Peninsula	2	Madrigal-Leer et al. (2020); Nieddu et al. (2020)
Individuals aged > 80 year within province of Olgliastra (Sardinia)	1	Fastame et al. (2018)
Individuals ages 89 years or older in the LBZ Municipalities of Sardinia & Northern Sardinia	2	Pes et al. (2020, 2021)
Individuals aged 90 years and older from Villigrande (Sardinian Village)	1	Pes et al. (2018)
Centenarian residents of municipalities in Sardinia	3	Deiana et al. (1999); Poulain et al. (2004); Pes et al. (2013)

Longevity Blue Zone (LBZ) Municipalities including six villages: Arzana, Baunei, Seulo, Talana, Urzuli and Villagrande.

Table 4 Frequencies of modes of PA that were reported for the oldest old to engage in their lifestyles or were discovered by measured assessments

Modes of PA	Frequency of Modes	Population & Country	Author & Year
Gardening and outdoor hobbies (sports or cultural/ social activities)	Days gardening/week 1 day = 5 (M), 15 (F) 2–4 days = 6 (M), 3(F) > 4 days = 2 (M), 1 (F) Mean hours/ week for outdoor hobbies: 1.7 ± 2.3 h (M), 2.3 ± 3 h (F) Hours a day Watching TV: < 1 h/day = 2 (M) 7 (F) 2-3 h/day = 7 (M) 3 (F) > 3 h/day = 4 (M) 9 (F)	Very Old (> 80 years) Sardinians (Sardinia, Italy) Total N = 33, N = 13 men, N = 20 women	Fastame et al. (2018)
Swimming, dancing, farming activities and walking (commute to work or village)	PA Continuous Score (MET min/ week): 3066 ± 4768.5 (M), 1022 ± 3066 (F), total median PA score = 1533 ± 3924 Time spent sitting (min/day): 90 ± 120 (M), 60 ± 240 (F),	90 yrs and older (Ikaria, Greece) Total N = 71, N = 34 males, N = 37 female	Legrand et al. (2021)
N/A	Gait Speed: > 13.04 s	Nicoya centenarians (Nicoya Peninsula,Costa Rica) Total N = 43, N = 18 males, N = 15 females	Madrigal-Leer et al. (2020)
Shepherd work, farming, and walking to and from work	Daily distance to work (km): 12.4 ± 7.8 Average terrain slope (%) 15.2 ± 6.6 Intensity and time for activity: Shepherd: low-moderate intensity, continuous daily, and constant throughout year. Walking long distances and steep slopes Farming: high intensity and concentrated time	Sardinian centenarians (Sardinia, Italy) Total N = 1132, N = 415 men, N = 717 women	Pes et al. (2013)

Table 4 (continued)

Modes of PA	Frequency of Modes	Population & Country	Author & Year
Agriculture and animal husbandry (farming)	PAL: TEE / REE ratio (Mean ± SD): 1.78 ± 0.26 (M), 1.84 ± 0.25 (F) % EE-A ≥ 3 METs (Mean ± SD): 42.54 ± 7.90 (M), 46.31 ± 6.80 (F) STEPS per day (Mean ± SD): 12,110 ± 5141 (M), 12,799 ± 6420 (F) % of STEPS ≥ 3 METs (Mean ± SD): 29.10 ± 11.61 (M) 23.01 ± 10.73 (F) Sleep Time (hrs/day): 6.3 ± 1.6 (M), 5.6 ± 0.6 (F) Total Daily Resting Time (hrs/day): 8.5 ± 1.7 (M), 7.4 ± 1.1 (F)	90 yrs and older (Sardinia, Italy) Total N = 44, N = 27 men, N = 17 women	Pes et al. (2018)
Farm animal rearing, shepherds, agricultural activities and walking	Physical Activity and walking/ week: ≥ 3 times/week	89yrs and older (Sardinia, Italy) Total N = 300, N = 110 men, N = 190 women	Pes et al. (2020)
Walking, nature engagement and agricultural work	Frequency of Walking per/day and per/week: 2–3 h/day Daily walks/week	100 years and older (Loma Linda, California) Total N = 7, N = 5 women, N = 2 men	Spencer-Hwang et al. (2018)
Basho-fu weaving and gardening	U-Umi (spooling) hr/day: 2–3 h/day Duration of Task: 20 days	80 years and older (Okinawa, Japan)	Willcox et al. (2007b)

Physical Activity Levels (PAL); Total Energy Expenditure (TEE); Resting Energy Expenditure (REE), Energy Expenditure (EE-A); EE-A ≥ 3 METs = moderate levels of PA; Resting Time (RT) = total time spent in supine position; Sleep Time (ST) = time devoted to sleep, nighttime sleep, and naps.

the frequencies of PA and moderate to high levels of physical functioning (Akisaka et al., 1996; Chan et al., 1997; Deiana et al., 1999; Legrand et al., 2019, 2021; Madrigal-Leer et al., 2020; Nieddu et al., 2020; Panagiotakos et al., 2011; Pes et al., 2018, 2020, 2021; Willcox et al., 2007a, 2008) enable the oldest old to engage in long-term community activities that result in moderate to high levels of PA (Legrand et al., 2019, 2021; Panagiotakos et al., 2011; Pes et al., 2013, 2018) and moderate to high levels of autonomy and independence (Akisaka et al., 1996; Chan et al., 1997; Legrand et al., 2019; Neiddu et al., 2020; Pes et al., 2018, 2020, 2021; Willcox et al., 2008).

Pertaining to the analysis of specific activity frequencies engaged in by participants, there was a high heterogeneity in values limiting overall population comparison. However, data was summarized from six quantitative (Fastame et al., 2018; Legrand et al., 2021; Madrigal-Leer et al., 2020; Pes et al., 2013, 2018, 2020) and two qualitative studies (Spencer-Hwang et al., 2018; Willcox et al., 2007b). In relation to agricultural activities, the majority of oldest old Sardinians reported gardening 1–4 days per week, with 1.7–2.3 hours on average allocated for outdoor hobbies per week (Fastame et al., 2018), while centenarians working as shepherds would walk a mean distance of 12.4 km to and from work and on an average slope of 15.2% daily (Pes et al., 2013). Parameters around walking frequency values that were not directly linked to a specific activity included the Sardinian ≥ 90 years of age engaging in 12,110 steps per day for men and 12,799 steps per day for women on average (Pes et al., 2018) and engaging in PA or walking ≥ 3 times per week (Pes et al., 2020). This is relative to the percentage of participant's total energy expenditure (TEE) of ≥ 3 METs which is the corresponding threshold for moderate physical activity which exceeds 40% of participants (Pes et al., 2018).

A qualitative summary of studies is presented in Table 5, depicts the activities within culture and environment that illustrates the relationships between hobbies, work and outdoor activities. The illustrations provided by Loma Linda centenarians introduce themes of resiliency factors, kinetic lifestyle, nature engagement, and resting reset. Specific activities that were reported include daily walks for 2–3 hours to school or around the community, dusk-to-dawn activities, farming, outdoor activities, horseback riding, and gardening. "Sabbath afternoon" involved one weekly day of "rest" where participants would engage in enjoyable lower intensity activities in contrast with their more labouring weekly activities (Spencer-Hwang et al., 2018). The following is an illustration expressing PA established early in life and had 100% agreement of the following statement that reported that.

> "Going to school consisted of walking 2 miles… We spent a lot of time in nature, and [we would go] up in the mountains and swim in the lake… There was always a place to go outside" (Spencer-Hwang et al., 2018).

The illustrations in Table 5, of oldest old women living in the Okinawan region reflect, that despite their age, they each engage in Basho-fu weaving and have done so throughout their lives. Basho-fu weaving, also known as, spooling was categorized with the in-home activities as a low intensity activity that is one of the most

Table 5 Qualitative data representing participant illustrations and main findings of physical activity engagement

Author & Year	Phenomena of Interest	Methods	Methodology	Themes	Description	Illustrations	Findings
Spencer-Hwang et al. (2018)	Loma Linda, CA United States. Centenarians (> 100yrs)	Focus groups and semi structured key informant interviews	Integrative grounded theory	Adverse childhood exposures and practices of lifestyle and resiliency factor (Kinetic life, nature engagement, and resting reset)	Kinetic life A lifestyle immersed in activities that require physical movement from early in the morning to evening	*"I had to get up in the morning and go find the cows… to milk the cows and separate the milk … go to school … [which consisted of] walking 2 mile."*	N = 7 (100%) centenarians reported the citations. "Participants described outdoor [lifestyles with] physical activity from dawn to dusk. Centenarians … from farming families raised livestock, gardened, baked, and cared for younger siblings for the most part of the days. Additionally, centenarians reported daily walks (2–3 h) to school, a nearby town, a neighbor's house, and church. "
					Nature Engagement Extensive exposure to natural and outdoor environments	*"We spent lots of time in nature, [picking] huckleberries up in the mountains and [swimming] in the lake. Even when we were working, … [we would] run and play."*	N = 7 (100%) centenarians reported the citations. "Regarding nature engagement…those from rural or farming backgrounds, "nature" was a way to earn a living: Working the soil to grow food and raising cattle to sustain their families but also as an outlet for enjoyment."
					Resting Reset Day of Sabbath: Weekly day of rest away from routine activities to rejuvenate physically and mentally with family and friends; and regular sleep patterns of at least 8 h of rest at routine times	*"My brothers [and I] went horseback riding… it was just the time to be outside… We went to a mountain about a half an hour from us, and we picnicked … there was always a place to go outside*	N = 7 (100%) centenarians reported the citations. Findings representing participation in active rest and outdoor activities whenever possible

Table 5 (continued)

Author & Year	Phenomena of Interest	Methods	Methodology	Themes	Description	Illustrations	Findings
Willcox et al. (2007b)	Okinawa, Japan. Elderly women of the village > 80 years	Field work	Ethnography vignettes	Percentages of women that do "*basho-fu weaving,*" the type of activities they carry out and how much time (in days) they allocate to each activity	Observed number of days required for *Basho-fu* production by activity Interviewee: Toshiko Taira, early 80's	*"There was one year when we made up to 100 rolls of [textile] material."*	All five (n = 5) Centenarians reported Basho-fu weaving (Spooling) "Spooling [fibers] into balls of yarn… is the single most labour-intensive activity; this is one of the main activities done by the elderly women in the village." Number of Days Required for Basho-fu production by activity: cutting/ bundling/ washing fibers (5d), Spooling (20d), Twisting (4d), Adjusting (1d), Dyeing preparation (1d), Knotting plashed pattern (2d), Dyeing (10d), Vertical thread reeling (3d), Reeling up preparation (3d), Weaving (10d), The last washing (1d)
					Interviewee: Kayo Yamashiro, 87 years old	*"I grow my own vegetables…We do [spooling] together sometimes [with friends]. Other times I do it by myself."*	87-year-old: "She grows her own vegetables in her garden, and, like most aged women in Kijaha, she lives alone… She estimates that she does u-umi about 2–3 h a day. Some days, however, she gets absorbed in the task and continues until 8 or 9 P.M"

Table 5 (continued)

Author & Year	Phenomena of Interest	Methods	Methodology	Themes	Description	Illustrations	Findings
					Interviewee: Kazu Taira, 90 years old	*"I do u-umi, but I also run the loom… [I am] independent… [and] active…It's important not to slow down too much…I am busy all the time."*	90-year-old: engages in spooling and loom, obtains preserved autonomy
					Interviewee: Maka Yoshihama, 101 years old	*"I never thought that I would live this long. Maybe [it is] the u-umi [that is] keeping me going"*	101-year-old: "[Maka] remains tied to the *basho-fu* weaving network. Every couple of weeks, Maka's daughter makes trips to Kijaha to pick up the fiber that her mother will later spin into thread."
					Interviewee: Kimi Nakada, 86 years old	*"I used to work doing basho as a child… By keeping your fingers busy with this detailed work it also keeps your mind sharp and prevents [senility]."*	86-year-old: continues spooling
					Interviewee: Nabi Kinjo, 107 years old	*"If I did not have basho-fu weaving in my life, I would surely die… We had nothing after the war but these basho plants and some looms hidden in the mountains…Basho-fu weaving kept us alive."*	107-year-old: "Actively engaged in the practice of [*u-umi]* until shortly before her death."
					Interviewee: 90-year-old villager	*I could weave five mats a day on a good day… I [did not] have to leave my home [to work]."*	Opportunity to weave more because of the convenience of "[working] out of their own homes, [giving] them flexibility."

*Sabbath afternoon = rest day, 7th day of week; *Basho-fu* = weaving; *U-umi* = spooling; d = days.

labour-intensive activities, in which women will spool for 20 days until completion for either income or as a hobby. The women also describe the detail and fine motor skills it takes to complete spooling, which is the one thing they believe keeps them sharp and still alive (Willcox et al., 2007b). Information about the oldest old men in Okinawa was not provided. The following as an illustration of an Okinawan woman in her early 80's that goes by, Toshiko Taira was quoted saying that.

> "There was one year when we made up to 100 rolls of [textile] material" (Willcox et al., 2007b).

Contrasting data on durations of rest was represented to provide an alternative understanding of the Blue Zone population's continuous movement throughout the day. In contrast with the PA continuous scores (average 1533 MET min/week) reported by Legrand et al. (2021), the average time spent sitting per day for Ikarian residents ≥ 90 years of age is 90 min per day. Similar results with a different form of measurement were reported for the Sardinian participants ≥ 90 years of age regarding productive rest. The total daily resting time was measured by the participant's duration of night's sleep and time spent in supine in the waking day, which resulted in only 8.5 hours for men and 7.4 hours of total daily rest on average out of a 24-hour period (Pes et al., 2018).

Modes of PA reported in each study per Blue Zones region are synthesized in Table 6, along with the categorized activities, including a categorization for studies that did not specify modes of activity. The most common mode of PA found across 12 studies was agricultural activities (Fastame et al., 2018; Nieddu et al., 2020; Legrand et al., 2019, 2021; Panagiotakos et al., 2011; Pes et al., 2013, 2018, 2020, 2021; Poulain et al., 2004; Spencer-Hwang et al., 2018; Willcox et al., 2007b), whereas, seven studies reported no specific modes of PA (Akisaka et al., 1996; Chan et al., 1997; Deiana et al., 1999; Madrigal-Leer et al., 2020; Nieddu et al., 2020; Willcox et al., 2007a, 2008). The prevalent modes of PA that are represented in the included studies were synthesized for visual analysis in Fig. 2, including the number of studies that reported a mode of PA and the corresponding Blue Zone. Throughout the studies conducted on Sardinia, four studies reported agricultural activities (Nieddu et al., 2020; Pes et al., 2018, 2020; Poulain et al., 2004) and four studies reported farming as predominant modes within the Sardinian literature (Pes et al., 2013, 2018, 2020, 2021).

Due to cases of participants reporting to engage in more than one activity, a population percentage was not able to be synthesised with activity sample sizes, however, Fig. 3 includes the percentage amount of the predominant intensity that is engaged in by the oldest old. It is significant to note that more than 60% of activities engaged in by the Ikarian, Sardinian and Loma Linda's regions are moderate intensity activities (Fastame et al., 2018; Legrand et al., 2019, 2021; Panagiotakos et al., 2011; Pes et al., 2018, 2020; Spencer-Hwang et al., 2018), while Okinawan centenarians reflect that 83% of their activities engaged in are low intensity activities (Willcox et al., 2007b). Considering Nicoya studies did not provide activity sample sizes, nor a mode of PA, an activity intensity synthesis could not be completed for this region.

Discussion

Key Findings

Throughout eighteen papers in this scoping review, there are significant findings across the five Blue Zones. Findings in this current scoping review consolidate the following for the first time in research: 1) Overall, centenarians are performing consistent and continuous movements daily that are predominantly moderate intensity activities, 2) their modes of PA are influenced by environment, geography, and culture. The main findings of our study conclude that the homogeneous environment in Blue Zones creates a demand for living a traditional lifestyle. For example, walking to commute, working labour-intensive occupations, participating in outdoor hobbies, and navigating complex terrain with constant exposure to uneven surfaces.

By maintaining traditional lifestyles, many of the Blue Zone regions rely on traditional economic activities that are centered around highly physical occupations such as farming, shepherd work, and agriculture (Pes et al., 2018, 2020). Pes et al., (2013) highlights that shepherd work was the most common occupation in the Sardinian Blue Zone region and the average daily walking distances of 12.4 ± 7.8 (km) at an average slope of 15.2 ± 6.6 (%) is demanding and most likely apply to shepherd workers in these mountainous regions. This type of physical occupation is considered moderate intensity that is maintained constantly throughout the year. This would involve walking long distances up and downhill on steep and narrow paths (Pes etal., 2013). Whereas past researchers have found that only 6 % of Australian workers, 65 years and older, are full-time and 5% are part-time workers (Foskey et al., 2005). In parallel to centenarians working beyond the expected age of retirement, the Blue Zone populations are showing a low level of rest throughout the day. Legrand et al., (2021) reports that nonagenarians (90 yrs. and older) in Ikaria, Greece show remarkably little time spent sitting (minutes/day):90 ± 120 (males), 60 ± 240 (females). This is a significant finding as prior-research revealed that participants > 60 years of age spent between 5-9 hours sedentary per waking day; where these adults reported 3.3 hours in leisure sitting and 3.3 hours watching T.V (Harvey et al., 2015). The continuous activity, work life, and total rest time in Blue Zonecentenarians was an unexpected finding in this scoping review. This pattern of results reflects the predominantly moderate levels of physical activity preformed throughout the dayand is exceeding The American College of Sports Medicine (ACSM) recommendations of > 30 mins moderate intensity exercise for ages 65 years and older (Nelson etal., 2007).

The lower socio-economic status found across all Blue Zones reflects thelabour-intensive occupations and the high levels of PA engaged in by centenarians (Legrand et al., 2019, 2021; Nieddu et al., 2020; Wilcox et al., 2007b). These findings are interesting as previous research as sociate low socioeconomic status with health risk behaviours in older adults, however, does not specify whether this applies to rural areas or cities (Shankar et al., 2010). Health risk behaviours consisted of smoking, alcohol consumption and low

Table 6 Summary of prevalent modes of physical activity in Blue Zones referenced in studies

Modes of Physical activity	Numbers of Studies	References
Agricultural Activities (gardening, farming, shepherd work)	12	Fastame et al. (2018); Nieddu et al. (2020); Legrand et al. (2019, 2021); Panagiotakos et al. (2011); Pes et al. (2013, 2018, 2020, 2021); Poulain et al. (2004); Spencer-Hwang et al. (2018); Willcox et al. (2007b)
In-home Activities (housekeeping, basho-fu weaving)	3	Legrand et al. (2019); Panagiotakos et al. (2011); Willcox et al. (2007b)
Outdoor Hobbies (sports, social/cultural, nature engagement, swimming, horseback riding, dancing)	3	Fastame et al. (2018); Legrand et al. (2021); Spencer-Hwang et al. (2018)
Walking (i.e. hiking in the mountains)	6	Legrand et al. (2019, 2021); Panagiotakos et al. (2011); Pes et al. (2013, 2020); Spencer-Hwang et al. (2018)
Other Labour Occupations	2	Legrand et al. (2019); Panagiotakos et al. (2011)
N/A (Modes not specified)	7	Akisaka et al. (1996); Chan et al. (1997); Deiana et al. (1999); Madrigal-Leer et al. (2020); Nieddu et al. (2020); Willcox et al. (2007a, 2008)

levels of physical activity, where the combination of all three is high (Shankar et al., 2010). This has the opposite effect on the Blue Zone population as low socioeconomic status and traditional lifestyle drive continuous PA through work life and hobbies (Pes et al., 2013).

While an interpretation was provided on the continuous levels of physical activity, the environment and cultural influences of these Blue Zone regions play a key part in centenarian's movements through physical occupations, commuting, andleisure-time primarily outdoors. Each Blue Zone region is in a geographical location that is isolated yet condensed with endless opportunity for community members to be encouraged to engage in the outdoors (Pes et al., 2018; Spencer-Hwanget al., 2018). It can be hypothesized that the nature of their small communities, and advanced social and cultural networks that provide a safety net is a significant factor that allows the oldest old the prospect of being outdoors. A study conducted by Tucker-Seeley et al. (2009), reports on the perceived safety of an older adult's neighborhood as a barrier for engagement in leisure-time physical activity. In addition to perceived safety, the following were shown to determine the participation in outdoor PA for older adults:1) pedestrian infrastructure, 2) access to facilities, 3) aesthetics and 4) environmental conditions (Moran et al., 2014). Interestingly, amongst these factors such as pedestrian infrastructure, which includes sidewalk quality, maintenance and obstacles, the Blue Zone region's infrastructures are not kept to the same standard. Although, in Western society, the street and sidewalk quality may in still motivation and ease the fear of falls (Moran et al., 2014),

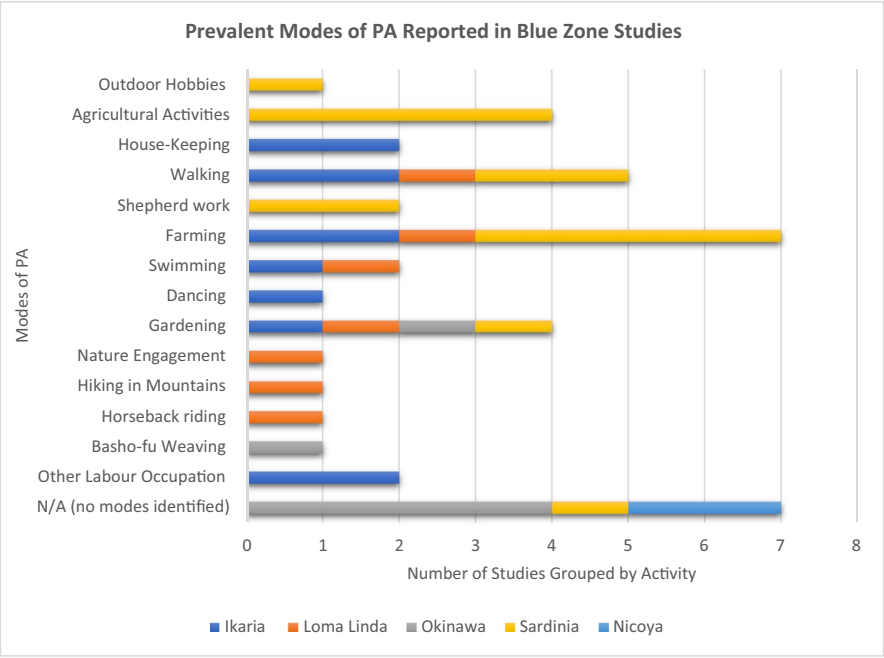
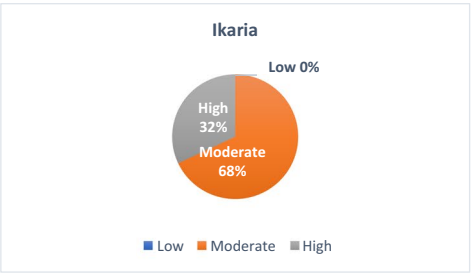


Fig. 2 The prevalence of modes of PA in Blue Zones that are identified in each study, including the number of studies that did not identify a mode

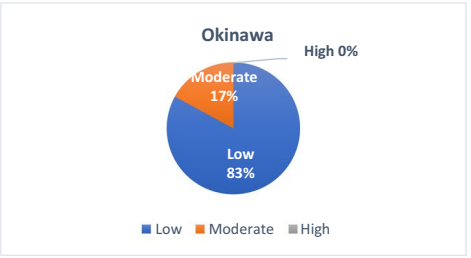
however, the quality of walkways is not the reality of these small cobble-stoned villages in often mountainous regions (Legrand et al., 2019, 2021; Pes et al., 2013; Poulain et al., 2004).

Limitations

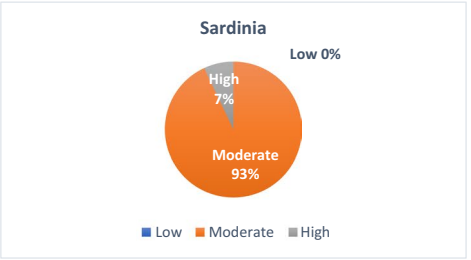
Considering the high heterogeneity of values and tests measured across all studies included in this scoping review, there were limitations in synthesizing comparative representations and statistical summary. While a range of different activities were reported in each study, a comparative population summarization was not able to be synthesized due to the potential of underrepresenting certain activity populations. Exclusively, the studies investigating the Nicoya population did not report modes of physical activity, despite referring to lifestyle practices of participants. This can be attributed to the limitations of this study's inclusion criteria. An article would still be included based on referring to environment and physically active lifestyles, without specifically referring to the modes of PA engaged in. This resulted in the inclusion of multiple studies that did not provide modes of PA but offered other supplemental information. Another drawback was the population sizes for Blue Zone studies with reported modes of PA, such as,



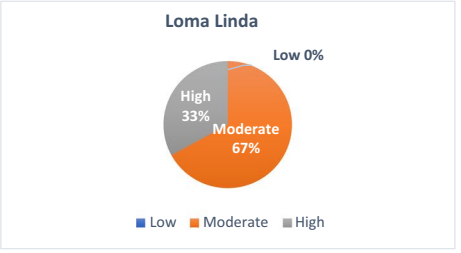
a) The percentage of activities in Ikaria engaged in a specific intensity.



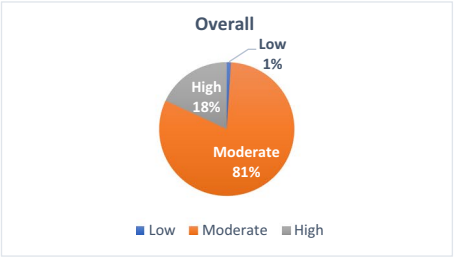
b) The percentage of activities in Okinawa engaged in a specific intensity.



c) The percentage of activities in Sardinia engaged in a specific intensity.



d) The percentage of activities in Loma Linda engaged in a specific intensity



e) Overall percentages of intensities engaged in throughout 4 Blue Zones

Fig. 3 The engagement prevalence of low, moderate, and high intensity activities overall and for each individual Blue Zone identified in eight studies. *Note* a) In Ikaria, 68% of the activities engaged in were moderate intensity activities (Legrand et al., 2019, 2021; Panagiotakos et al., 2011). b) In Okinawa, 83% of activities engaged in were low intensities activities (Willcox et al., 2007b). c) In Sardinia, 93% of activities engaged in were moderate intensity activities (Fastame et al., 2018; Pes et al., 2018, 2020). d) In Loma Linda, 67% of activities engaged in were moderate intensity activities (Spencer-Hwang et al., 2018). e) Overall, throughout Ikaria, Okinawa, Sardinia and Loma Linda, 81% of activities engaged moderate intensity activities (Fastame et al., 2018; Legrand et al., 2019, 2021; Panagiotakos et al., 2011; Pes et al., 2018, 2020; Willcox et al., 2007a, b; Spencer-Hwang et al., 2018)

Loma Linda, and Okinawa. The overall conclusion and findings of these two regions potentially contain skewed data as there would be an overrepresentation of the specific activities reported in the Loma Linda (Spencer-Hwang et al., 2018) and Okinawa study (Willcox et al., 2007b). Lastly, this scoping review was not able to draw the conclusion that PA correlated with longevity, as this would require comparative national health data, and the inclusion of biological and genetic studies for comparison of other contributing factors of longevity within Blue Zones. Despite these limitations, the present study has significantly enhanced the understanding of the relationship between modes of PA, environment, and cultural influences of centenarians residing in the five Blue Zones.

Future Directions

The present study can be utilized as a tool for researchers to carry further investigation into Loma Linda, Nicoya and Okinawa regions. These were Blue Zones with either small sample sizes or did not provide specification to modes of PA, which requires further research. Future studies are encouraged to report sample sizes along with the specific mode of activity for an overall population synthesis of predominant modes of PA.

The clinical implications of this review involve providing Allied Healthcare professionals with lifestyle models that can easily be undertaken by older adults. By providing older adults with outdoor lifestyle prescriptions, Allied Healthcare practitioners can ensure activities that offer greater adherence and an increase in functional capacity compared to indoor exercise (Lacharité-Lemieux et al., 2015).

Conclusion

Overall, the centenarians in Blue Zones are a highly physically active population performing continuous and consistent movements daily, maintaining daily hobbies, and working beyond the expected age of retirement. The predominant modes of PA for centenarians across the studies included in the present scoping review were agricultural activities including, gardening, farming, and shepherd work, while the predominant level of intensity for PA was found to be moderate. The key findings represent a significant effect on PA by environmental and cultural influences of each region, where the more isolated land, extended on-foot commutes, diverse walking terrain, social life, and the maintenance of traditional meals and occupations each play an integral role of centenarian's active lifestyles.

Appendix

Table 7 Search strategy processes used for each electronic database

Database	Date Searched	Search Strategy	# of Results
Pub Med	Dec 1, 2021	("Blue Zone*"[tiab] OR Sardinia*[tiab] OR Ikaria*[tiab] OR Nicoya*[tiab] OR "Loma Linda*"[tiab] OR Okinawa*[tiab]) AND (Centenarian*[tiab] OR "80 years and older"[tiab] OR "Oldest Old*"[tiab] OR "90 years and older"[tiab] OR Octogenarian*[tiab] OR Nonagenarian*[tiab] OR "Aged, 80 and over"[Mesh] OR "Longest Lived"[tiab]) AND ("Physical activity"[tiab] OR Exercise[Mesh] OR Exercise*[tiab] OR "Leisure Activities"[Mesh] OR "Activities of Daily Living"[Mesh] OR Movement[Mesh] OR Movement*[tiab] OR Longevity[tiab] OR Longevity[Mesh] OR "Motor Activity")	114
Web of Science	Dec 1, 2021	("Blue Zone*" OR Sardinia* OR Ikaria* OR Nicoya* OR "Loma Linda*" OR Okinawa*) AND (Centenarian* OR "80 years and older" OR "Oldest Old*" OR "90 years and older" OR Octogenarian* OR Nonagenarian* OR "Aged, 80 and over" OR "Longest Lived") AND ("Physical activity" OR Exercise OR Exercise* OR "Leisure Activities" OR "Activities of Daily Living" OR Movement OR Movement* OR Longevity OR Longevity OR "Motor Activity")	93
ProQuest Dissertations & Theses Global	Dec 1, 2021	(TI,AB("Blue Zone*") OR TI,AB(Sardinia*) OR TI,AB(Ikaria*) OR TI,AB(Nicoya*) OR TI,AB("Loma Linda*") OR TI,AB(Okinawa*)) AND (TI,AB(Centenarian*) OR TI,AB("80 years and older") OR TI,AB("Oldest Old*") OR TI,AB("90 years and older") OR TI,AB(Octogenarian*) OR TI,AB(Nonagenarian*) OR TI,AB("Aged, 80 and over") OR TI,AB("Longest Lived")) AND (TI,AB("Physical activity") OR TI,AB(Exercise*) OR TI,AB("Leisure Activities") OR TI,AB("Activities of Daily Living") OR TI,AB(Movement*) OR TI,AB(Longevity) OR "Motor Activity")	1
CINAHL	Dec 1, 2021	((TI "Blue Zone*" OR AB "Blue Zone*") OR (TI Sardinia* OR AB Sardinia*) OR (TI Ikaria* OR AB Ikaria*) OR (TI Nicoya* OR AB Nicoya*) OR (TI "Loma Linda*" OR AB "Loma Linda*") OR (TI Okinawa* OR AB Okinawa*)) AND ((TI Centenarian* OR AB Centenarian*) OR (TI "80 years and older" OR AB "80 years and older") OR (TI "Oldest Old*" OR AB "Oldest Old*") OR (TI "90 years and older" OR AB "90 years and older") OR (TI Octogenarian* OR AB Octogenarian*) OR (TI Nonagenarian* OR AB Nonagenarian*) OR (MH "Aged, 80 and over"+) OR (TI "Longest Lived" OR AB "Longest Lived")) AND ((TI "Physical activity" OR AB "Physical activity") OR (MH Exercise+) OR (TI Exercise* OR AB Exercise*) OR (MH "Leisure Activities"+) OR (MH "Activities of Daily Living"+) OR (MH Movement+) OR (TI Movement* OR AB Movement*) OR (TI Longevity OR AB Longevity) OR (MH Longevity+) OR "Motor Activity")	21

Table 7 (continued)

Database	Date Searched	Search Strategy	# of Results
Google Scholar	Dec 1, 2021	(TI,AB("Blue Zone*") OR TI,AB(Sardinia*) OR TI,AB(Ikaria*) OR TI,AB(Nicoya*) OR TI,AB("Loma Linda*") OR TI,AB(Okinawa*)) AND (TI,AB(Centenarian*) OR TI,AB("80 years and older") OR TI,AB("Oldest Old*") OR TI,AB("90 years and older") OR TI,AB(Octogenarian*) OR TI,AB(Nonagenarian*) OR TI,AB("Aged, 80 and over") OR TI,AB("Longest Lived")) AND (TI,AB("Physical activity") OR TI,AB(Exercise*) OR TI,AB("Leisure Activities") OR TI,AB("Activities of Daily Living") OR TI,AB(Movement*) OR TI,AB(Longevity) OR "Motor Activity")	7

Table 8 Studies measuring quantitative data and outcome measures that report modes, and levels of PA, physical function, and frequencies of engaged in with a variety of unit measures

Blue Zone/ Country	Author & Year	Population & Sample Size	Outcome Measures	Outcome Values	Modes of PA	Main Findings
Ikaria, Greece	Legrand et al. (2019)	90 yrs. and older. Total N = 71, N = 34 males, N = 37 female	ADL scale scored out of 6.0 IADL scale scored out of 8.0 (F) and 5.0 (M) Mean categorized IADL score (%): High, Moderate, Low Grip Dynamometer (kg) (Mean ± SD)	4.0/6.0 (mean) Scores > 5 = 88.2% (M), 59.5% (F) Scores < 3 = 11.8% (M), 27% (F) 4.2/8 (F), 3.6/5 (M) High = 56.3%, Moderate = 18.3%, Low = 25.4% 17.0 ± 6.7 (F), 26.5 ± 8.9 (M)	Occupations of the village: Farmers n = 21, Housewives n = 15, Sailors n = 8, Fishermen n = 6, Workers n = 6, Intermediate Craftsmen n = 6, Trader Coal miner n = 4, Other n = 5	The most common occupation in Ikaria is farming. The mountainous terrain influences more variation and levels of PA
	Legrand et al. (2021)	90 yrs. and older. Total N = 71, N = 34 males, N = 37 female	IPAQ -7 items score (%) PA Continuous Score (MET-min/week) Time spent sitting (min/day)	Low = 40.5% (F), 14.7% (M); Moderate = 27% (F), 26% (M); High = 32.4% (F), 58.8% (M) 3066 ± 4768.5 (M), 1022 ± 3066 (F), total median PA score = 1533 ± 3924 (MET-min/week) 90 ± 120 (M), 60 ± 240 (F)	Swimming in the Ikarian Sea, Dancing at the Panigiria festival, farming activities and walking (to go to work or the villages)	Physical activity was linked to occupation and social gatherings. Time spent sitting reflects the high levels of PA and (MET-min/week) reflects the energy expended
	Panagiotakos et al. (2011)	80 yrs and older Total N = 187 N = 89 males N = 98 females	IPAQ -6 items score (Physical activity status, %)	Low = 16.3% (M), 29.8% (F) Moderate = 66.6%(M), 68.1% (F) High = 22.1% (M), 2.1%(F)	Walking, working, gardening, and housekeeping	Daily activities reported: working and leisure activities. Men were more physically active compared to women. Overall, 6 out of 10 participants over the age of 90 were physically active

Table 8 (continued)

Blue Zone/ Country	Author & Year	Population & Sample Size	Outcome Measures	Outcome Values	Modes of PA	Main Findings
Nicoya Peninsula, Costa Rica	Madrigal-Leer et al. (2020)	Community-dwelling centenarians. Total N = 43, N = 18 males, N = 15 females	Grip Strength (hand dynamometer) BADL performance (Barthel Scale): IADL performance (Lawton Scale): Gait speed:	N = 25 participants performed test Mean grip strength = 12.6 kg (5.48 SD) for men, 7 kg (3.41 SD) for women Unable to perform task: total N = 19, N = 5 (M), N = 14 (F) Mean score = 69.2 points (29.1 SD) for men, 44.2 points (33.9 SD) for women Mean score = 1.4 points for mean, 1 point for women > 13.04 s: total N = 24, N = 13 (M), N = 11 (F)	N/A	No modes of PA reported Functional Evaluation concluded 10 centenarians with total BADL dependence and 27 centenarians with total IADL dependence. Men performed better than women in gait speed test and obtained higher scores in Barthel Index, reflecting higher functionality
	Nieddu et al. (2020)	80 yrs. and older Total N = 60, N = 31 males, N = 29 females	Performance-based functional ability test: BADL (6 domains evaluates autonomy) IADL (3 items estimate functional autonomy in performing IADLs)	Severe disability (score < 3): N = 4 (12.9%) (M), N = 8 (27.6%) (F) Moderate disability or no disability (score ≥ 3): N = 27 (87.1%) (M), N = 21 (72.4%) (F) Severe disability: N = 3 (9.7%) (M), N = 6 (20.7%) (F) Moderate disability or no disability: N = 28 (90.3%) (M), 23 (79.3%) (F)	N/A	Nicoya's isolated region has a low prevalence of physical disability. Only a quarter of participants were categorized with severe disability
Okinawa, Japan	Akisaka et al. (1996)	Native Okinawan Centenarians. Total N = 21, N = 4 males, N = 17 females	ADL 11-function test (scored out of 5)	Bed-ridden (1 point): N = 0 (M), N = 1 (F) Moveable around bed (≤ 3 points): N = 0 (M), N = 3 (F) Normal (> 3 points): N = 4 (M), N = 13 (F)	N/A	No modes of PA reported ADL scored showed the functional capacity of Okinawan centenarians, compared to other Japanese prefectures. Only one subject was bedridden

Table 8 (continued)

Blue Zone/ Country	Author & Year	Population & Sample Size	Outcome Measures	Outcome Values	Modes of PA	Main Findings
	Chan et al. (1997)	Centenarians in Okinawa. Total N = 39, N = 11 males, N = 28 females	ADL physical activity—7 items (scored out of 5: completely independent = 5, completely dependent = 1)	Average Scores: Total = 3.8, (M) = 4.5, (F) = 3.8	N/A	No modes of PA reported. Males' score: moderate to high independence and moderate to completely independent. PA scores (M): independent but slow. Females' scores: independent but slow and independent with difficulty
	*Willcox et al., (2007a, b)	Okinawan centenarians ages 92–102 N = 22, N = 20 female, N = 2 males	ADL (Inoue Index) 7 items, 1 (completely dependent) to 5 (completely independent) total score of 55	92 yrs: 49.0 ± 8.1 97 yrs: 45.0 ± 9.3 99 yrs: 40.8 ± 11.5 101 yrs: 36.8 ± 12.5 102 yrs: 36.6 ± 12.6	N/A	No modes of PA reported Results support a proxy measure of disability-free life expectancy
	Willcox et al. (2008)	Supercentenarians (followed from age 99 and over) Total N = 20, N = 3 men, N = 17 women	ADL (Inoue index): Max score = 55 (completely independent), min score = 11 (completely dependent)	Average ADL scores: N = 9 (99–103 yrs), 43.7 ± 11.4; N = 7 (104–107 yrs), 37.4 ± 13.2; N = 4 (108–111 yrs), 20.5 ± 3.5	N/A	No modes of PA reported. Majority of participants ages 99–107 yrs reported to be completely independent and independent but slow. Participants ages 109–111 scored on average to be independent with difficulty and partially dependent. No supercentenarians reported to be completely dependent The two main functions that had the most rapid decline were motor skills and sensory acuity
Sardinia, Italy	Deiana et al. (1999)	Centenarians n = 141	Interview: Lifetime habits (working activity, hobbies, other leisure time activities, and physical exercise Physical Function assessed: (BADL and IADL) Index of ADL assessment	N/A N/A N/A	N/A	No modes of PA reported Lifetime habits and physical function were assessed, but results were not reported Favorable interactions between participant's environment and lifestyle are likely to contribute to longevity

Table 8 (continued)

Blue Zone/ Country	Author & Year	Population & Sample Size	Outcome Measures	Outcome Values	Modes of PA	Main Findings
	Fastame et al. (2018)	Very Old (> 80 years). N = 33, N = 13 male, N = 20 female	Mean hours/week for outdoor hobbies: Days/week for Gardening: # participated in PA: Gardening: Outdoor Hobbies: Sport: Cultural/Social:	1.7 ± 2.3 (M) 2.3 ± 3 (F) Days/week 1 day = 5 (M), 15 (F) 2–4 days = 6 (M), 3(F); > 4 days = 2 (M), 1 (F) N = 8 (M), N = 5 (F) N = 6 (M), N = 10 (F) N = 3 (M), N = 2 (F) N = 3 (M), N = 8 (F)	Gardening and outdoor hobbies (sport or cultural/ social)	High significance of the effect of outdoor leisure engagement on age, subjective well-being, and depressive symptoms
	Nieddu et al. (2020)	90 yrs. and older Total N = 150, N = 61 males, N = 89 females	Performance-based functional ability test: BADL (6 domains evaluates autonomy) IADL (3 items estimate autonomy in performing IADLs)	Severe disability (score < 3): N = 9 (14.7%) (M), N = 22 (24.7%) (F) Moderate disability or no disability (score ≥ 3): N = 52 (85.2%) (M), N = 67 (75.3%) (F) Severe disability: N = 7 (11.5%) (M), N = 19 (21.3%) (F) Moderate disability or no disability: N = 54 (88.5%) (M), N = 70 (78.7%) (F)	Agricultural Activity	The level of functional capacity detected moderate or no disability (BADL score ≥ 3) three quarters of the subjects with a higher value in females compared to males
	Pes et al. (2013)	Sardinian Centenarians. Total N = 1132, N = 415 men, N = 717 women	Pastoralism score (#1–4), a score # was obtained by coding each municipality as 1 (no shepherds), 2 (farmers outnumbered shepherds), 3 (shepherds outnumbered farmers), 4 (only shepherds) Average terrain slope (%) Daily distance to workplace (km) Robustness score (0–3)	Mean Pastoralism score = 2.8 ± 1.4 Average terrain slope = 15.2 ± 6.6% Daily distance to work-place = 12.4 ± 7.8 km Robustness score = 1.9 ± 0.8	Shepherd work, farming, walking to and from work	Most common occupation reported: shepherds. Shepherds engage in lower intensity, but more continuous PA compared to farmers. Occupation demands: higher terrain slope, longer daily distance to reach workplace, and documented higher avg body robustness in population

Table 8 (continued)

Blue Zone/ Country	Author & Year	Population & Sample Size	Outcome Measures	Outcome Values	Modes of PA	Main Findings
	Pes et al. (2018)	90 yrs. and older. Total N = 44, N = 27 males, N = 17 female	6-item ADL Questionnaire (0–6 score Motor Activity Index: PAL: TEE / REE ratio (Mean ± SD) STEPS per day (Mean ± SD) % EE-A ≥ 3 METs (Mean ± SD) % STEPS ≥ 3 METs (Mean ± SD)	4.9 ± 1.5 (M), 4.8 ± 1.4 (F) 1.78 ± 0.26 (M), 1.84 ± 0.25 (F) 12,110 ± 5141 (M), 12,799 ± 6420 (F) 42.54 ± 7.90 (M), 46.31 ± 6.80 (F) 29.10 ± 11.61(M), 23.01 ± 10.73 (F)	Agriculture, or animal husbandry (farming)	Physical functionality scores high in both genders. PAL values indicate "moderate" activity. Index of PA are the highest reported in literature for > 90 years adults. Activity > 3 METS exceeded 40% in both genders. High correlation between energy expenditure (kcal) and PAL with the 6-item ADL questionnaire scores
	Pes et al. (2020)	89yrs and older from two cohorts (LBZ & NSS) LBZ: Total N = 150, N = 89 women, N = 61 males NSS: Total N = 150, N = 101 females, N = 49 males	6-item basic ADL: scores categorized by "severe disability" (ADL < 3) and "moderate or no disability" (ADL ‡3) Physical activity (# participants walking ≥ 3 or < 3 times/week):	LBZ Severe Disability = 29 (19%) Moderate or no disability = 121(81%) NSS Severe Disability = 16 (10%) Moderate or no disability = 134(90%) LBZ: < 3 times/week = 9 (6%) (M), 35 (23%) (F) ≥ 3 times/week = 52 (39%) (M), 54(36%) (F) NSS: < 3 times/week = 20 (13%) (M), 39 (26%) (F) ≥ 3 times/week = 29 (19%) (M), 62 (41%) (F)	LBZ Farm animal rearing, shepherds, agricultural activities and walking NSS Walking	LBZ: traditional economic activity continues centered on pastoralism. Daily physical activity represented significantly greater frequencies in men, compared to NSS

Table 8 (continued)

Blue Zone/ Country	Author & Year	Population & Sample Size	Outcome Measures	Outcome Values	Modes of PA	Main Findings
	Pes et al. (2021)	90 yrs. and older. Total N = 150, N = 61 males, N = 89 females	IADL Performance Tests: Timed 4-distnace walk test Progressive standing balance Sit-to stand (× 5 timed test) 400 m walking endurance	Severe disability: N = 9 (14.7) (M), N = 20 (22.5) (F) Moderate or no disability: N = 52(85.2) (M), N = 69 (77.5) (F) N/A N/A N/A N/A	Animal farming	Animal farming is the main occupation and mode of physical activity in Sardinia. Physical performance is higher in males compared to females
	Poulain et al. (2004)	EBZ centenarians. Total N = 631, N = 269 (M), N = 362 (F) RBZ Centenarians. Total N = 91 N = 47 (M), N = 44 (F)	N/A	N/A	Agriculture, pasteurizing,	Specific climate and cultural features of Sardinia including lifestyle, are characteristics revealed to be favoring extreme longevity

ADL = activities of daily living; IADL = instrumental activities of daily living; IPAQ = International Physical Activity Questionnaire; PAL = Physical Activity Levels, REE = Resting energy expenditure; TEE = total energy expenditure; EE-A = Energy Expenditure; EE-A ≥ 3 METs = moderate levels of PA; STEPS measured by the SensewearTM Armband; Northern Sardinia Sample (NSS); Longevity Blue Zone (LBZ); Extended Blue Zone (EBZ); Restricted Blue Zone (RBZ); F = female, M = male

*6-Item ADL Questionnaire = lower score, less disability

*ADL scale out of 6.0 = high score, high level of independence

*IADL scale scored out of 8.0 for females (F) and 5.0 for males (M) = high score, high level of autonomy

*IPAQ categorical scores = low, moderate, or high levels of physical activity

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