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Abstract

Background: frailty syndrome is common amongst older people. Low physical activity is part of frailty, but long-term prospective studies investigating leisure-time physical activity (LTPA) during the life course as a predictor of frailty are still warranted. The aim of this study is to investigate whether earlier life LTPA predicts frailty in older age.
Methods: the Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER) included older adults (aged 60–77 years) from the general population who were at increased risk of cognitive decline. Frailty was assessed for 1,137 participants at a baseline visit using a modified version of Fried's phenotype, including five criteria: weight loss, exhaustion, weakness, slowness and low physical activity. Self-reported data on earlier life LTPA were available from previous population-based studies (average follow-up time 13.6 years). A binomial logistic regression analysis was used to investigate the association between earlier life LTPA and pre-frailty/frailty in older age.
Results: the prevalence of frailty and pre-frailty was 0.8% and 27.3%, respectively. In the analyses, pre-frail and frail groups were combined. People who had been physically very active (OR 0.37, 95% CI 0.23–0.60) or moderately active (OR 0.45, 95% CI 0.32–0.65) earlier in life had lower odds of becoming pre-frail/frail than individuals who had been sedentary.

Conclusions: frailty was rare in this relatively healthy study population, but almost a third of the participants were pre-frail. Earlier life LTPA was associated with lower levels of pre-frailty/frailty. The results highlight the importance of physical activity when aiming to promote healthy old age.

Key Points

- Earlier life leisure-time physical activity may reduce the risk of older age pre-frailty/frailty.
- Earlier life leisure-time physical activity may reduce the risk of older age pre-frailty/frailty amongst both men and women.
- The results were statistically significant for participants with a follow-up of less than 10 years and more than 10 years.
- Leisure-time physical activity is most likely an important way to promote a healthy old age.

Introduction

In an ageing population, frailty increases the risk of disability, falls, hospitalisation and death [1–5]. Currently, many different instruments are available to measure frailty [6]. Commonly used definitions are phenotypic or physical frailty (including weight loss, exhaustion, low physical activity, weakness and slowness) [1,7], and deficit accumulation frailty, which combines various clinical conditions of an individual into a 'Frailty Index' [8]. Consequently, there are two suggested pathways for how an individual may become frail: frailty might be a result of physiological changes of ageing that are not disease-based (phenotype) or a consequence of diseases or disabilities (deficit accumulation) [1].

Previous studies have identified earlier life risk factors, such as obesity and low physical activity, which may predispose an individual to frailty in old age [9–12]. Physical activity has also been shown to be associated with delaying or slowing down the progression of frailty [13]. The health benefits of physical activity [14] have been seen on various components of frailty (e.g. sarcopenia and functional impairment) [15]. However, studies investigating how leisure-time physical activity (LTPA) in earlier life predicts later life frailty over long follow-up periods are scarce.

The aim of this study is to investigate how earlier life LTPA predicts old-age frailty over an average of 13.6 years of follow-up. We hypothesise that individuals who are physically active during their leisure-time are less likely to become frail or pre-frail in older age.

Methods

The Finnish Geriatric Intervention Study to Prevent Cognitive Impairment and Disability (FINGER) [16] is a multicentre randomised controlled trial (ClinicalTrials.gov identifier: NCT01041989), carried out at six centres in Finland. Participants (total n = 1,260, aged 60–77 years) were recruited from previous population-based non-communicable disease risk factor surveys: the National FINRISK Study [17] and the Finnish Type 2 Diabetes Prevention Program's Population Survey (FIN-D2D) [18]. The included participants had Cardiovascular Risk Factors, Aging and Dementia (CAIDE) risk score [19] of ≥6 and cognition at a mean level or slightly lower than expected for age, measured using the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) neuropsychological battery [20]. Exclusion criteria included malignant disease, major depression, dementia or substantial cognitive decline, a Mini-Mental State Examination (MMSE) score < 20, symptomatic cardiovascular disease, revascularisation within one year, severe loss of vision, hearing or communicative ability and conditions preventing cooperation. The FINGER study protocol is described in detail elsewhere [16,21]. For investigating the association between older age frailty and earlier life LTPA, the participants' data from the FINRISK and the FIN-D2D studies were linked to the FINGER baseline data. The study was approved by the Ethical Committee of the Helsinki and Uusimaa Hospital District. Written informed consent was obtained from all participants [16].

Earlier life LTPA assessment (conducted between 1972 and 2007)

LTPA was assessed with the question: How much do you exercise and stress yourself physically in your leisure time? The response options were the following: (1) in my leisure time, I read, watch TV and work in the household with tasks which do not make me move much and which do not physically tax me, (2) in my spare time, I walk, cycle or exercise otherwise at least 4 h per week, excluding travel to work, (3) in my spare time, I exercise to maintain my physical condition, for at least 3 h per week and (4) in my spare time, I regularly exercise several times a week in competitive sports or other heavy sports [22–24]. The responses were categorized into 1) low (option 1), 2) moderate (option 2), and 3) high (options 3 and 4).

Frailty assessment (conducted between 2009 and 2011)

Frailty was defined using a modified Fried's phenotype [1] with the following components (Table 1):

Weight loss was assessed with a self-reported question: 'How much does your current weight differ from your previous year weight?' The percentage of weight loss was calculated as the reduced weight divided by the sum of the later-life weight and reduced weight. Weight loss of 5% or more or over 4.5 kg during the previous year was categorised as weight loss.

Exhaustion was assessed with the self-reported question: 'Have you had weakness or tiredness during the last month (30 days)?' with the response options (1) not at all, (2) quite little, (3) some, (4) quite a lot and (5) very much. The participants reporting quite a lot or very much were categorised as having exhaustion.

Low physical activity was assessed with two self-reported questions: 'How often do you participate in LTPA that lasts at least 20 minutes and causes breathlessness and sweating?' with the response options (1) five times a week or more often, (2) four times a week, (3) three times a week, (4) two times a week, (5) once a week, (6) less than once a week and (7) not at all due to disease or physical disability; and 'How many minutes per day on average you take up other leisure time activities which require physical activity?' with the response options (1) less than 15 min daily, (2) 15–29 min, (3) 30–59 min and (4) 1 h or more. Participants reporting once a week or less and less than 15 min daily were categorised as being physically inactive.

Weakness was defined from hand-grip strength measurements using a hydraulic hand dynamometer (Saehan SH 500, Saehan Co, Korea). The measurement was performed sitting with the arm downside of the body and the elbow flexed at 90°. The better of two measures from the dominant hand was used. In case the dominant hand was sore or injured or the measurement was missing, the non-dominant hand measurement was used. If the dominant hand was not determined, we used the measurement from the right hand (30 cases). Cut-off points proposed by Fried et al. [1] were used and adjusted for gender and body mass index (BMI) [1] (Table 1).

Slowness was defined by adapting the criteria proposed by Fried et al. [1], from a 4-m usual gait speed measurement, without an acceleration lane, performed indoors at the research site and timed with a hand-held stopwatch. The better of two performances was used, and cut-off points were adjusted for gender and height (Table 1).

Participants with three or more components were classified as frail, one to two as pre-frail and none as robust.

The earlier life covariates

Information on physician-diagnosed diseases was assessed using self-reported questionnaires, and the sum variable included the number of following diseases: myocardial infarction, stroke, high blood pressure, heart failure, coronary artery disease, asthma, arthritis, or other joint disorder. The BMI was calculated dividing body weight (kg) with the squared height (m²). Education was reported in years. Smoking status had four categories: (1) never a smoker, (2) quit smoking over 1/2 years ago, (3) quit smoking less than 1/2 years ago and (4) current smoker.

The later life covariates

The FINGER study measurement protocol is described in detail elsewhere [16,21]. Self-reported physician-diagnosed medical disorders were inquired at the FINGER screening interview by a study physician, and the total number of the following diseases was used: high blood pressure, heart failure, angina pectoris, cancer, asthma, pulmonary emphysema or chronic bronchitis, gallstones or gall bladder inflammation, rheumatoid arthritis, other articular disease, back illness, chronic urethritis or nephritis, cerebrovascular disease, diabetes, depression, and other psychological illnesses.

Statistical analyses

The population characteristics are described with means and standard deviations or proportions. The association between frailty and the population characteristics were tested using a T-test for continuous variables and a Chi-squared test for categorical variables. Due to the limited number of frail individuals, frail and pre-frail groups were combined into one group for the final analyses. We also conducted the sensitivity analyses without frail individuals and excluding physical activity from the frailty definition.

A binomial logistic regression analysis was used to investigate the association between earlier life LTPA and later life pre-frailty/frailty. All models were adjusted first for age [3,25] at earlier life assessment, sex [3,25], follow-up time and research centre and then additionally for earlier life BMI [9], education [1], chronic diseases [3,5], smoking [10] and older age chronic diseases. The results are expressed as odds ratios and 95% confidence intervals. P-values <0.05 were considered statistically significant. All statistical analyses were performed using Stata version 11.2.

Results

The mean age of the participants was 56.0 (SD 10.9) years at the time of the earlier life assessment, ranging from 25 to 74 years (median 58, interquartile range 49–64 years).

Of the 1,260 FINGER study participants, 1,137 had complete data to evaluate older age frailty. The prevalence of frailty and pre-frailty was 0.8% and 27.3%, respectively. Weakness (11.9%) was the most frequent reason for belonging to the pre-frail/frail group. The next most common reasons were weight loss (7.9%), exhaustion (6.2%), low physical activity (5.1%) and slowness (1.9%) (Appendix 1 in Supplementary data). Individuals with missing data were slightly older than the study participants (data not shown). Information about earlier life LTPA was available

Table 1. Modified Fried's phenotype used in the present study

	Modified Fried's phenotype		
Weight loss	How much does your current weight differ from your previous year weight? Weight loss of 5% or more or over 4.5 kg during the previous year was categorised as weight loss.		
Exhaustion	Have you had weakness or tiredness during the last month (30 days)? (1) not at all (2) quite little (3) some (4) quite a lot (5) very much The participants reporting quite a lot or very much were categorised as having exhaustion (options 4–5)		
Low physical activity	How often do you participate in LTPA that lasts at least 20 min and causes breathlessness and sweating? (1) five times a week or more often (2) four times a week (3) three times a week (4) two times a week (5) once a week (6) less than once a week (7) not at all due to disease or physical disability How many minutes per day on average you take up other leisure time activities that require physical activity? (1) less than 15 min daily (2) 15–29 min (3) 30–59 min (4) 1 h or more Participants reporting once a week or less (options 5–7) and less than 15 min daily (option 1) were categorised as being physically inactive		
Weakness	Highest measure from dominant hand (two trials), stratified by gender and BMI Cut-off for grip strength (kg) criterion for frailty		
	BMI: Men	Grip strength (kg)	BMI: Women	Grip strength (kg)
	≤24.00	≤29	≤23.00	≤17
	24.01–26.00	≤30	23.01–26.00	≤17.3
	26.01–28.00	≤30	26.01–29.00	≤18
	>28.00	≤32	>29.00	≤21
Slowness	4-m usual walking speed, stratified by gender and height. Cut-off for time to walk 4 m criterion for frailty.		
	Height	Walk time		
	Men	Women		
	≤173 cm	≤159 cm	≥6.15 s	
	>173 cm	>159 cm	≥5.26 s	

Participants with three or more components were classified as frail, one to two as pre-frail and none as robust.

for 1,131 participants. Of the pre-frail/frail participants, 28.5% reported low levels of LTPA during the earlier life assessment. The corresponding proportion was 14.5% in the robust group ($P < 0.001$) (Table 2).

The follow-up time ranged between 1.8 and 39.6 years (mean 13.6, SD 10.2, median 12.7, and interquartile range 4.2–19.3 years). The mean age at the time of the older age assessment was 69.3 (SD 4.7) years.

Individuals who had been more physically active in the leisure-time in earlier life were less frequently pre-frail/frail in older age. The high and moderate LTPA groups had significantly lower odds of being pre-frail/frail than individuals with low rates of LTPA. Adjusting for potential confounders did not significantly change the estimates (Table 3). The results were statistically significant separately for men and women (Appendix 2 in Supplementary data) and for those with a follow-up of less than 10 years and 10 years or over (Appendix 3 in Supplementary data). The results remained the same when frail participants were excluded (data not shown).

Table 2. Earlier life and later life characteristics of the study participants according to the presence or absence of pre-frailty/frailty in older age

Characteristics	Total (*n* = 1,137)	Robust (*n* = 818)	Pre-frail/frail (*n* = 319)[a]	*P*-value
Earlier life assessments in the FINRISK and D2D studies (surveys in various years between 1972 and 2007)				
Follow-up time (*n* = 1,137)	13.6 (SD 10.2)	13.5 (SD 10.3)	13.9 (SD 10.1)	0.533
Sex (*n* = 1,137)				
Men (*n* = 615), *n* (%)	615 (54.1%)	451 (55.1%)	164 (51.4%)	
Women (*n* = 522), *n* (%)	522 (45.9%)	367 (44.9%)	155 (48.6%)	0.258
Age in years (*n* = 1,137)	56.0 (SD 10.9)	56.0 (SD 10.8)	55.9 (SD 10.9)	0.979
Education in years (*n* = 1,127)	10.0 (SD 3.3)	10.0 (SD 3.4)	10.0 (SD 3.1)	0.905
Sum of diseases[b] (*n* = 1,102)	0.6 (SD 0.8)	0.6 (SD 0.8)	0.7 (SD 0.9)	0.001
Body mass index (*n* = 1,135)	27.5 (SD 4.4)	27.0 (SD 4.1)	28.7 (SD 4.8)	< 0.001
Smoking regularly (*n* = 1,120), *n* (%)				
Non-smoking	628 (56.1%)	466 (57.7%)	162 (51.8%)	
Quit smoking over 1/2 years ago	295 (26.3%)	205 (25.4%)	90 (28.8%)	
Quit smoking less than 1/2 years ago	19 (1.7%)	13 (1.6%)	6 (1.9%)	
Smoking	178 (15.9%)	123 (15.2%)	55 (17.6%)	0.348
LTPA (*n* = 1,131), *n* (%)				
Low	208 (18.4%)	118 (14.5%)	90 (28.5%)	
Moderate	697 (61.6%)	517 (63.4%)	180 (57.0%)	
High	226 (20.0%)	180 (22.1%)	46 (14.6%)	< 0.001
Later life assessments from the FINGER study between 2009 and 2011				
Age in years (*n* = 1,137)	69.3 (SD 4.7)	69.2 (SD 4.6)	69.5 (SD 4.8)	0.230
Body mass index (*n* = 1,137)	28.2 (SD 4.7)	27.7 (SD 4.3)	29.5 (SD 5.4)	< 0.001
Sum of chronic diseases[c] (*n* = 1,101)	1.8 (SD 1.3)	1.6 (SD 1.3)	2.2 (SD 1.4)	< 0.001

Values are means and standard deviations (SDs) if not otherwise specified. Abbreviations: standard deviation (SD); percentages (%). [a]Pre-frail *n* = 310 and frail *n* = 9 [b]Sum of chronic diseases during earlier life assessments: myocardial infarction, stroke, high blood pressure, heart failure, coronary artery disease, asthma, arthritis, or other joint disorder. [c]Sum of chronic diseases during the later life assessments: high blood pressure, heart failure, angina pectoris, cancer, asthma, pulmonary emphysema or chronic bronchitis, gallstones or gall bladder inflammation, rheumatoid arthritis, other articular disease, back illness, chronic urethritis or nephritis, cerebrovascular disease, diabetes, depression, and other psychological illnesses.

Due to a wide age range at the time of the earlier life physical activity assessment, we investigated the influence of LTPA on pre-frailty/frailty separately for participants who were under 60 years of age and those 60 or older at the time of the physical activity assessment. In both age groups, high levels of LTPA were associated with a lower risk of pre-frailty/frailty in later life (Table 3).

In the sensitivity analyses where physical inactivity was excluded from the frailty definition, the association between earlier life LTPA and pre-frailty/frailty remained statistically significant (data not shown).

Discussion

This study showed that individuals with high or moderate LTPA earlier in life are less likely to become pre-frail/frail in older age compared with sedentary individuals. Our findings are in line with the few previous longer-term studies showing that high mid-life LTPA was associated with a lower prevalence of frailty amongst Caucasian men [11], and vigorous physical activity reported approximately ten years earlier reduced frailty progression in older age [12]. The association between LTPA and frailty risk remained significant even after controlling for several other frailty-related risk factors.

This supports the hypothesis that LTPA is an independent predictor of frailty risk.

We also found that moderate or high LTPA was associated with a lower risk of frailty amongst people under 60 and those aged 60 or older at the time of the physical activity assessment. Other studies have also shown that physical activity at an older age is associated with lower levels of frailty development [13,26]. It should be acknowledged that low physical activity is one of the components of frailty phenotype and earlier and later life physical activity strongly correlate. However, based on the sensitivity analyses where physical inactivity was excluded from the frailty definition, low earlier life LTPA level was still associated with frailty syndrome.

A considerable proportion of older people who are frail are free of comorbidities and disability. However, frailty increases the risk of diseases and functional decline [3,5]. In our analyses, we adjusted for the presence of chronic diseases both in earlier life and at an older age. These adjustments did not markedly modify the results, suggesting that LTPA may have an independent preventive role regarding frailty.

Almost a third of our study participants were pre-frail, but frailty was rare. The relatively young study population and the definition of frailty including the choice of cut-off points that were not cohort-specific may explain the lower

Table 3. Odds ratios for pre-frailty/frailty according to earlier life LTPA

	Robust n (%)	Pre-frail/frail n (%)	OR (95% CI)	P-value
All study participants				
Model 1 (n = 1,131)				
LTPA: low	118 (14.5%)	90 (28.5%)	1	
LTPA: moderate	517 (63.4%)	180 (57.0%)	0.42 (0.30–0.58)	< 0.001
LTPA: high	180 (22.1%)	46 (14.6%)	0.31 (0.20–0.47)	< 0.001
Model 2 (n = 1,074)				
LTPA: low	110 (14.2%)	85 (28.4%)	1	
LTPA: moderate	493 (63.6%)	171 (57.2%)	0.45 (0.32–0.65)	< 0.001
LTPA: high	172 (22.2%)	43 (14.4%)	0.37 (0.23–0.60)	< 0.001
Model 3 (n = 1,041)				
LTPA: low	107 (14.2%)	83 (29.0%)	1	
LTPA: moderate	479 (63.4%)	162 (56.6%)	0.45 (0.31–0.64)	< 0.001
LTPA: high	169 (22.4%)	41 (14.3%)	0.38 (0.23–0.61)	< 0.001
Age group < 60 years old				
Model 1 (n = 645)				
LTPA: low	74 (16.0%)	52 (28.6%)	1	
LTPA: moderate	282 (60.9%)	103 (56.6%)	0.50 (0.32–0.78)	0.002
LTPA: high	107 (23.1%)	27 (14.8%)	0.34 (0.20–0.60)	< 0.001
Model 2 (n = 619)				
LTPA: low	70 (15.7%)	49 (28.2%)	1	
LTPA: moderate	272 (61.1%)	100 (57.5%)	0.54 (0.34–0.87)	0.011
LTPA: high	103 (23.2%)	25 (14.4%)	0.41 (0.23–0.75)	0.004
Model 3 (n = 598)				
LTPA: low	68 (15.7%)	48 (28.9%)	1	
LTPA: moderate	264 (61.1%)	94 (56.6%)	0.53 (0.33–0.86)	0.010
LTPA: high	100 (23.2%)	24 (14.5%)	0.43 (0.23–0.81)	0.009
Age group 60 years or older				
Model 1 (n = 486)				
LTPA: low	44 (12.5%)	38 (28.4%)	1	
LTPA: moderate	235 (66.8%)	77 (57.5%)	0.31 (0.18–0.53)	< 0.001
LTPA: high	73 (20.7%)	19 (14.2%)	0.25 (0.12–0.50)	< 0.001
Model 2 (n = 455)				
LTPA: low	40 (12.1%)	36 (28.8%)	1	
LTPA: moderate	221 (67.0%)	71 (56.8%)	0.36 (0.20–0.64)	0.001
LTPA: high	69 (20.9%)	18 (14.4%)	0.33 (0.15–0.70)	0.004
Model 3 (n = 443)				
LTPA: low	39 (12.1%)	35 (29.2%)	1	
LTPA: moderate	215 (66.6%)	68 (56.7%)	0.35 (0.19–0.65)	0.001
LTPA: high	69 (21.4%)	17 (14.2%)	0.31 (0.14–0.69)	0.004

Abbreviations: odds ratio (OR), confidence interval (CI) and leisure-time physical activity (LTPA). Model 1 adjusted for: age at earlier life assessment, sex, follow-up time and research centre. Model 2 adjusted for: age at earlier life assessment, sex, BMI, education, follow-up time, earlier life chronic diseases, smoking and research centre. Model 3 adjusted for: age at earlier life assessment, sex, BMI, education, follow-up time, earlier life chronic diseases, smoking, research centre and older age diseases.

prevalence of pre-frailty compared with other studies [25]. The main purpose of the FINGER study was to investigate the effect of a multidomain intervention on cognition and disability, and thus participation required a certain level of health. Compared with the participants who attended the FINGER study, the non-attendees were older, less educated and less physically active and had more vascular risk factors [21]. Earlier studies have also indicated the FINGER study population to be relatively healthy and functionally independent [27,28]. Because the prevalence of frailty was low, the presented results reflect mostly the association between LTPA and pre-frailty. This was confirmed in the sensitivity analyses, where frail participants were excluded, and the association remained the same.

This study has several strengths. The long follow-up time and broad clinical assessment of participants at the time of the outcome assessment are its main strengths. Although the exclusion criteria most likely ruled out frail individuals from the study, our study also included individuals with chronic conditions. For example, we did not exclude people previously diagnosed with stroke, Parkinson's disease or minor depression [1]. This increases the generalisability of the findings. This study also included both genders. Furthermore, the population was fairly similar to the same age Finnish population in terms of their risk factor levels [21]. The study had some limitations as well. First, the data available for this study did not enable the use of the exact Fried's phenotype [1] criteria for the definition of frailty.

We used self-reported estimates of weight loss which may include a mixture of intentional and non-intentional weight loss. Exhaustion was assessed with a question regarding weakness or tiredness within the last 30 days. The long assessment period may have resulted in recall bias, and to partly control for this, we categorised only those individuals who reported having quite a lot or very much exhaustion. The self-reported questionnaire with four categories of LTPA may have limited sensitivity. In addition, we cannot rule out that some of the participants may have had symptoms of frailty already at the time of the LTPA assessment.

Detecting early risk factors for frailty, such as physical inactivity, provides opportunities for interventions in clinical practice and public health policy [3]. Our study strengthens knowledge about the importance of physical activity in the prevention of frailty. However, it is also important to highlight the importance of multidisciplinary approaches in frailty prevention, including nutritional guidance, for example. Future studies should focus on investigating what the most effective types and intensities of physical activity are for delaying the onset of frailty or slowing down its progression. Especially important will be intervention studies to establish that an increase in physical activity can reduce the incidence of frailty during ageing.

Conclusion

Frailty was relatively rare in this Finnish population, who were at increased risk of cognitive decline and were aged 60–77 years. However, almost a third of the participants were pre-frail. Earlier life LTPA was associated with a lower risk of pre-frailty/frailty and may contribute to the prevention of frailty in older age.

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