

## Living Alone is Associated with Poorer Muscular Strength, Lower 25-hydroxy-vitamin D and Lower Bone Mineral Density in Icelandic Community Dwelling Old Adults

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### Abstract

**Background:** Living alone has been a significant public health concern among older adults given its association with a wide range of adverse health outcomes. The aim of this study was to examine whether living alone is associated with physical strength and bone health in community-dwelling older adults.

**Methods:** This was a secondary analysis of existing cross-sectional data of old adults (N = 182, 73.7 ± 5.7yrs, 58.2% female) from the Reykjavik capital area in Iceland. Information on socioeconomic, health, dietary intake and physical function was collected. 25-hydroxy-vitamin D (25OHD) and bone mineral density (BMD) were measured. Participants were grouped retrospectively into "living alone" and into "in cohabitation".

**Results:** Of our subjects, 76.4% were in cohabitation and 23.6% lived alone. Participants who lived alone were older (74.5 ± 5.6 vs. 72.1 ± 5.0, P = 0.008) and more often female (74.4 vs. 53.2%, P = 0.014), but there were no differences in education, smoking, number of medications, physical activity (PA) or body mass index (BMI). According to age and gender corrected analyses, participants in cohabitation had higher grip strength (6.2 ± 2.4lb, P = 0.011), higher 25OHD (13.1 ± 6.3nmol/L, P = 0.037) and higher BMD (z-score lumbar: 1.195 ± 0.417, P = 0.005; z-score femur: 0.421 ± 0.219, P = 0.054; z-score total: 0.846 ± 0.290, P = 0.004). Statistical correction for PA, BMI, education and fish oil intake did not change the results.

**Conclusion:** In comparison to old adults who live in cohabitation, Icelandic old adults who live alone have poorer physical strength, lower 25OHD and lower BMD, which can increase their risk for wrist- or hip fracture. These differences between groups were not explained by physical, dietary or social confounding variables.

**Keywords:** Osteoporosis; Old Adults; Socioeconomic Status

### Introduction

Osteoporosis, i.e., low bone mass and deterioration of bone tissue, is a serious health issue, particularly as populations in Western countries age rapidly. This condition can lead to an increased

risk of bone fractures [1,2], with high costs of treatment creating a financial burden for those involved and the society. Additionally, fractures can seriously decrease physical function and mobility, negatively impact quality of life, and result into an increased mor-

tality rate [3,4]. Appropriate strategies targeting the most vulnerable populations are desperately needed.

In general, social factors such as socioeconomic status, social support, relationship and religion are related to health and consequently there is also some evidence documenting that there are vulnerable groups within a society being linked to low bone mineral density (BMD) and higher fracture risk. E.g., low socioeconomic status (SES) has been reported to be associated with low BMD and higher risk of osteoporosis [5,6]. Loneliness and living alone have been significant public health concerns among older adults given their associations with a wide range of adverse health outcomes. However, the overall evidence is limited regarding the relationship between bone health and living alone vs. living in cohabitation [7-11].

A study from Korea reported that individuals living alone had significantly lower BMD and greater odds of osteoporosis than individuals living in cohabitation [7]. In earlier published case-control studies living alone was independently associated with increased fracture risk in Norway [8] and in Denmark [9]. Also, living alone was associated with increased fracture risk in a population-based study in Finish women [10]. However, an Australian study provides equivocal evidence reporting that living alone was associated with lower bone mineral content (BMC) in Australian-born men but related to higher femoral neck BMC in immigrants from Southern Europe [11].

Several of the above mentioned studies fall short to investigate the potential mechanisms for the observed differences between social groups. These mechanisms are not fully understood but may involve some known modifiable risks and preventive behavioral factors, including body mass index (BMI), physical exercise, cigarette smoking, alcohol consumption and use of anti-osteoporotic drugs [12-17].

In order to gain knowledge on the relationship between living alone, bone health and lifestyle, we conducted this cross-sectional study. The aim of the present work was 1) to compare bone health and related variables (i.e., physical function, 25-hydroxy-vitamin D (25OHD), parathyroid hormone (PTH) and BMD) between old adults living alone vs those in cohabitation; and 2) to investigate whether differences in lifestyle explain differences in bone health between the groups.

This was a secondary data analysis from baseline data of a previously published randomized, controlled trial, designed to examine the effect of post-exercise protein ingestion on the efficacy of strength training in old people [18].

## Methods

Several papers have been published from this study and in the present paper we followed the methods of Geirsdottir et al. 2012 [19], Arnarson et al. 2013 [3], Arnarson et al. 2014 [20] and Ramel et al. 2015 [21]. The similarity found between the present paper and the above mentioned articles is restricted to the Methods chapter. The present paper contains novel scientific content with focus on living alone and bone health not presented previously.

## Subjects

Participants (N = 236, range 65-92 years) were recruited within the Capital Area in Iceland. Exclusion criteria were major orthopedic disease, pharmacological interventions known to affect muscle mass and low cognitive function according to Mini-Mental State Examination (MMSE)  $\leq 19$  points) [12,22]. Subjects had also to be free from disorders that could significantly affect their body composition. Some of the participants had hypertension, hyperlipidemia or type 2 diabetes [23] although the enrolled subjects looked apparently healthy. The study received permission from the Icelandic National Bioethics Committee (VSNb2008060007/03-15) and has therefore been performed in accordance with the ethical standards as described by the Declaration of Helsinki 1964 and its later amendments. The subjects gave their written informed consent before participation in the study.

## Body composition and bone mineral density

Body weight was measured in light underwear (Seca scale model no. 708, Seca, Hamburg, Germany) and height was measured with a calibrated stadiometer (model no. 206; Seca, Hamburg, Germany). Body mass index (BMI) was calculated as  $\text{kg/m}^2$  and obesity defined as  $\text{BMI} \geq 30 \text{ kg/m}^2$ . Body composition (lean body mass = LBM) and BMD (presented as z-scores for femur, lumbar and total) was assessed using dual energy x-ray absorptiometer (DXA, Hologic QDR-2000 plus<sup>®</sup>, Hologic Inc., Waltham, MA, USA) at the Icelandic Heart Association, Kopavogur, Iceland.

## Physical function

### Six Minute Walk for Distance (6MWD)

The 6MWD (m) was conducted in a gym hall according to the guidelines from the American Thoracic Society [24].

**Grip strength**

Hand grip strength (lb.) was measured using a hydraulic hand dynamometer (Baseline® Baseline Evaluations Corporation). The maximal achieved grip strength from three attempts was recorded as the subject’s grip strength.

**Questionnaires**

Questionnaires were used to receive information on socio-demographic characteristics, i.e., education (categorized as "high" vs. "low"), alcohol, current smoking, fish oil use (all categorized as "yes" and "no") and medication count. Participants' cohabitation status was retrospectively categorized into married/cohabitation and single/divorced/widowed.

**Leisure-time physical activity (LTPA)**

LTPA during the last year was estimated using a questionnaire [25] based on the Compendium of Physical Activities [26] and the Paffenberger’s questionnaire [27]. It contains questions on the subjects’ participation in sports, exercises or other physical activities. In statistical analysis LTPA is used as min/week.

**Biochemical measurements**

Participants were instructed to avoid strenuous exercise and alcohol consumption the day before the drawing of fasting blood samples at baseline and endpoint. The blood samples were centrifuged and the serum was stored at -80°C for subsequent analysis at the University Hospital in Reykjavik, Iceland. Measurement of 25OHD (nmol/L) was conducted by a chemiluminescence immunoassay using the DiaSorin LIAISON 25OHD TOTAL assay (DiaSorin, Inc., Stillwater, Minnesota). Serum intact parathyroid hormone (PTH, pg/mL) was measured by chemiluminometric assay (Chiron Diagnostic corporation, USA).

**Statistical analysis**

Statistical analysis was conducted using SPSS for Windows version 22.0 (SPSS, Chicago, IL, USA). The Kolmogorov-Smirnov test was used to investigate the distribution of the data. In table 1, data are shown as mean ± standard deviation (SD). Comparison between groups, e.g., married/cohabitation vs. single/divorced/widowed, was done using independent samples' t-test (normally distributed variables) or Mann-Whitney-U test (not normally distributed variables). Chi-square statistics were used to investigate differences in distribution of categorical variables between participants married/cohabitation and single/divorced/widowed.

	<b>Married/ cohabitation</b>	<b>Single/ divorced/ widowed</b>	
	<b>(n = 139)</b>	<b>(n = 43)</b>	
<b>Variables</b>	<b>mean ± SD</b>	<b>mean ± SD</b>	<b>P-value</b>
Age (years)			
Male (yes in %)			
Higher education (yes in %)	72.1 ± 5.0	74.5 ± 5.6	0.008
Smoking (yes in %)	46.8	25.6	0.014
Alcohol (yes in %)	23.9	14.0	n.s.
Fish oil (yes in %)	5.8	9.5	n.s.
LTPA (h/week)	84.9	71.4	0.048
Number of medications	51.1	53.8	n.s.
BMI (kg/m <sup>2</sup> )	5.9 ± 5.4	6 ± 6.9	n.s.
Lean body mass (kg)	2.1 ± 1.6	1.7 ± 1.3	n.s.
Grip strength (lb)	28.7 ± 4.7	28.8 ± 5.1	n.s.
6MWD (m)	45.9 ± 9.9	44.4 ± 7.7	0.001
Lumbal BMD (z-score)	66.4 ± 19.7	53.5 ± 13.7	0.001
Femur BMD (z-score)	470 ± 75	437 ± 79	0.013
Total BMD (z-score)	1.26 ± 1.80	0.29 ± 1.93	0.016
PTH (pg/mL)	0.39 ± 0.95	0.33 ± 0.97	n.s.
25-OH-vitamin (nmol/L)	1.11 ± 1.18	0.70 ± 1.26	0.050
	45.8 ± 18.4	50.5 ± 23.3	n.s.
	66.9 ± 26.8	56.1 ± 25.5	0.022

**Table 1:** Baseline characteristics of the participants (N = 182).

Multivariate general linear models (GLM) were used to investigate differences in grip strength, 6MWD, BMD, 25OHD and PTH be-

tween participants being married/in cohabitation vs participants being divorced/single/widowed. Results in table 2 are shown as parameter estimates using two different statistical models for each outcome: models 1 include intercept, age, gender and cohabitation

status; models 2 additionally include BMI, fish oil intake, education and physical activity. Effect sizes *B* give the estimated differences in the outcome variables between the two cohabitation groups. The level of significance was set at  $P < 0.05$ .

Parameter	Model 1 (corrected for age and gender)				Model 2 (additionally corrected for education, physical activity, BMI and fish oil)			
	B	95% CI		P-value	B	95% CI		P-value
Dependent Variable: grip strength (lb)								
Intercept	88.855	58.738	118.972	0.001	79.820	41.284	118.357	0.001
Age (years)	-0.621	-1.032	-0.209	0.003	-0.609	-1.073	-0.144	0.011
Male <sup>1</sup>	33.531	29.493	37.569	0.001	34.290	30.034	38.545	0.001
Married/in cohabitation <sup>2</sup>	6.165	1.412	10.918	0.011	6.930	1.992	11.867	0.006
Basic education <sup>3</sup>					2.061	-2.510	6.632	0.373
LTPA (hours/week)					0.160	-0.230	0.550	0.418
BMI (kg/m <sup>2</sup> )					0.199	-0.249	0.648	0.380
Fish oil "no" <sup>4</sup>					-2.341	-6.568	1.885	0.274
Dependent Variable: 6MWD								
Intercept	937.308	752.755	1121.861	0.001	1010.123	804.060	1216.187	0.001
Age (years)	-6.892	-9.415	-4.370	0.001	-5.967	-8.452	-3.482	0.001
Male <sup>1</sup>	19.745	-5.000	44.491	0.117	22.454	-0.302	45.210	0.053
Married/in cohabitation <sup>2</sup>	26.556	-2.570	55.682	0.074	22.727	-3.677	49.131	0.091
Basic education <sup>3</sup>					-9.822	-34.266	14.623	0.427
LTPA (hours/week)					2.641	0.556	4.726	0.014
BMI (kg/m <sup>2</sup> )					-5.063	-7.461	-2.664	0.001
Fish oil "no" <sup>4</sup>					4.552	-18.047	27.150	0.690
Dependent Variable: BMD lumbar (z-scores)								
Intercept	-3.040	-8.217	2.137	0.247	-6.085	-12.651	0.482	0.069
Age (years)	0.041	-0.029	0.112	0.249	0.070	-0.010	0.149	0.084
Male <sup>1</sup>	0.192	-0.502	0.886	0.585	0.313	-0.412	1.038	0.394
Married/in cohabitation <sup>2</sup>	1.195	0.378	2.012	0.005	1.354	0.512	2.195	0.002
Basic education <sup>3</sup>					0.342	-0.437	1.121	0.385
LTPA (hours/week)					0.046	-0.020	0.113	0.169
BMI (kg/m <sup>2</sup> )					0.007	-0.069	0.083	0.857
Fish oil "no" <sup>4</sup>					0.246	-0.474	0.966	0.500
Dependent Variable: femur (z-score)								
Intercept	-1.598	-4.313	1.118	0.246	-3.555	-7.021	-0.089	0.045
Age (years)	0.025	-0.012	0.062	0.179	0.038	-0.004	0.080	0.075
Male <sup>1</sup>	-0.405	-0.769	-0.040	0.030	-0.355	-0.737	0.028	0.069

Married/in cohabitation <sup>2</sup>	0.421	-0.007	0.850	0.054	0.493	0.049	0.937	0.030
Basic education <sup>3</sup>					0.194	-0.217	0.605	0.352
LTPA (hours/week)					0.023	-0.012	0.058	0.199
BMI (kg/m <sup>2</sup> )					0.022	-0.018	0.063	0.273
Fish oil "no" <sup>4</sup>					0.085	-0.295	0.465	0.659
Dependent Variable: BMD total (z-scores)								
Intercept	1.411	-2.190	5.012	0.439	0.520	-4.011	5.051	0.820
Age (years)	-0.014	-0.064	0.035	0.563	0.005	-0.049	0.060	0.847
Male <sup>1</sup>	-0.248	-0.731	0.234	0.310	-0.191	-0.692	0.309	0.450
Married/in cohabitation <sup>2</sup>	0.846	0.278	1.415	0.004	0.912	0.331	1.492	0.002
Basic education <sup>3</sup>					-0.012	-0.550	0.525	0.964
LTPA (hours/week)					0.040	-0.006	0.086	0.089
BMI (kg/m <sup>2</sup> )					-0.029	-0.082	0.024	0.274
Fish oil "no" <sup>4</sup>					0.066	-0.431	0.563	0.794
Dependent Variable: 25OHD (nmol/L)								
Intercept	19.785	-57.853	97.423	0.615	-14.153	-98.207	69.902	0.739
Age (years)	0.495	-0.566	1.557	0.357	0.787	-0.227	1.800	0.127
Male <sup>1</sup>	-6.789	-17.19	3.621	0.199	-1.440	-10.72	7.842	0.759
Married/in cohabitation <sup>2</sup>	13.069	0.816	25.322	0.037	12.281	1.510	23.051	0.026
Basic education <sup>3</sup>					10.055	0.084	20.026	0.048
LTPA (hours/week)					1.615	0.764	2.465	0.001
BMI (kg/m <sup>2</sup> )					0.102	-0.876	1.080	0.836
Fish oil "no" <sup>4</sup>					-17.61	-26.83	-8.395	0.001
Dependent Variable: PTH (pg/mL)								
Intercept	16.644	-43.183	76.471	0.583	21.035	-51.126	93.197	0.564
Age (years)	0.522	-0.296	1.340	0.209	0.217	-0.654	1.087	0.623
Male <sup>1</sup>	2.176	-5.846	10.198	0.592	1.250	-6.719	9.218	0.756
Married/in cohabitation <sup>2</sup>	-8.476	-17.92	0.966	0.078	-8.985	-18.23	0.261	0.057
Basic education <sup>3</sup>					4.781	-3.779	13.341	0.271
LTPA (hours/week)					-0.582	-1.312	0.148	0.117
BMI (kg/m <sup>2</sup> )					0.514	-0.326	1.354	0.227
Fish oil "no" <sup>4</sup>					6.442	-1.472	14.356	0.109

**Table 2:** Parameter estimates derived from multivariate GLM describing the differences between participants being married/in cohabitation (n = 139) vs participants being divorced/single/widowed (n = 43).

<sup>1</sup>as compared to female; <sup>2</sup> as compared to single/divorced/widowed; <sup>3</sup>as compared to higher education; <sup>4</sup>as compared to fish oil "yes".

## Results

Data were available for 182 participants, i.e., 106 women and 76 men. The characteristics of participants categorized by cohabita-

tion status can be seen in table 1. Gender distribution between the cohabitation categories was uneven and women were overrepre-

sented in the single/divorced/widowed category ( $P = 0.014$ ). Variables related to socioeconomics and lifestyle did not differ between the categories (with the exception of more frequent alcohol intake and younger age reported by married/in cohabitation), however measurements of physical strength, -function, BMD and 25OHD were consistently more favorable in the married/in cohabitation category.

In order to further investigate these differences and to see whether confounding of age, gender distribution or other covariates explain findings from simple bivariate statistics in table 1, we conducted multivariate GLM. After correction for age and gender (Table 2, models 1), cohabitation status was no longer significantly related to 6MWD (but borderline), but otherwise, GLM largely confirmed the bivariate findings. Further correction for BMI, fish oil, LTPA and education (Table 2, models 2) did only marginally change effect sizes B and P values (in both directions). Although many of these covariates were by themselves significantly related to several of the outcome variables, they did not explain the differences between cohabitation categories.

## Discussion

This cross-sectional study investigated the relationship between living alone and bone health (and related variables) and compared old adults living alone with those in cohabitation. We found that measurements of physical strength, -function, BMD and 25OHD were significantly better in the married/in cohabitation category, however, these differences were not explained by different lifestyle of the two groups.

The differences in muscle strength and physical function, 25OHD and BMD between the two cohabitation categories were considerable or around 0.5 SD. Similar results have been reported previously, i.e., individuals living alone have significantly lower BMD and greater odds of osteoporosis as well as of greater fracture risk than individuals living in cohabitation [7-10], although not all studies are in agreement [11]. As participants in the living alone category were significantly older and more often women, we used GLM to find out whether these differences persist after correction for these socio-economic confounders. It showed that social characteristics did not explain the observed differences in outcome variables between categories, although it should be mentioned that the difference in 6MWD decreased from 33 m (bivariate analysis) to 27 m (no longer significant) after correction for age and gender.

Mechanisms which could potentially explain such differences between social categories are not fully understood but may involve well described modifiable lifestyle factors [12-17]. We hypothesized that relevant lifestyle variables, i.e., LTPA, fish oil intake and BMI would explain differences in bone health related outcome variables between the cohabitation categories. For these lifestyle variables there is empirical evidence available linking them to bone health [28-30]. However, when comparing the groups in the bivariate analysis, there was not difference in lifestyle between them. Consequently, correction for lifestyle in the GLM did not alter the associations between cohabitation status and bone health related outcome variables.

Our study shows that cohabitation status matters regarding bone health related variables, however, it does not deliver any potential answer why participants living alone do worse compared to their counterparts in cohabitation. In that context it is important to consider residual confounding. Residual confounding describes the problem in epidemiology when a potential confounder is not or not fully accounted for due to measurement error or simply due to non consideration in the statistical analysis. Further, some of the observed differences between cohabitation categories, e.g., BMD, are the result of a live long interplay between environmental variables and genetic characteristics and thus a potentially important covariate, measured at one time point during lifetime, fails to show significant associations.

Other reasons for our findings could include misreporting which has been shown to be more in individuals in a lower social class leading to underestimation of the disparity when using self-reported information [31].

However, marriage and cohabitation have been shown to be closely related to health [32] and married people experience lower morbidity and mortality across diverse health threats as cancer, heart attacks and surgery [33]. Conversely, living alone is associated with increased risk for cardiovascular disease and all-cause mortality [34]. There are several reasons why cohabitation may exert a beneficial health impact. Partners spend time together during a wide variety of activities, such as eating, leisure, housekeeping, child-care and sleep [29]. Spouses also often share resources and investments such as joint finances or home-ownership and partnership serves as a source for intense support [29].

### Strength and limitations

It is a strength of the present study that we measured and included many potential confounders with the purpose to explain differences between cohabitation categories. However, the present study was of cross-sectional nature and can thus not distinguish between cause and consequence for an observed association. Further, we did not have information on for how long participants have been in in cohabitation or living alone.

### Conclusion

This cross-sectional study found that physical strength, -function, BMD and 25OHD were significantly better in participants who were married or in cohabitation in comparison to participants living alone. Interestingly, these differences were not explained by different lifestyle of the two groups reported at old age. The observed differences might be a consequence of inequalities affecting outcomes during a longer time period.

### Conflict of Interest

The authors declare no conflict of interest.

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