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REVIEW PAPER

Association Between Social Support and Bone Health Outcomes: a Systematic Review

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Abstract
Previous studies on the association between social support and bone health outcomes did not produce consistent results. The main goal of this study was to resolve the inconsistency by systematically examining the studies on the association in the last two decades. In order to do that, we distinguished between two types of social supports: structural supports, which is the pattern of person's social relationship, and functional support, which is the perceived specific functions from social ties. For fracture, structural social support, especially marital (or cohabitation) status, showed a strong association between both men and women. For osteoporosis, however, only functional social support seemed to have an association, especially only among women. We want to take this conclusion as tentative since there are only 21 research papers on the topic during the period examined. We also ask for more diverse and elaborated measures of social supports developed in social studies.

Keywords Social network · Social support · Structural support · Functional support · Osteoporosis · Fracture · Bone health · Bone mineral density

Introduction

Background

Is social support associated with bone health? If so, how they are related to each other? These questions are worth to be investigated because many other physical health outcomes have been revealed to be influenced by diverse social supports from social relationships [1, 2]. The beneficial influences have been explained by several mechanisms. Social supports provide useful and tangible help, elevate self-esteem or self-efficacy, encourage healthy behaviors, prevent risky behaviors, buffer the adverse effects from stressful events, and thus, affect cardiovascular, neuroendocrine, and immune functions [3–6]. Through these mechanisms, social relationships and the following social supports are known to be related to diverse health outcomes, such as mortality [7–12], cardiovascular functions [13–25], or breast cancer [26]. Social support is also expected to affect bone health as well because healthy behaviors can be encouraged by social supports such as better nutrition [27–29], more physical activities [30–32], or more outside activities that could provide sufficient sunlight exposure [33, 34].

Although the benefits of social support have not been reviewed in a compressive way, conclusions from some studies implied that social support can be beneficial to prevent bone-related problems, especially fracture. Brennan and the colleagues reviewed the literature about the socioeconomic gradients of fracture and found that marital status and the size of the household are related to fracture [35]. Similarly, using seven cohort studies from the USA and Europe, Benetou and colleagues reached the same conclusion that living with someone or being married could be helpful to prevent fracture in the older ages [36]. Although the previous reviews focused mainly on the socioeconomic gradient of the bone health, they indicate that social support from others (mostly spouses) can be helpful for the bone health.

In order to clarify the role of social support, distinctive kinds of social supports need to be examined separately. Social support can be divided into two types: structural

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support and functional support [1]. Structural support refers to the pattern or form of a person's social supportive relationships such as the number of friends (size), the extent of diversity of friends, for example, regarding racial-ethnic groups (racial heterogeneity), and the extent of the relationship between the friends of himself or herself (density). Functional support, on the other hand, refers to the extent to which the social relationships involve the perceived specific functions such as emotional, instrumental, and financial support [2]. This distinction is meaningful because each type of social support has been known to have a different influence [13, 37].

Objective

The main purpose of this review is to extend the understanding of the association between social support and bone health. To do so, we used three strategies. First, we examined the progress of the osteoporosis across two stages: osteoporosis and fracture. We needed to distinguish the two stages since fracture occurs in physical and acute manner while decreasing bone mineral density is a chronic and metabolic consequence. This difference suggests that distinctive kind of social support might be effective at each stage. Second, we also distinguished between two types of social support as we described: structural and functional support [13]. Within this conceptual frame, the most frequently examined social support in the previous studies, marital or cohabitation status is one of the most basic measurements of structural support. Finally, we needed to be aware that the relationship between social support and bone health could be contingent on sex. This is necessary not only because osteoporosis demonstrates different biological mechanisms for men and women but also because social support could have different mechanisms depending on the sex of the person. For various biological reasons, osteoporosis is believed to be more prevalent in women rather than men [38]. Men tend to have substantially larger and thicker bones as well as stronger bending and comprehensive strength than women [39]. Also, it is reported that men's peak bone density is higher and takes place later than women's one, which suggests that women have higher chances of osteoporosis development [40]. Additionally, some studies showed that women undergo faster decrements of bone mass with age [41]. Especially, postmenopausal women are recognized to be at a high risk of osteoporosis development and, consequently, fracture occurrence [42]. Reduction in bone mineral density in women can be caused by the decrease of estrogen in postmenopausal period, which leads to faster osteoporosis development in women than in men [43].

Also, the patterns and meanings of social supports are quite different across genders [44–46]. Older women tend to have larger and more diverse ties that span across friends, adult children, and husbands while older men's supportive networks often consist only of the wife who plays the role of main caregiver [44, 47, 48]. Because of this, older men with poorer social networks and supports are more likely to be isolated and physically vulnerable, and thus, wives' supports are essential as a buffer for various kinds of health problems including anxiety or angina [48, 49].

Methods

Study Selection

We reviewed papers published from January 1 in 1998 to December 31 in 2017. We searched papers through three major databases: PubMed, PsycINFO, and Web of Science. We selected papers so that at least one term related to social support *and* at least one term related to osteoporosis should be included in the searching request. Terms about social support were as following: 'social support', social network', 'social isolation', 'social participation', 'social engagement', 'social activity', 'marriage', 'marital support', 'family support', 'living alone', 'residency type', and 'household size'. Terms about bone health were 'osteoporo', 'bone', 'fracture', and 'BMD'. We used 'osteoporo' as a searching keyword instead of 'osteoporosis' so that we could search studies that included not only 'osteoporosis' but also 'osteoporotic' and other relevant terms.

We excluded all non-empirical or non-human researches. Inclusion criteria are presented in Table 1.

Studies that included the following as the dependent variables were selected: bone mineral density (BMD), bone mineral content (BMC), and fracture occurrence. In the case of bone mineral density, the dependent variable could be either continuous variable or binary variable which was diagnosed at the level of t-score < -2.5 based on the WHO's criteria [50].

Figure 1 demonstrates the selection. The total number of searched studies was 6923 (2963 from PubMed, 336 from PsycINFO, 3624 from Web of science) and 1972 studies were removed because of the duplication. We also excluded 4706 articles by manually examining the title and abstract based on the exclusion criteria. Through this process, we identified 245 potentially appropriate papers which were examined closely by reading the full texts. In the end, we came up with the list of 21 articles. All the studies were about adults. Detailed information on each study design, sample, and results are summarized in the Appendix Table 3.

Some researchers analyzed data separately for different subsamples in one paper. For example, Hokby (2003), Espino (2000), and Reimers (2007) divided their sample into male and female while Vestergaard (2006) study was divided into different samples by age. Thus, although we analyzed 21 studies, we could examine 44 subsamples in total.

Table 1 Study inclusion criteria

Criteria	Included values
Object	Human only
Design	Observational cross-sectional study
	Observational longitudinal study
	Case-control cross-sectional study
	Case-control longitudinal study
Sample size	All size
Dependent variable : bone health measures	1) Osteoporosis
	- Bone density mineral (continuous)
	- Bone density mineral (binary: t-score < − 2.5)
	- Bone mineral content
	2) Fracture
Independent variable : social support measures	1) Structural support
	- Marital status
	- Household size
	- Belonging to social groups
	2) Functional support
	- Intimacy with network members
	- Spousal support
	- Objective support
	- Subjective support
	- Availability of social support
	- Participation in social activities
	- Participation in volunteer activities

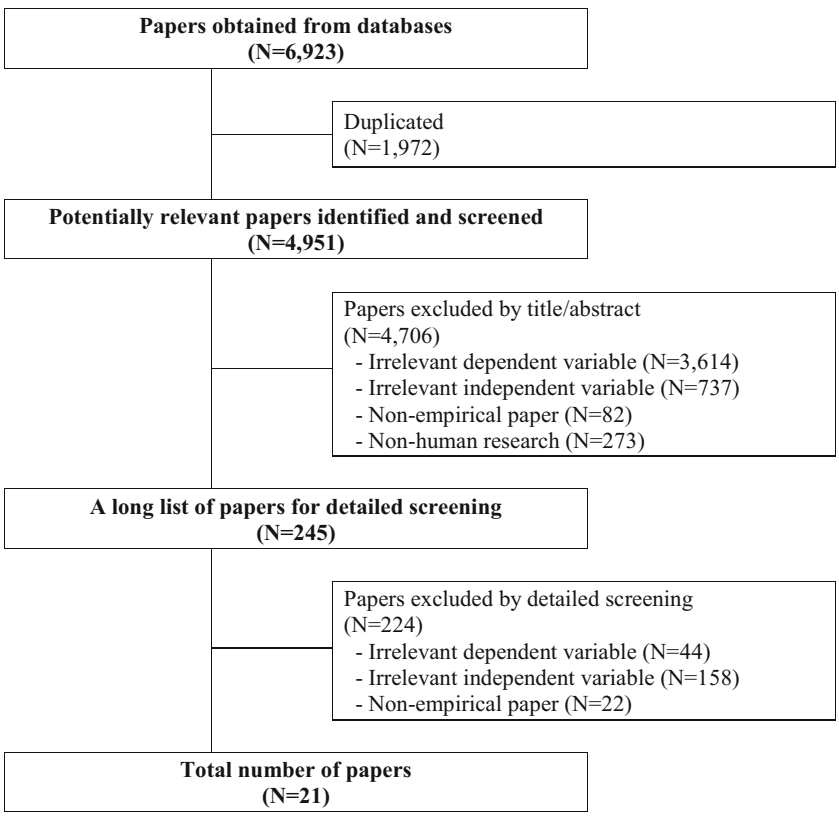


Fig. 1 Flowchart of the systematic review

Meta-Analysis

To examine the consistent tendency of the association between fracture and structural social support, especially being married or living with someone, we conducted a meta-analysis [51]. In order to compare the results from different studies, we used the reported results in each paper and calculated the odds ratio of having fracture among those who were married (or living with someone) compared to those who were not married (or living alone). We used a random-effect model because there would be heterogeneity of the population characteristics of each study. Using Stata 15 and the module *Metan*, we computed the combined odds ratio of being fractured [52]. The results were displayed in a forest plot. In addition, to test the gender difference with regard to the association, a meta-regression was conducted. Some research reported results for men and women separately; thus, we used these results separately if possible. The gender composition of each sample was coded as 'female only', 'male only', or 'both female and male without differentiation' to examine the difference based on the characteristic of the study populations. Module Metareg in STATA 15 was used for the computation. We could not do the meta-analysis on osteoporosis or other types of social supports because there was not enough number of studies to examine.

Results

Frequency Trends

Figure 2 shows the number of research papers about the relationship between bone health and social support in the last 20 years. The most striking was that there have been only a few studies during two decades: only 21 studies. This is quite disappointing considering that since the 1970s, social epidemiology has brought a lot of strong evidence on the relationship between social support and diverse health outcomes [2, 5, 9, 37, 53] such as mortality [7, 8, 10–12], cardiovascular function [13–25], or immune function [26, 54–60]. Another distinguishing finding was that there have been much more studies about fracture than osteoporosis: 15 vs. 9. Also, the trend for fracture studies was quite different from the one for osteoporosis. Except for the period from 2006 to 2009, the studies about the relationship between fracture and social support have been very scarce. With contrast to this, the number of studies on the association of social support with osteoporosis has been constantly increasing during the period. Next, we reviewed the association between fracture and structural social support, which refers to the pattern of supportive social ties around a person.

Fracture and Structural Social Support

Among various types of structural social supports, marital (or cohabitation) status was the single most frequently examined one in previous studies. Thus, we conducted a meta-analysis to test the effect of being married or living with someone, first. In addition to the meta-analysis, we also tested whether the relationship between fracture and marital (or cohabitation) status is contingent on the sex of the person. Structural support measures other than being married or living with someone were reviewed separately because there was no enough number of studies for a meta-analysis.

Figure 3 summarizes the association between marital (or cohabitation) status and the risk of fracture. The upper part of the forest plot illustrates the decreased fracture risk of the married (combined odds ratio = 0.55, 95% C.I. 0.39~0.79) and the lower plots present the decreased risk of those who are living with someone (combined odds ratio = 0.86, 95% C.I. 0.82~0.91). Both 'being married' and 'living with someone' were statistically significantly associated with lower risk of fracture and the overall association was also significant (combined odds ratio = 0.68, 95% C.I. 0.61~0.76). Most studies reported statistically significant positive association while only two studies reported negative associations and none of them was statistically significant.

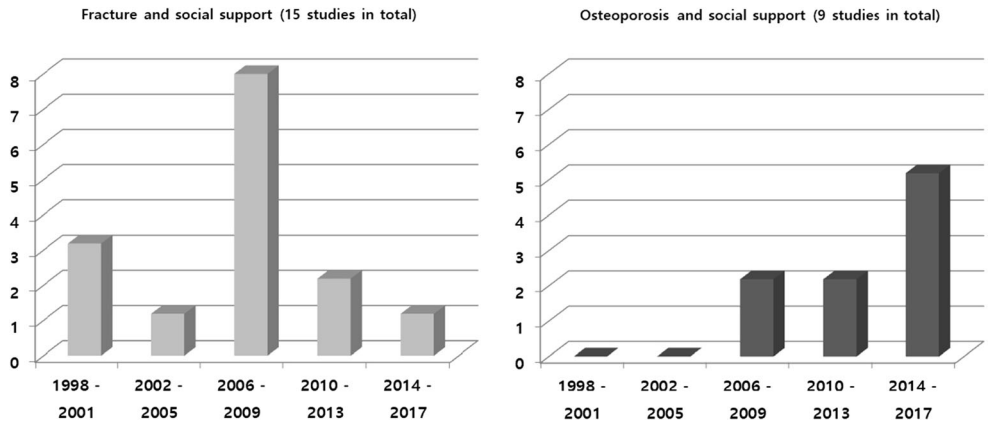
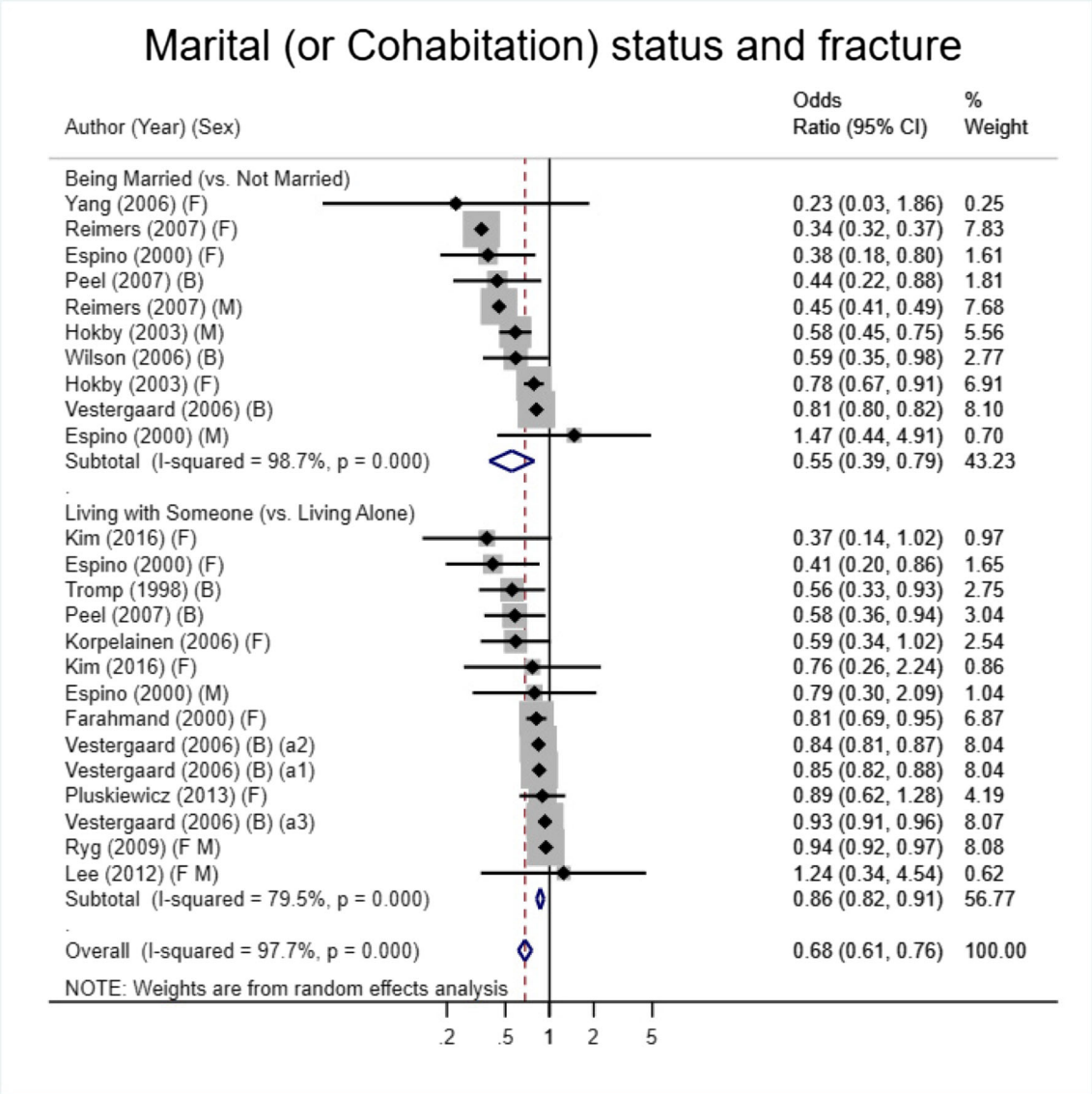


Fig. 2 Number of studies about the association between bone health and social support



F: Female-only sample
M: Male-only sample
B: Sample including both female and male subjects without differentiating them
Vestergaard (2006) reported statistics from each of different age sample
- a1: age < 40
- a2: age 40 - 60
- a3: age > 60

Fig. 3 Marital (or cohabitation) status and fracture

We also tested whether the sex of the person makes difference. A meta-regression result revealed that there is no sex difference. The magnitude of the association between marital (cohabitation) status and fracture was slightly smaller for male-only samples compared to the female-only samples; yet, the difference was not statistically significant. Other than being married or living with someone, belonging to social groups was studied as a possible structural support to prevent fracture in one study [61]. In a bivariate analysis model, belonging to social groups was related to lower risk but the statistical significance disappeared in an adjusted model after controlling for other risk factors.

Since only two studies examined the structural support other than marital (or cohabitation) status for fracture, a meta-analysis was not conducted. One study showed that engaging in social activities could be associated with lower risk of fracture [62]. Another one also reported similar results in that

engaging in volunteer activities (e.g., community service, civic, and committee roles) is related with lower risk of fracture in both unadjusted and adjusted models [61].

In short, we could summarize the association of fracture with social supports as following. Fracture risk was consistently lower in the married people or those who were living with someone. Second, we could not confirm the statistically significant gender difference. Third, other social support measures other than being married or living with someone have been explored only in a few studies.

Osteoporosis and Structural Social Support

Table 2 presents the summaries of the studies about social support and osteoporosis by sex and the types of social supports.

The association of structural social support with osteoporosis was much weaker than with fracture. In general, statistically non-significant results fairly outnumbered significant ones. Among the male population, only five results, four for being married and one for living with

Table 2 Osteoporosis and social support across different sex

Type of social support	Social support measures	Sex	
		Male	Female
Structural Support	Being married	Miller-Martinez (2014): (L/ Pr/ Adj/ Sig+) Nabipour (2011)a: (L/ Cs/ Adj/ Sig+) Nabipour (2011)a: (W/ Cs/ Adj/ Sig+) Nabipour (2011)c: (W/ Cs/ Adj/ Sig+) Nabipour (2011)b: (L/ Cs/ Adj/ NS) Nabipour (2011)c: (L/ Cs/ Adj/ NS) Nabipour (2011)d: (L/ Cs/ Adj/ NS) Nabipour (2011)a: (H/ Cs/ Adj/ NS) Nabipour (2011)b: (H/ Cs/ Adj/ NS) Nabipour (2011)c: (H/ Cs/ Adj/ NS) Nabipour (2011)d: (H/ Cs/ Adj/ NS) Nabipour (2011)a: (F/ Cs/ Adj/ NS) Nabipour (2011)b: (F/ Cs/ Adj/ NS) Nabipour (2011)c: (F/ Cs/ Adj/ NS) Nabipour (2011)d: (F/ Cs/ Adj/ NS) Nabipour (2011)b: (W/ Cs/ Adj/ NS) Nabipour (2011)d: (W/ Cs/ Adj/ NS)	Lee (2017): (L F/ Cs/ Unadj/ Sig+) Pluskiewicz(2014): (F H/ Cs/ Unadj/ Sig+) Miller-Martinez (2014): (L/ Pr/ Adj/ NS) Lee (2017): (L F/ Cs/ Adj/ NS) Wang (2008): (F/ Cs/ Adj/ NS) Yang (2006): (C/ Cs/ Adj/ NS) Wang (2008): (F/ Cs/ Unadj/ NS) Erez (2012): (L H/ Cs/ Unadj/ NS)
	Living with someone	Nabipour (2011)a: (L/ Cs/ Adj/ Sig+) Nabipour (2011)b: (L/ Cs/ Adj/ NS) Nabipour (2011)c: (L/ Cs/ Adj/ NS) Nabipour (2011)d: (L/ Cs/ Adj/ NS) Nabipour (2011)a: (H/ Cs/ Adj/ NS) Nabipour (2011)b: (H/ Cs/ Adj/ NS) Nabipour (2011)c: (H/ Cs/ Adj/ NS) Nabipour (2011)d: (H/ Cs/ Adj/ NS) Nabipour (2011)a: (F/ Cs/ Adj/ NS) Nabipour (2011)b: (F/ Cs/ Adj/ NS) Nabipour (2011)c: (F/ Cs/ Adj/ NS) Nabipour (2011)a: (W/ Cs/ Adj/ NS) Nabipour (2011)b: (W/ Cs/ Adj/ NS) Nabipour (2011)c: (W/ Cs/ Adj/ NS) Nabipour (2011)d: (W/ Cs/ Adj/ NS) Nabipour (2011)d: (F/ Cs/ Adj/ Sig−)	Kim (2016): (L F/ Cs/ Unadj/ Sig+) Kim (2016): (L F/ Cs/ Adj/ NS)
Functional Support	Spousal Support	Miller-Martinez (2014): (L/ Pr/ Adj/ NS)	Miller-Martinez (2014): (L/ Pr/ Adj/ Sig+)
	Intimacy with network members	No studies	Lee (2017): (L F/ Cs/ Adj/ Sig+) Lee (2017): (L F/ Cs/ Unadj/ Sig+)

*L, H, F, W, and C indicate different regions: L for lumbar, H for hip, F for femur, W for whole body, and C for Calcaneus

**Pr and Cs indicate research designs: Pr for prospective and Cs for cross-sectional

***Adj and Unadj indicate whether the regression model included control variables: Adj for the adjusted model and Unadj for the unadjusted model

****Sig+, NS, and Sig− indicate statistical significance and the direction of coefficient: Sig+ for positive and $p < 0.05$, NS for $p \geq 0.05$, and Sig− for negative and $p < 0.05$

*****a, b, c, and d indicate different origins of the sample: a for Australian-born, b for North-west Europe, c for Eastern or South Eastern Europe, and d for Southern Europe

someone, out of 33 showed statistically significant positive associations. The strongest evidence came from one prospective study. It demonstrated that men who had constantly been married during the 9 to 10 years of follow-up period had higher bone mineral density [63]. We do not want to overemphasize the null association of structural support with osteoporosis among men based on two reasons. First, although there have been 33 results, all the results except one came from a single research project [64]. Thus, we do not believe that there has been enough number of studies for any robust conclusion. Second, the only prospective study revealed a statistically significant positive association.

Among the female population, not a single study showed statistically significant association after controlling for other risk factors. In unadjusted models, being married or living with someone was related to higher bone mineral density but, when other factors were controlled for, the associations became non-significant [65, 66].

Osteoporosis and Functional Social Support

Although we do not have enough number of studies for a robust conclusion, functional social support seemed to have a positive association with osteoporosis among the female population while there was no single evidence among men. For women, the loss of bone mineral density seemed to be related with the lack of spousal support in one prospective study [63] and lower intimacy level of the social ties in another study [65]. There was a study that was not included in Table 2 since it did not distinguish between male and female subjects [67]. It reported that osteoporotic older adult group had a lower level of objective support, which is an actual or visible social support, and subjective support such as a feeling of being understood and respected.

Conclusion

First, in the last 20 years, there was only a limited number of studies about the association between social support and bone-related health outcomes: 21 studies in total. Second, structural support, especially marital (or cohabitation) status, was associated with a lower risk of fracture. The beneficial association of structural support was observed both in male and female subjects. Third, structural support did not show a consistent association with osteoporosis as with fracture. Fourth, unlike structural support, functional support seemed to prevent osteoporosis, especially among female adults.

Discussion

Different types of social supports may be effective for different stages of bone health: fracture vs. decrease in bone density. The fracture could be prevented by merely having someone to live with since the risk of fracture is easily visible. For example, in-depth interviews with osteoporotic older women showed that their husbands performed more housework tasks when they could not do the works anymore [38]. In contrast to this, losing bone density mineral is not visible and thus, even people who live together could underestimate the risk. Also, it is more likely to be the emotional or informational support that helps to prevent the loss of bone mineral density rather than the mere presence of social ties. We believe that this could be a partial explanation for the fact that structural social support showed a positive association with lower risk of fracture while functional social support seemed to have a relationship with higher bone density.

Also, only women seemed to benefit from functional social supports for osteoporosis. Quality rather than quantity of social relations has been known to have a bigger association with various health outcomes for women compared to men such as blood pressure [68, 69] or endocrine functions [70]. In addition, women usually take the role of caregiver within the household. Therefore, the mere existence of their wives could guarantee sufficient functional support for the men while the mere existence of husbands might not guarantee the same benefits for women.

Limitations

Our conclusions are limited for three reasons. First, as Figs. 1 and 2 show, we simply have a too small number of studies. Although we examined research articles for two decades, we ended up with only 21 papers, which is quite surprising considering many other health studies have accumulated a good amount of evidence that confirmed systematic relationships between social supports and health outcomes [6, 70, 71]. We definitely need more studies to examine the relationship between bone health and social supports in the future.

Not only the number of studies but also the number of measurements for social supports was very small. Only marital (or cohabitation) status was frequently examined among structural supports. Many other potentially important basic structural supports such as size, density, or composition were rarely examined. In the same manner, various functional supports such as emotional, informational, instrumental, and financial support were hardly studied. We believe that future studies with more elaborated and diverse measurements of social supports could find more significant relationships. For example, one study showed that both structural support, which was measured by the number of friends, and functional

support, which is measured by intimacy with friends, had a strong association with the risk of osteoporosis [65]. Lastly, we need more research that can probe the causal directions between bone health and social support by collecting data set that allows modern statistical tools such as survival analysis or counter-factual analysis. This is crucial because it is evident that the causality works in both ways between bone health and social supports. People surrounded with good social supports are more likely to enjoy better bone health and at the same time, people who suffer from bone problems would have a limited range of social relationship [35, 36, 72–84].

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Compliance with Ethical Standards

Conflict of Interest Yoosik Youm, Seungwon Lee, and Ekaterina Baldina declare that they have no conflict of interest.

Ethical Approval Not applicable.

Informed Consent Not applicable.

Appendix

Table 3 Social support and bone health in studies 1998–2018

Study (year)	Study design (1) Longitudinal/ cross-sectional (2) Case-control/ observational	Sample			Social variable (independent) □ Functional support ○ Structural support	Results and outcomes (CI 95%)
		Sex	*N*	Age		
Tromp et al. (1998) [81]	(1) Longitudinal (38 months) (2) Observational	F&M	1288	> 60	○Not living alone	○O.R. = 0.56 (0.32~0.91) (Sig/Adj/Fr)
			1469			O.R. = 0.40 (0.25~0.91) (Sig/Unadj/Fr)
Espino et al. (2000) [73]	(1) Longitudinal (2 years) (2) Observational1)	F	1662	> 65	①Being married ②Not living alone	①O.R. = 0.38 (0.18~0.80) (Sig/Adj/Fr) ②O.R. = 0.41(0.20~0.86) (Sig/Adj/Fr)
		M	1233			①O.R. = 1.47 (0.44~4.9) (NS/Adj/Fr) ②O.R. = 0.79 (0.30~2.09) (NS/Adj/Fr)
Farahmand et al. (2000) [74]	(1) Longitudinal (2 years) (2) Case-control	F	1327 (case) 3262 (control)	51–80	○Not living alone	○O.R. = 0.81 (0.69~0.95) (Sig/Adj/Fr)
Hökby et al. (2003) [75]	(1) Cross-sectional 2) Observational	M	2308	> 65	○Being married①	○O.R. = 0.58 (0.45~0.75) (Sig/Adj/Fr)
		F	7112	> 65		○O.R. = 0.78 (0.67~0.91) (Sig/Adj/Fr)
Korpelainen et al. (2006) [77]	(1) Cross-sectional (2) Observational	F	407	70–73	○Not living alone	○O.R. = 0.59 (0.33~1.00) (Sig/Adj/Fr)
Vestergaard et al. (2006) [82]	(1) Cross-sectional (2) Case-control (matched by sex and age)	F&M	124,655 (Case) 373,962 (Control)	< 40	①Not living alone①①	①O.R. = 0.85 (0.82~0.88) (Sig/Adj/Fr)
				40–60		O.R. = 0.84(0.81~0.87) (Sig/Adj/Fr)
				> 60		O.R. = 0.93(0.90~0.95) (Sig/Adj/Fr)
				43.4 ± 27.4	②Being married	②O.R. = 0.81 (0.82~0.88) (Sig/Adj/Fr)
Wilson et al. (2006) [83]	(1) Longitudinal (2 years) (2) Observational	F&M	5630	≥70	①Being married (vs widowed) ②Being married (vs never married)	①O.R. = 0.59 (0.35~0.98) (Sig/Adj/Fr) ②O.R. = 0.71(0.22~2.13) (NS/Adj/Fr)
Yang et al. (2006) [84]	(1) Cross-sectional (2) Observational	F	278	Mean = 50	○Being married	○O.R. = 0.53 (0.26~1.1) (NS/Adj/C)

Table 3 (continued)

Study (year)	Study design (1) Longitudinal/ cross-sectional (2) Case-control/ observational	Sample			Social variable (independent) □ Functional support ○ Structural support	Results and outcomes (CI 95%)
		Sex	*N*	Age		
						O.R. = 0.23 (0.03~1.86) (Sig/Adj /Fr)
Reimers (2007) [79]	(1) Cross-sectional (2) Observational	F	235,605 (total)	> 65	○Being married	○O.R. = 0.34 (0.32~0.37) (Sig/Adj/Fr)
		M				○O.R. = 0.45 (0.41~0.49) (Sig/Adj/Fr)
Peel et al. (2007) [62]	(1) Cross-sectional (2) Case-control (matched by sex and age)	F&M	126 (Case) 261 (Control)	> 65	①Being married ②Not living alone ③Social activities more than 4	①O.R. = 0.44 (0.22~0.88) (Sig/Adj/Fr) ②O.R. = 0.58 (0.36~0.94) (Sig/Unadj/Fr) ③O.R. = 0.30 (0.17~0.54) (Sig/Adj/Fr)
Warburton (2008) [61]	(1) Cross-sectional (2) Observational	F&M	387	> 65	①Belonging to social groups ②Volunteer activity □ Level of social support	①O.R. = 0.50 (0.31~0.81) (Sig/Unadj/Fr) ②O.R. = 0.61 (0.38~0.99) (Sig/Adj/Fr) □O.R. = 0.52(0.33~0.81) (Sig/Unadj/Fr)
Wang et al. (2008) [41]	(1) Cross-sectional (2) Observational	F	344	≥65	○Being married (vs divorced or widowed)	○O.R. = 1.32 (0.70~2.49) (NS/Unadj/F) O.R. = 1.22 (0.66~2.25) (NS/Adj/F)
Ryg et al. (2009) [80]	(1) Longitudinal (3 years) (2) Observational	F&M	169,145	77.0	○Not living alone	○H.R. = 0.94 (0.92~0.96) (Sig/Adj/Fr)
Nabipour et al. (2011) [64]	(1) Cross-sectional (2) Observational	M	849 (a)	> 70	①Being married	①Beta = 0.76 (Sig /Adj/L) Beta = 0.052(Sig /Adj/ W) Beta = 0.045(NS/Adj/ H) Beta = 0.033(NS/Adj/F)
			118 (b)	> 70		Beta = 0.066(NS/Adj/H) Beta = 0.036(NS/Adj/ F) Beta = 0.059(NS/Adj/L) Beta = − 0.43(NS/Adj/W)
			175(c)	> 70		Beta = 0.141(Sig/Adj/W) Beta = 0.041(NS/Adj/H) Beta = 0.014(NS/Adj/F) Beta = 0.049(NS/Adj/L)
			358(d)	> 70		Beta = − 0.68(NS/Adj/H) Beta = − 0.090(NS/Adj/F) Beta = − 0.037(NS/Adj/L) Beta = − 0.012(NS/Adj/W)
			849 (a)	> 70	②Living alone	②Beta = − 0.051(Sig/Adj/L) Beta = − 0.034(NS/Adj/H) Beta = − 0.005(NS/Adj/F) Beta = − 0.046(NS/Adj/W)
			118 (b)	> 70		Beta = − 0.051(NS/Adj/H) Beta = 0.001(NS/Adj/F) Beta = − 0.061(NS/Adj/L) Beta = 0.055(NS/Adj/W)
			175(c)	> 70		Beta = − 0.046(NS/Adj/H) Beta = 0.007(NS/Adj/F) Beta = 0.040(NS/Adj/L) Beta = − 0.086(NS/Adj/W)
			358(d)	> 70		Beta = 0.111(Sig/Adj/F) Beta = 0.080(NS/Adj/H)

Table 3 (continued)

Study (year)	Study design (1) Longitudinal/ cross-sectional (2) Case-control/ observational	Sample			Social variable (independent) □ Functional support ○ Structural support	Results and outcomes (CI 95%)
		Sex	*N*	Age		
						Beta = 0.077(NS/Adj/L) Beta = 0.037(NS/Adj/W)
Lee et al. (2012) [78]	(1) Longitudinal (8.1 years) (2) Case-control (matched by sex, age. BMI, BMD, diagnosis, treatment and follow up period)	F&M	517	56–95	○Not living alone	○O.R. = 1.24 (0.34~4.54) (NS/Adj/Fr)
Pluskiewicz et al. (2014) [66]	(1) Cross-sectional (2) Observational	F	623	66.4 ± 7.8	○Being married (vs not married)	○O.R. = 0.30 (0.17~0.52) (Sig/Unadj/F H) O.R. = 0.89 (0.62~1.28) (NS/Unadj/Fr)
Miller-Martinez et al. (2014) [63]	(1) Longitudinal (9–10 years) (2) Observational1)	M	202	25–75	○Being married □Greater support from spouse	○Effect size in S.D. = 0.29 (0.04~0.53) (Sig/Adj/L) □Effect size in S.D. = 0.12 (− 0.20~0.44 (NS/Adj/L)
		F	186			○Effect size in S.D. = 0.12 (− 0.09~0.32) (NS/Adj/L) □Effect size in S.D. = 0.35 (0.1~0.59) (Sig/Adj/L)
Ma et al. (2015) [67]	(1) Cross-sectional (2) Case-control	F&M	112 (case) 102 (control)	68.79 ± 8.93	1 Objective support 2 Subjective support 3 Availability of support	1 Mean diff. = − 1.83 (− 1.19~− 2.47) (Sig/Unadj/L F W) 2 Mean diff. = − 3.39 (− 2.40~− 4.38) (Sig/Unadj/L F W) 3 Mean diff. = − 0. 88 (− 1.28~− 0.48) (Sig/Unadj/L F W)
Erez et al. (2012) [72]	(1) Cross-sectional (2) Observational	F	62	64.12 ± 8.44	○Being married (vs not married, widowed or divorced)	○O.R. = 0.35 (0.12~1.06) (NS/Unadj/L H)
Kim et al. (2016) [76]	(1) Cross-sectional (2) Observational	F	3058	> 45	○Not living alone	○O.R. = 0.61 (0.45~0.84) (Sig/Unadj/L F) O.R. = 1.14 (0.79~1.64) (NS/Adj/L F) O.R. = 0.76 (0.26~2.24) (NS/Adj/Fr) O.R. = 0.37 (0.14~1.02) (NS/Unadj/Fr)
Lee et al. (2017) [65]	(1) Cross-sectional (2) Observational	F	1846	71.29 ± 4.47	○Being married (vs not married) □Intimacy with network members	○O.R. = 0.72 (0.60~0.87) (Sig /Unadj/L F) O.R. = 1.06 (0.85~1.33) (NS/Adj/ L F) □O.R. = 0.87 (0.78–0.96) (Sig/Adj/L F) O.R. = 0.87 (0.77~0.99) (Sig/Unadj/L F)

*L, H, F, W, and C indicate different regions: L for lumbar, H for hip, F for femur, W for whole body, and C for Calcaneus

**Fr indicates fracture

***Adj and Unadj indicate whether the regression model included control variables: Adj for adjusted model and Unadj for unadjusted model

****Sig and NS indicate statistical significance of coefficient: Sig for $p < 0.05$, NS for $p \geq 0.05$

*****a, b, c, and d indicate different origins of the sample: a for Australian-born, b for North-west Europe, c for Estern or South Eastern Europe, and d for Southern Europe

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