Supplement 1 - Literature review of the association between sandwich caring and health or well-being∙

We searched the PubMed database for any studies published before February 6, 2024, to find studies investigating the association between sandwich care and health. Search terms were: ((Sandwich\*[Title/Abstract]) OR (intergeneration\*[Title/Abstract])) AND ((caring) OR (care\*)) AND (health[Mesh])). We also hand-searched lists of references from relevant papers. We identified 11 cross-sectional studies and five longitudinal studies. Studies included populations in East Asia, Europe, Israel and the USA. There has been a major gap in understanding the health effects of sandwich care from longitudinal studies, and we did not identify any studies focusing on health trajectories around transitions into sandwich care.

|  |  |  |  |
| --- | --- | --- | --- |
| **Author and year** | **Region, data and age** | **Study design** | **Results** |
| Albertini et al. Journals of Gerontology: Series B, 20231 | Europe. Survey of Health, Ageing and Retirement in Europe. Aged 50+. Mean age 63. | Longitudinal | Becoming a sandwich carer at age 50+ had a detrimental effect on women’s but not men’s psychological health and well-being. Becoming a sandwich carer was less detrimental to the psychological health and well-being of women living in social-democratic regimes. |
| Hsu et al. Aging & Mental Health, 20222 | Taiwan. Taiwan Longitudinal Study on Aging. Aged 50+ | Longitudinal | Sandwich caregiving was associated with improved mental health. |
| Liu and Chen. Research on Aging, 20223 | China. China Health and Retirement Longitudinal Study. Aged 45+. | Longitudinal | ‘Sandwich’ grandparents who cared for both grandchildren and parents had improved life satisfaction. |
| Turgeman-Lupo et al. European Journal of Work and Organizational Psychology, 20204 | Israel. Israeli employees. Mean age 49. | Longitudinal | Sandwich carers were more likely to experience an increase in depressive symptoms, compared with all other care statuses. |
| Xu. Social Science & Medicine, 20195 | China. China Health and Retirement Longitudinal Study. Aged 45+ | Longitudinal | ‘Sandwich’ grandparents who cared for both grandchildren and parents  reported greater life satisfaction, fewer depressive symptoms, and reduced hypertension compared with non-carers. |
| Kim et al. The Journals of Gerontology: Series B, 20236 | USA. Behavioral Risk Factor Surveillance System. Aged 18+ | Cross-sectional | Sandwich care women reported adverse mental health effects but better physical health, while sandwich care men reported adverse physical health effects. |
| Owsiany et al. International Journal of Aging and Human Development, 20237 | USA. CloudResearch Prime Panels. Aged 19-75 | Cross-sectional | Sandwich care was associated with higher levels of personal burnout. |
| Lei et al. Journal of the American Geriatrics Society, 20228 | USA. National Study of Caregiving (NSOC) and National Health and Aging Trends Study (NHATS). Mean age 46 | Cross-sectional | Sandwich carers were more likely to be Medicaid enrollees and report emotional difficulties. |
| Brenna. Health Policy, 20219 | Italy. European Health Interview Survey. Aged 35–59 | Cross-sectional | Women sandwich carers had a higher probability of being depressed. No association was found among men. |
| Tan. Journal of Aging and Health. 201810 | China, Japan, Korea, and Taiwan. East Asian Social Survey (EASS). | Cross-sectional | Sandwich care was associated with lower life satisfaction among women only but not among men. |
| DePasquale et al. 201711 | USA. Work Family and Health Study. Employees. Women mean age 47, men mean age 45. | Cross-sectional | Sandwich carers exhibited higher family-to work conflict than non-carers. |
| DePasquale et al. Journals of Gerontology: Series B, 201612 | USA. Work Family and Health Study. Employed women. Mean age 39. | Cross-sectional | Sandwich carers had higher levels of perceived stress, psychological distress, and  work-family conflict than other  carers. |
| McGarrigle et al. International Journal of Public Health, 201313 | Ireland. Irish Longitudinal Study on Ageing. Women aged 50-69. | Cross-sectional | Among sandwich-generation women, there was no association between providing childcare to grandchildren and self-reported health. |
| Daatland et al. European Journal of Ageing, 201014 | Norway. Norwegian Life-course, Ageing and Generations Study. Norwegian Generations and Gender Study. Aged 18-84 | Cross-sectional | Sandwich carers had poorer subjective well-being than non-carers. |
| Rubin and White-Means, J Fam Econ Iss, 200915 | USA. 1,999 Wave of the National Long Term Care Survey. Aged 65+ | Cross-sectional | Sandwich carers were more likely to report  having higher subjective stress/  objective burden when compared  to non-sandwiched carers. |
| Buffardi et al. Journal of Occupational Health Psychology, 199916 | USA. The Survey of Federal Employees. Employees. Age range/ mean age not reported | Cross-sectional | Sandwich carers reported less leave satisfaction and work-family balance than filial carers or parents of children. |

Supplement 2 - Process of sample selection in outcome dataset

|  |  |  |
| --- | --- | --- |
|  | **GHQ outcome** | **SF-12 outcome** |
| **Sandwich carers** | **N** | **N** |
| Sandwich carers at any wave across 10 waves | 4552  (fathers=1511; mothers=3041) | 4552  (fathers=1511; mothers=3041) |
| After excluding only one wave of parenthood | 4141  (fathers=1375; mothers=2766) | 4141  (fathers=1375; mothers=2766) |
| After excluding those without observations of parenthood at least once before and once after sandwich care onset age | 2632  (fathers=905; mothers=1727) | 2632  (fathers=905; mothers=1727) |
| After excluding missing outcome a | 2184  (fathers=724; mothers=1460) | 2309  (fathers=757; mothers=1552) |
| After excluding missing covariates a | **2082**  (fathers=683; mothers=1399) | **2223**  (fathers=722; mothers=1501) |
| **Matched non-sandwiched parents** | **N** | **N** |
| Parent non-carers at any wave across 10 waves | 17964  (fathers=8390; mothers=9574) | 17964  (fathers=8390; mothers=9574) |
| After excluding only one wave of parenthood | 13627  (fathers=6363; mothers=7264) | 13627  (fathers=6363; mothers=7264) |
| After excluding those without older relative | 13413  (fathers=6254; mothers=7159) | 13413  (fathers=6254; mothers=7159) |
| After 1:1 matching, successfully matched with sandwich carer | 2076  (fathers=680; mothers=1396) | 2219  (fathers=720; mothers=1499) |
| After those without observations of parenthood at least once before and once after sandwich care onset age | **1952**  (fathers=640; mothers=1312) | **2078**  (fathers=675; mothers=722) |
| **Total** | **N** | **N** |
| Sandwich carers and matched parent non-carers | **4034**  (fathers=1323; mothers=2711) | **4301**  (fathers=2078; mothers=2223) |

a Standard practice in epidemiology is to include outcomes in imputation models but not use the imputed values in subsequent analyses. In our sample, most of the missing data comes from missing outcomes. About 60% of these missing outcomes come from non-participation in the self-completion questionnaire (where the GHQ and SF-12 come from) and about 40% come from proxy responses. Considering the missing data from covariates is very small (missing N is about 100) and multiple imputation in combination with propensity score matching is a very complex process and an area of active research interest as to the best approach to take, we have decided not to impute the missing data.

Supplement 3 - Details of covariates used in propensity score matching

Age was measured in years. Ethnicity was measured as White, Black, Indian, Pakistani/Bangladeshi, and other Asian / other. We were not able to distinguish more nuanced ethnic groups due to small sample size. Educational qualifications were categorised into whether have a university degree. Employment status was combined with working hours, including working full-time with long hours (40+ hours/week), working full-time (30-40 hours/week), working part-time (<30 hours/week) and not working. Occupational class was measured by the National Statistics Socio-economic Classification (NS-SEC) three-class version (managerial/professional, intermediate, and routine/manual) plus a 'currently not working' category. Household income was measured by monthly total household net income divided by the OECD equivalence scale and was split into quintiles. Number of children includes natural/ adopted/step children under age 16 in the household. Partnership status included single, married, cohabiting, and separated or widowed. Urbanicity was dichotomised as urban or rural based on the population size/density of where the respondent lives. As our samples are parents, all the above covariates were measured at the first wave of parenthood (i.e. having a child under age 16 at home). Number of waves of parenthood before becoming a sandwich carer was included as a covariate to adjust for the unequal chance of being selected into our sample.

Supplement 4 - Baseline characteristics of sandwich carers and matched parents non-carers

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **GHQ outcome** | | | **SF-12 outcome** | | |
| **Baseline characteristics** | **Sandwich carers**  **(N=2082)** | **Matched parents non-carers**  **(N=1952)** | **p** | **Sandwich carers**  **(N=2223)** | **Matched parents non-carers**  **(N=2079)** | **p** |
| **Age, mean (SD)** | 36∙8 | 36∙8 | 0∙77 | 36∙8 | 36∙8 | 0∙64 |
| **Women (%)** | 67 | 67 | 0∙98 | 68 | 67 | 0∙95 |
| **Ethnicity (%)** |  |  |  |  |  |  |
| White | 83 | 82 | 0∙0010 | 81 | 81 | 0∙0040 |
| Black | 4 | 6 |  | 5 | 6 |  |
| Indian | 4 | 4 |  | 4 | 4 |  |
| Pakistani/Bangladeshi | 7 | 5 |  | 8 | 6 |  |
| Asian/other | 2 | 3 |  | 2 | 3 |  |
| **Marriage (%)** |  |  | 0∙24 |  |  | 0∙23 |
| Single | 10 | 8 |  | 10 | 8 |  |
| Married | 65 | 67 |  | 66 | 68 |  |
| Separated/widowed | 6 | 6 |  | 6 | 7 |  |
| Live as couple | 19 | 19 |  | 18 | 18 |  |
| **Number of children in household (%)** |  |  | 0∙27 |  |  | 0∙90 |
| 1 | 44 | 42 |  | 43 | 42 |  |
| 2 | 38 | 41 |  | 39 | 39 |  |
| 3+ | 18 | 17 |  | 18 | 19 |  |
| **Household income quintiles (%)** |  |  | 0∙34 |  |  | 0∙45 |
| Lowest | 18 | 19 |  | 20 | 19 |  |
| 2 | 23 | 20 |  | 23 | 21 |  |
| 3 | 22 | 22 |  | 21 | 23 |  |
| 4 | 21 | 21 |  | 20 | 21 |  |
| Highest | 17 | 18 |  | 16 | 16 |  |
| **Education qualification (%)** |  |  | 0∙99 |  |  | 0∙90 |
| University degree | 25 | 25 |  | 24 | 24 |  |
| No university degree | 75 | 75 |  | 76 | 76 |  |
| **Employment status (%)** |  |  | 0∙50 |  |  | 0∙31 |
| Part time | 32 | 32 |  | 32 | 31 |  |
| Full time | 34 | 36 |  | 33 | 36 |  |
| Full time long hours | 6 | 6 |  | 6 | 6 |  |
| Not working | 28 | 26 |  | 29 | 27 |  |
| **Occupational class (%)** |  |  | 0∙55 |  |  | 0∙53 |
| Professional/  managerial | 30 | 32 |  | 30 | 32 |  |
| Intermediate | 18 | 18 |  | 17 | 17 |  |
| Routine/manual | 24 | 24 |  | 24 | 23 |  |
| Not working | 28 | 26 |  | 29 | 27 |  |
| **Urban/rural (%)** |  |  | 0∙57 |  |  | 0∙83 |
| Urban | 78 | 77 |  | 78 | 79 |  |
| Rural | 22 | 23 |  | 22 | 21 |  |

p values show the statistical differences between sandwich carers and matched non-carers.

Supplement 5- Comparing baseline characteristics between sandwich carers included in the analysis and sandwich carers who were excluded from the analysis.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Baseline characteristics** | **N** | **Included sandwich carers** | **N** | **Excluded Sandwich carers\*** |
| **Age, mean (SD)** | 2082 | 36∙8 | 2470 | 38.0 |
| **Women (%)** | 2082 | 67 | 2470 | 66 |
| **Ethnicity (%)** | 2082 |  | 2455 |  |
| White |  | 83 |  | 75 |
| Black |  | 4 |  | 5 |
| Indian |  | 4 |  | 5 |
| Pakistani/Bangladeshi |  | 7 |  | 12 |
| Asian/other |  | 2 |  | 3 |
| **Marriage (%)** | 2082 |  | 2467 |  |
| Single |  | 10 |  | 11 |
| Married |  | 65 |  | 66 |
| Separated/widowed |  | 6 |  | 6 |
| Live as couple |  | 19 |  | 17 |
| **Number of children in household (%)** | 2082 |  | 2470 |  |
| 1 |  | 44 |  | 50 |
| 2 |  | 38 |  | 34 |
| 3+ |  | 18 |  | 16 |
| **Household income quintiles (%)** | 2082 |  | 2457 |  |
| Lowest |  | 18 |  | 22 |
| 2 |  | 23 |  | 23 |
| 3 |  | 22 |  | 20 |
| 4 |  | 21 |  | 18 |
| Highest |  | 17 |  | 16 |
| **Education qualification (%)** | 2082 |  | 2440 |  |
| University degree |  | 25 |  | 22 |
| No university degree |  | 75 |  | 78 |
| **Employment status (%)** | 2082 |  | 2373 |  |
| Part time |  | 32 |  | 31 |
| Full time |  | 34 |  | 32 |
| Full time long hours |  | 6 |  | 5 |
| Not working |  | 28 |  | 32 |
| **Occupational class (%)** | 2082 |  | 2381 |  |
| Professional/  managerial |  | 30 |  | 28 |
| Intermediate |  | 18 |  | 17 |
| Routine/manual |  | 24 |  | 23 |
| Not working |  | 28 |  | 32 |
| **Urban/rural (%)** | 2082 |  | 2468 |  |
| Urban |  | 78 |  | 81 |
| Rural |  | 22 |  | 19 |

Excluded sandwich carers are those who were excluded either due to missing data or without observations of parenthood at least once before and once after sandwich care onset age and thus can not be modelled in the piecewise method.

Supplement 6 – Predicted mean GHQ-12 & SF-12 scores (95% CIs) in each year

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **GHQ** | | | | | | **SF-12 MCS** | | | | | | **SF-12 PCS** | | | | | |
|  | **Sandwich carers** | | | **Parents non-carers** | | | **Sandwich carers** | | | **Parents non-carers** | | | **Sandwich carers** | | | **Parents non-carers** | | |
| **Year** | **AME** | **Lower 95% CI** | **Upper 95% CI** | **AME** | **Lower 95% CI** | **Upper 95% CI** | **AME** | **Lower 95% CI** | **Upper 95% CI** | **AME** | **Lower 95% CI** | **Upper 95% CI** | **AME** | **Lower 95% CI** | **Upper 95% CI** | **AME** | **Lower 95% CI** | **Upper 95% CI** |
| **-9** | 10∙9 | 9∙8 | 12∙1 | 10∙5 | 9∙4 | 11∙6 | 51∙5 | 49∙6 | 53∙4 | 49∙5 | 47∙5 | 51∙5 | 53∙7 | 52∙0 | 55∙3 | 53∙7 | 52∙1 | 55∙4 |
| **-8** | 11∙8 | 11∙1 | 12∙6 | 10∙1 | 9∙4 | 10∙8 | 50∙3 | 49∙0 | 51∙6 | 50∙9 | 49∙6 | 52∙2 | 52∙4 | 51∙3 | 53∙5 | 53∙0 | 52∙0 | 54∙1 |
| **-7** | 10∙9 | 10∙4 | 11∙5 | 10∙5 | 9∙9 | 11∙0 | 49∙5 | 48∙5 | 50∙4 | 50∙2 | 49∙2 | 51∙1 | 52∙4 | 51∙6 | 53∙3 | 54∙2 | 53∙4 | 55∙0 |
| **-6** | 11∙5 | 11∙0 | 12∙0 | 10∙9 | 10∙5 | 11∙4 | 48∙9 | 48∙0 | 49∙7 | 49∙8 | 49∙0 | 50∙6 | 52∙9 | 52∙2 | 53∙7 | 53∙7 | 53∙0 | 54∙4 |
| **-5** | 11∙5 | 11∙1 | 11∙9 | 10∙9 | 10∙5 | 11∙3 | 48∙7 | 48∙0 | 49∙4 | 50∙1 | 49∙4 | 50∙8 | 52∙3 | 51∙7 | 52∙9 | 53∙3 | 52∙7 | 53∙9 |
| **-4** | 11∙5 | 11∙2 | 11∙9 | 10∙6 | 10∙3 | 11∙0 | 49∙1 | 48∙5 | 49∙7 | 50∙1 | 49∙5 | 50∙7 | 52∙6 | 52∙1 | 53∙2 | 53∙0 | 52∙5 | 53∙5 |
| **-3** | 11∙6 | 11∙2 | 11∙9 | 10∙9 | 10∙6 | 11∙2 | 48∙6 | 48∙1 | 49∙2 | 49∙9 | 49∙4 | 50∙4 | 52∙3 | 51∙8 | 52∙8 | 53∙1 | 52∙6 | 53∙5 |
| **-2** | 11∙6 | 11∙3 | 11∙8 | 10∙9 | 10∙6 | 11∙2 | 48∙4 | 48∙0 | 48∙9 | 49∙3 | 48∙8 | 49∙7 | 51∙8 | 51∙4 | 52∙3 | 53∙0 | 52∙6 | 53∙4 |
| **-1** | **11∙6** | **11∙3** | **11∙9** | **11∙0** | **10∙8** | **11∙3** | **48∙2** | **47∙7** | **48∙6** | **49∙2** | **48∙8** | **49∙6** | **51∙8** | **51∙4** | **52∙3** | **52∙7** | **52∙3** | **53∙1** |
| **0** | **12∙2** | **11∙9** | **12∙4** | **11∙0** | **10∙7** | **11∙2** | **47∙3** | **46∙9** | **47∙8** | **48∙7** | **48∙2** | **49∙1** | **51∙6** | **51∙1** | **52∙0** | **52∙8** | **52∙4** | **53∙2** |
| **1** | 12∙2 | 11∙9 | 12∙5 | 10∙9 | 10∙6 | 11∙1 | 46∙9 | 46∙4 | 47∙4 | 48∙8 | 48∙3 | 49∙2 | 51∙5 | 51∙1 | 52∙0 | 52∙5 | 52∙1 | 52∙9 |
| **2** | 12∙1 | 11∙8 | 12∙4 | 11∙0 | 10∙8 | 11∙3 | 47∙0 | 46∙5 | 47∙5 | 48∙3 | 47∙8 | 48∙8 | 51∙1 | 50∙6 | 51∙5 | 52∙2 | 51∙8 | 52∙6 |
| **3** | 12∙0 | 11∙7 | 12∙3 | 11∙2 | 10∙9 | 11∙5 | 47∙2 | 46∙7 | 47∙8 | 48∙5 | 48∙0 | 49∙0 | 51∙3 | 50∙8 | 51∙8 | 52∙2 | 51∙8 | 52∙7 |
| **4** | 12∙1 | 11∙7 | 12∙4 | 10∙8 | 10∙5 | 11∙2 | 46∙7 | 46∙1 | 47∙2 | 48∙2 | 47∙7 | 48∙8 | 50∙9 | 50∙4 | 51∙4 | 51∙9 | 51∙4 | 52∙3 |
| **5** | 12∙2 | 11∙9 | 12∙6 | 11∙1 | 10∙8 | 11∙5 | 46∙2 | 45∙6 | 46∙8 | 48∙1 | 47∙5 | 48∙7 | 50∙8 | 50∙3 | 51∙4 | 51∙7 | 51∙2 | 52∙2 |
| **6** | 12∙4 | 12∙0 | 12∙8 | 11∙5 | 11∙1 | 11∙9 | 46∙2 | 45∙5 | 46∙9 | 48∙0 | 47∙3 | 48∙6 | 50∙4 | 49∙8 | 51∙1 | 51∙5 | 51∙0 | 52∙1 |
| **7** | 12∙3 | 11∙8 | 12∙7 | 11∙2 | 10∙7 | 11∙6 | 46∙4 | 45∙6 | 47∙1 | 47∙1 | 46∙3 | 47∙8 | 49∙8 | 49∙1 | 50∙5 | 51∙7 | 51∙1 | 52∙4 |
| **8** | 12∙8 | 12∙1 | 13∙5 | 11∙2 | 10∙5 | 11∙9 | 45∙5 | 44∙4 | 46∙6 | 47∙2 | 46∙0 | 48∙3 | 49∙8 | 48∙8 | 50∙8 | 51∙3 | 50∙3 | 52∙2 |

Supplement 7 – Predicted levels of health outcomes with 95% confidence intervals before and after becoming a sandwich carer by care hours, comparing sandwich carers and matched parent non-carers





Supplement 8 – Results of gender difference in the association between sandwich care and slope change

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Care × transition slope change × gender \*** | **p** | **Lower 95% CI** | **Upper 95% CI** | **Care × post-transition slope change × gender \*** | **p** | **Lower 95% CI** | **Upper 95% CI** |
| **GHQ** | Sandwich carers | -0∙02 | 0∙95 | -0∙5 | 0∙5 | 0∙03 | 0∙91 | -0∙6 | 0∙6 |
| **SF-12 MCS** | Sandwich carers | 0∙3 | 0∙47 | -0∙6 | 1∙2 | -0∙4 | 0∙48 | -1∙4 | 0∙6 |
| **SF-12 PCS** | Sandwich carers | -0∙3 | 0∙43 | -1∙1 | 0∙4 | 0∙1 | 0∙78 | -0∙7 | 1∙0 |
|  |  | **Care hours × transition slope change × gender †** | **p** | **Lower 95% CI** | **Upper 95% CI** | **Care hours × post-transition slope change × gender †** | **p** | **Lower 95% CI** | **Upper 95% CI** |
| **GHQ** | 5-9 h/w | -0∙4 | 0∙41 | -1∙5 | 0∙6 | 0∙5 | 0∙45 | -0∙7 | 1∙7 |
| 10-19 h/w | -0∙2 | 0∙78 | -1∙5 | 1∙1 | 0∙2 | 0∙75 | -1∙2 | 1∙7 |
| 20+ h/w | 0∙1 | 0∙92 | -1∙6 | 1∙8 | -0∙1 | 0∙96 | -2∙0 | 1∙9 |
| **SF-12 MCS** | 5-9 h/w | 0∙3 | 0∙77 | -1∙5 | 2∙0 | -0∙5 | 0∙64 | -2∙5 | 1∙5 |
| 10-19 h/w | 0∙05 | 0∙97 | -2∙1 | 2∙2 | -0∙1 | 0∙96 | -2∙5 | 2∙3 |
| 20+ h/w | 1∙9 | 0∙18 | -0∙9 | 4∙7 | -2∙0 | 0∙22 | -5∙2 | 1∙2 |
| **SF-12 PCS** | 5-9 h/w | 0∙7 | 0∙36 | -0∙8 | 2∙2 | -0∙7 | 0∙39 | -2∙5 | 1∙0 |
| 10-19 h/w | -0∙6 | 0∙49 | -2∙5 | 1∙2 | 0∙8 | 0∙46 | -1∙3 | 2∙9 |
| 20+ h/w | -1∙4 | 0∙24 | -3∙9 | 1∙0 | 0∙8 | 0∙59 | -2∙0 | 3∙5 |

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