# Physical and mental health outcomes following housing improvements: evidence from the GoWell study

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## ABSTRACT

**Background** Existing research points towards physical and mental health gains from housing improvements, but findings are inconsistent and often not statistically significant. The detailed characteristics and variability of housing improvement works are problematic and studies are often small, not experimental, with short follow-up times.

**Methods** A quasi-experimental design was used to assess the impact on physical health and mental health (using SF-12v2 Physical and Mental health component summary scales) of four types of housing improvement works—central heating, 'Secured By Design' front doors, fabric works, kitchens and bathrooms—both singly and in pairwise combinations. A longitudinal sample of 1933 residents from 15 deprived communities in Glasgow, UK was constructed from surveys carried out in 2006, 2008 and 2011. Sociodemographic characteristics and changes in employment status were taken into account.

**Results** Fabric works had positive associations with physical health (+2.09, 95% CI 0.13 to 4.04) and mental health (+1.84, 95% CI 0.04 to 3.65) in 1–2 years. Kitchens and bathrooms had a positive association with mental health in 1–2 years (+2.58, 95% CI 0.79 to 4.36). Central heating had a negative association with physical health (−2.21, 95% CI −3.74 to −0.68). New front doors had a positive association with mental health in <1 year (+5.89, 95% CI 0.65 to 11.14) and when provided alongside kitchens and bathrooms (+4.25, 95% CI 1.71 to 6.80). Gaining employment had strong associations with physical health (+7.14, 95% CI 4.72 to 9.55) as well as mental health (+5.50, 95% CI 3.27 to 7.73).

**Conclusions** Fabric works may provide insulation benefits and visual amenity benefits to residents. Front doors may provide important security benefits in deprived communities. Economic regeneration is important alongside property-led regeneration.

## INTRODUCTION

This paper examines changes in mental and physical health following housing improvements in 15 deprived communities in Glasgow, UK. The associations between poor housing conditions and physical as well as mental health are well established,[1–3] but the effects of improving existing housing conditions are more difficult to ascertain on a generalisable basis.[4] Yet public policies at the international level and within the UK identify the improvement of housing conditions as a means to address the social determinants of health and to reduce health inequalities,[5–7] as a result of which health impact assessments have been recommended to be carried out for all UK public policies including housing improvements.[8 9] It is also important to be able to assess the health impacts of housing improvements to both justify the expenditure of public funds, particularly when housing budgets have long been vulnerable to cuts in times of economic difficulty,[10] and in order to know how to maximise the benefits of housing investment.[11]

Despite the long-established association between housing conditions and health, the evidence linking *housing improvements* to *health outcomes* is still sparse, and often either of low quality or from cross-sectional data. The most common reason for excluding studies of housing improvements from the latest systematic reviews was that they did not provide data on *changes* in health outcomes.[12 13] The recent Cochrane Review covered 33 quantitative studies,[13] nine of which used the SF-36 Health Survey to assess health outcomes (we use the SF-12v2 Health Survey). Two studies reported statistically significant gains in general, physical and mental health associated with warmth interventions[14–16] and one study found no effect on any SF-36 health domains.[17] Two other studies assessed mental health impacts using the GHQ-12 scale, one finding an improvement and the other no effect after warmth interventions.[17 18] Four studies reported improvements (but not statistically significant) in general or physical health from rehousing or dwelling retrofitting,[19–22] although one study did report a statistically significant improvement in SF-36 physical functioning for those who had received dwelling fabric improvements.[21] Three studies have reported non-significant positive effects of rehousing or retrofitting on SF-36 mental health subscales, in one case only for women.[19 22 23] A further study also found no significant impact on GHQ12 scores.[24]

Thus, existing studies point towards physical and mental health gains from housing improvements, but not always consistently or to the extent of achieving statistical significance. The Cochrane Reviewers identified a number of issues with the interventions studied.[13] First, 'variation in the intervention [is] considerable', but as the interventions are often studied in broad categories we do not learn about the impacts of varied or specific interventions. Second, randomisation of allocation of the intervention is rare, as is the 'blinding' of the participants and analysts about who received what. Third, there is a high risk of 'contamination, where a proportion of the control group receives the intervention'; this 'may skew assessments of

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effectiveness'. There are other weaknesses in existing studies including: small sample size and lack of statistical power; lack of experimental designs; short follow-up times; and absence of baseline health status and unknown potential to benefit.

We seek to address some of these weaknesses through an examination of the effects of multiple, differentiated housing improvements on the physical and mental health of adult dwelling-occupants using a relatively large, quasi-experimental study over a period of up to 5 years.

## METHODS

### Study context

This study is conducted in Glasgow, UK, a relatively deprived postindustrial city with a poor health record.[25] The city has an unusually large social rented sector that a decade ago was considered to be in poor condition and in need of substantial investment.[26] The Council's housing stock was transferred to an independent housing association, Glasgow Housing Association (GHA) in 2003,[27] at which point an investment programme began to bring the stock up to (and often beyond) the Scottish Housing Quality Standard (SHQS) by 2015, in line with commitments made at the time of transfer.[28 29] By 2013, £1.2 billion was to have been spent by GHA on the stock improvement programme. In the first 7 years, substantial numbers of improvements had been provided across the city: 40 000 heating systems; 36 000 kitchens; 28 000 dwellings overclad; and 26 000 reroofings.[30] Our study looks at the impacts of these works on the occupants.

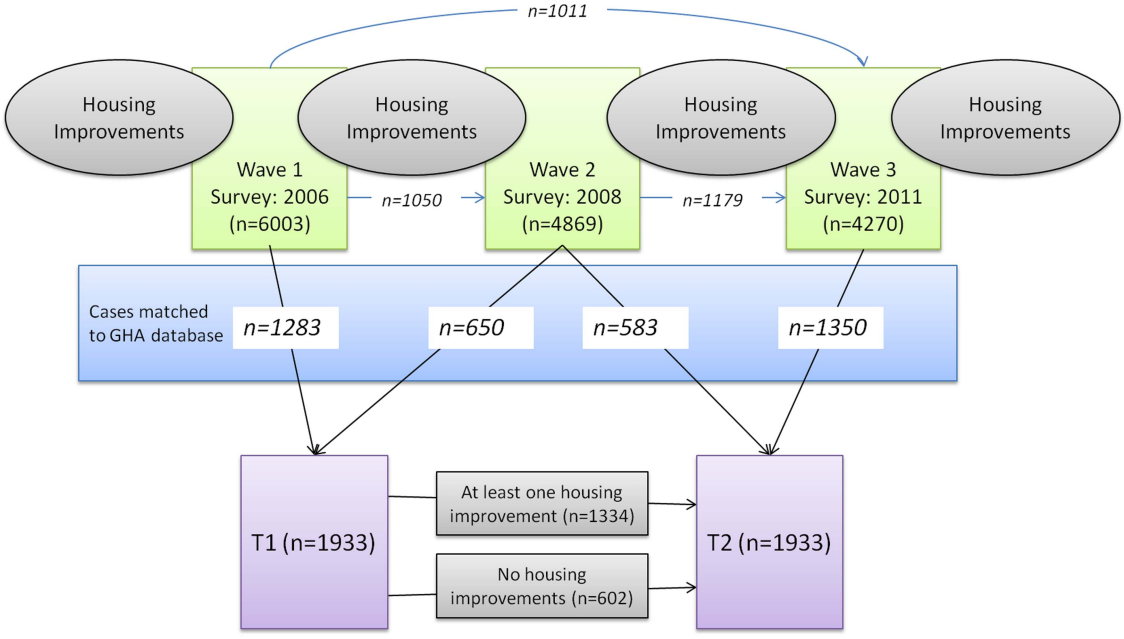
### Research design

Our analysis draws on three waves of survey data collected as part of GoWell, an ongoing study of the health and well-being impacts of regeneration across 15 of the most deprived communities in Glasgow.[31] The surveys were conducted in 2006 (wave 1), 2008 (wave 2) and 2011 (wave 3) using a repeat cross-sectional design with a nested longitudinal cohort.[32] Random samples of addresses were selected for interview across the study areas in waves 1 and 2. At wave 3, all previous addresses where an interview had been conducted were selected for the sample. In six areas where extensive demolition was taking place, all occupied dwellings were selected for interview at each wave. The surveys achieved response rates of 50.3%, 47.5% and 45.4%, respectively. Retrospective matching of names and addresses was used to identify the longitudinal cases embedded in the surveys, where we had interviewed the same householder in the same dwelling on more than one occasion.

We obtained GHA's records of all works to properties since 2003, along with the dates of completion. The database covers predominantly GHA social rented housing, but also includes owner occupied dwellings within GHA buildings. Through this process, we derived a matched, longitudinal sample of 1,933 cases, comprising 9.5% of all GHA households in our study areas.

Figure 1 shows the embedded longitudinal cohort and demonstrates how we constructed the subsample for analysis in this paper.

The types of works carried out to properties are shown in table 1. GHA categorises works into nine types, split into external, internal and common works. We examined effects of external and internal works: common works were extremely variable and rarely undertaken during our study period. We did not study the installation of new windows as too few had occurred in our sample. Thus, we identified respondents who had received four types of works between T1 and T2 interviews, across any of the survey interval pairings (W1–W2; W2–W3; W1–W3): *new kitchens and bathrooms plus rewiring (hereafter 'kitchens and bathrooms'); central heating; front doors; and fabric works*. From our sample, 1334 households (69%) received at least one of the four improvements between 2006 and 2011 compared with 55% of all GHA households in the study areas. This comprises 11.8% of all households (11 227) in the study areas who had at least one of these four improvements




*Note: Italics refer to longitudinal cases. Bold and italic are those matched to housing improvement database. Thin (blue) lines indicate the longitudinal subset from which we derive the T1-T2 sample. For example, T2 cases consist of 583 out of 1050 W1-W2 cases and 1350 cases derived either from W1-W3 (1,179) or W2-W3 (1,011).*

**Figure 1** Longitudinal sample construction.



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**Table 1** Types of housing improvement works

| Location | Category | Examples |
|---|---|---|
| External | High-rise fabric | Roof covering. Overcladding. Balcony repairs. Asbestos work |
| | Low-rise fabric | Roof covering. Cavity-fill. Gutters and downpipes. Rendering. Repointing. Cladding or insulation |
| | Doors | 'Secured By Design' doors |
| | Windows | Double-glazed windows |
| Common | Internal common works | Doors. Controlled-entry systems. Close painting. Lighting |
| | Environmental | Various |
| | Lifts | Replacement. |
| Internal | Heating | Full central heating system. Boiler replacement. Hot-water tank |
| | Kitchen, bathroom and rewiring | New kitchen and bathroom. Rewiring |

over the same period. Given the timings of our surveys, the survey interval ranges from 2 to 5 years, and the postintervention follow-up period from <1 to 5 years.

## Measures

We use the SF-12v2 Physical and Mental Health Component summary scales (PCS-12 and MCS-12, respectively) as the outcome measures. The SF-12v2 is a validated questionnaire for measuring health-related quality of life; scores are computed from responses to 12 questions and range from 0 to 100, with higher scores indicating better health.[33] As in previous analyses, we use the T2 score as the outcome, while controlling for the T1 score.[34] As discussed above, previous research has used SF-12 or SF-36 as outcome measures in studies of housing improvements, though not always differentiated into their physical and mental health components.[14 15 17 19–22] The physical and mental health scales are broad measures of self-rated health which are grounded in everyday language and experience and related to functional capabilities.

Four of the study areas are classified as demolition areas. Dwellings scheduled for demolition, as well as those with uncertain futures, receive some housing improvements, but these may be qualitatively different and of a smaller scale than elsewhere. We expect that residents in these areas may experience different health outcomes due to the scale of area regeneration and differing extent of works. We therefore control for whether the household was in a demolition area.

Age, gender, education and citizenship at T1 are included as sociodemographic control variables. Citizenship (British vs non-British) is included because several of the study areas contained recent migrants, mostly asylum seekers. Housing intervention studies usually assume that other variables remain constant and thus do not account for external changes affecting individuals. However, given the economic climate at the time of the study, we also investigate the effects of *changes* in employment status between interviews.

In order to take account of the fact that different improvements may have effects over different time periods, in the individual improvement models (see below), we divide the intervention group according to time from intervention to T2 interview: immediate <1 year; short term 1–2 years; medium term 3–5 years. Finally, in all models we include an identifier for the specific wave pairing to control for external influences on health, which may have affected respondents differently during different periods of the study (which spans the economic downturn post-2008), and for any duration effect due to survey interval variation.

## Analysis

Although we could not randomise the allocation of the housing improvements, nor could we randomise to a waiting list,[17] we nonetheless use the waiting list as a control. GHA's housing improvements are progressed on a pragmatic basis, with properties grouped into suitable clusters for contractual and logistical purposes, rather than prioritised on a needs-first basis.

We conduct the analysis in two stages, using multivariate linear regression modelling (using SPSS v21) in each case. First, we model the effects of all four housing improvements together on the PCS-12 and MCS-12 in order to assess the main effects of each improvement (see table 4). We then include pairwise interactions between the four improvements as a second step in this analysis. The control groups are those who received none of the four interventions between T1 and T2. We also control for having had any of the improvements pre-T1, rather than omitting all cases where any of the four improvements had occurred pre-T1, which would have resulted in an unviable control group.

Second, we model the effects of each of the four housing improvements separately for physical health (table 5) and mental health (table 6). In this case, we can exclude from each model anyone who had received the improvement in question pre-T1. In these models we are also able to divide the intervention group into three based on time since intervention. In each case we compare the intervention group to the same control group as before, those who did not receive any of the four improvements during the study period (T1–T2). We exclude owner occupiers from these models as being ineligible for improvement, with the exception of the fabric works model, as owner occupiers within a housing association block would receive this treatment.

Following the analysis, we held a seminar with practitioners involved in delivering the programme in order to hear their opinions on our results and to help us better understand the nature of the interventions and their reception by occupants.

# RESULTS

## Housing improvements

Two-thirds of the sample received housing improvements during the interval between their first and second interviews; the third who did not (n=602) form our control group. The largest group, 2 in 5 of the sample (40.3%) received one of the types of housing improvement; nearly a 5th (18.1%) received two improvements; and a 10th (10.6%) received three or four improvements. Table 2 shows the distribution of single and pairwise combinations of housing improvements included in our models.

## Sample characteristics

Table 3 compares the characteristics of the control and intervention groups at baseline. Compared with the control group, those who received housing improvements were slightly more likely to be male and not working, and slightly less likely to have educational qualifications. Those who received central heating or doors were much more likely to be non-British and living in a demolition area. In terms of physical health there is a mixed picture: those who received kitchens and bathrooms or fabric works had lower PCS-12 scores than the control group, while



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**Table 2** Receipt of housing improvements

| | On its own | Combined with | | | | All variations |
|---|---|---|---|---|---|---|
| | | Central heating | Doors | Fabric works | Kitchens and bathrooms | |
| Central heating | 70 (3.6) | – | 153 (7.9) | 169 (8.7) | 178 (9.2) | 374 (19.3) |
| Doors | 160 (8.3) | 153 (7.9) | – | 185 (9.6) | 192 (9.9) | 483 (25.0) |
| Fabric works | 218 (11.3) | 169 (8.7) | 185 (9.6) | – | 220 (11.4) | 575 (29.7) |
| Kitchens and bathrooms | 331 (17.1) | 178 (9.2) | 192 (9.9) | 220 (11.4) | – | 706 (36.5) |

Number (% of total sample). n=1933.

those who received central heating or doors had higher scores. Looking at mental health, all intervention groups had higher MCS-12 scores than the control group at baseline. However, the differences in baseline health scores were small, at up to 1-10th of the SD of the relevant score.

### Physical health

Physical health is worsening over time in our study group. Across the sample as a whole, physical health scores declined between T1 and T2 by around a third of a SD (−4.37). Being female and older (over 65 years of age) were associated with lower physical health scores (table 4). By far the biggest association with physical health was for employment: remaining in employment or gaining employment between T1 and T2 were associated with increases in PCS-12 scores of approximately two-thirds of a SD. After controlling for sociodemographic characteristics and area, two of the housing improvements had significant associations with physical health (table 4). Fabric works were associated with a positive gain in physical health (+2.03, 95% CI 0.73 to 3.32), whereas central heating was associated with a negative change in physical health (−2.21, 95% CI −3.74 to −0.68). There were no significant interaction effects of the housing improvements on physical health.

When we included the time since intervention in separate models for each housing improvement (table 5) we found a positive association of physical health with fabric works completed 1–2 years before the interview (+2.09, 95% CI 0.13 to 4.04). None of the other housing improvements showed any significant association with physical health during any period.

### Mental health

Mental health improved slightly over time across the sample, the mean increase being +1.16 between T1 and T2, equivalent to a tenth of a SD. Females had slightly lower T2 mental health scores than men (table 4). Older respondents and those who were non-British had higher T2 mental health scores than others. Remaining in employment or gaining employment over time was associated with higher T2 mental health scores of around half a SD. Kitchens and bathrooms were associated with higher mental health scores at T2 (+1.25, 95% CI 0.06 to 2.44). There was also a significant interaction whereby kitchens and bathrooms combined with doors were associated with a higher mental health score at T2 equivalent to around 40% of a SD (+4.25, 95% CI 1.71 to 6.80). This was the only interaction effect found in the model.

In the individual intervention models we see positive associations between mental health and all four housing improvements at particular times (table 6). The association of kitchens and bathrooms with mental health was stronger than in the combined model, but only more than a year after the intervention. The three other housing improvements showed positive associations with mental health during different periods. Doors had a strong positive association with mental health, equivalent to around half a SD of the MCS score, but only in the first year (+5.89, 95% CI 0.65 to 11.14). Fabric works were positively associated with mental health 1–2 years after the intervention (+1.84, 95% CI 0.04 to 3.65). Central heating had a positive association with mental health 3–5 years after the intervention (+3.34, 95% CI 0.11 to 6.58).

## DISCUSSION

We review the main findings from our study of the effects of housing improvements on occupants' health.

Fabric works had a positive association with physical and mental health. In the separate intervention models this was only a short-term effect 1–2 years after the intervention. We know from earlier analysis that there was a low level of awareness of external works among the study group.[35] These findings may also reflect two important aspects of fabric works. First, fabric works include over-cladding and insulation, which makes homes far warmer and more comfortable; this is important in the cold and wet climate of western Scotland. The biggest gain from

**Table 3** Baseline characteristics of control and intervention groups

| | Male (%) | Over 65 years (%) | Not working (%) | Educational qualifications (%) | Non-British (%) | PCS-12 $\bar{x}$(SD) | MCS-12 $\bar{x}$(SD) |
|---|---|---|---|---|---|---|---|
| Control: No improvements | 37.2 | 27.8 | 76.9 | 21.8 | 11.4 | 46.70 (11.68) | 47.35 (10.34) |
| Intervention Groups: | | | | | | | |
| Kitchen and bathroom | 39.2 | 29.5 | 84.9 | 16.9 | 7.1 | 45.69 (11.39) | 48.05 (9.81) |
| Central heating | 43.9 | 22.2 | 81.5 | 19.6 | 21.1 | 47.14 (10.82) | 48.89 (9.86) |
| Doors | 41.8 | 26.5 | 83.3 | 15.7 | 20.3 | 47.20 (11.06) | 47.72 (9.73) |
| Fabric works | 41.5 | 31.3 | 81.9 | 20.9 | 12.2 | 45.98 (11.12) | 48.48 (9.41) |
| Whole sample | 39.5 | 28.3 | 82.3 | 19.5 | 13.7 | 46.57 (11.43) | 47.91 (9.98) |

MCS, Mental Component Summary scales, PCS, Physical Component Summary scales



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**Table 4** Associations of housing improvements with SF-12 Physical & Mental Component Summary scales (PCS-12 and MCS-12) at T2

| | Outcome: PCS-12 T2 (β, (CI)) | Outcome: MCS-12 T2 (β, (CI)) |
|---|---|---|
| PCS-12 at T1 | 0.54 (0.48 to 0.59)* | 0.17 (0.12 to 0.22)* |
| Kitchen and bathroom during T1-T2 | −1.00 (−2.29 to 0.28) | 1.25 (0.06 to 2.44)* |
| Central heating during T1-T2 | −2.21 (−3.74 to −0.68)* | −0.31 (−1.73 to 1.11) |
| Doors during T1-T2 | −0.41 (−1.83 to 1.01) | −0.22 (−1.54 to 1.10) |
| Fabric works during T1-T2 | 2.03 (0.73 to 3.32)* | 1.09 (−0.11 to 2.29) |
| Demolition area | −0.02 (−1.58 to 1.54) | −0.05 (−1.50 to 1.40) |
| Gender (female) | 1.14 (0.04 to 2.25)* | −1.25 (−2.28 to −0.22)* |
| Over 65 years | −3.35 (−4.68 to −2.02)* | 7.18 (5.94 to 8.42)* |
| Education qualifications | 1.26 (−0.16 to 2.69) | −0.22 (−1.53 to 1.10) |
| Non-British | 1.78 (−0.01 to 3.57) | 4.22 (2.57 to 5.86)* |
| Remaining in employment | 6.53 (4.70 to 8.37)* | 5.81 (4.14 to 7.49)* |
| Moving out of employment | 0.71 (−1.71 to 3.14) | 2.91 (0.68 to 5.14)* |
| Gaining employment | 7.14 (4.72 to 9.55)* | 5.50 (3.27 to 7.73)* |
| Wave 1–wave 3 case | −3.91 (−5.45 to −2.37)* | −0.11 (−1.54 to 1.31) |
| Wave 2–wave 3 case | −2.46 (−4.05 to −0.86)* | 1.27 (−0.2 to 2.75) |
| Any work pre-T1 | −0.10 (−1.43 to 1.22) | −0.24 (−1.47 to 0.98) |
| Constant | 15.55 (11.80 to 19.30)* | 34.10 (30.38 to 37.82)* |
| $R^2$ | 0.335 | 0.128 |
| n | 1861 | 1861 |

*p<0.05.

GHA's housing investment programme has been in terms of energy efficiency. Prior to the programme, 65% of the Council's housing stock failed the SHQS on energy efficiency grounds, but by 2010, 80% of GHA stock was energy-efficient-compliant, with a potential 31% saving to occupants' heating bills.[36] These improvements can potentially benefit both physical and mental health. The second important aspect of fabric works, with which practitioners concurred, is the way it brightens up the external appearance of run-down buildings, especially in locations where there are many improvements in the same neighbourhood. This may be an important aspect of the built environment for mental health in a climate with low levels of daylight.[37] Furthermore, previous research in Glasgow has shown a strong association between visual amenity of the built environment and mental well-being.[38]

New front doors had a substantial positive association with mental health within the first year after intervention, but not thereafter. This may reflect the immediate perceived safety benefits provided by new doors in deprived areas where crime and antisocial behaviour, especially related to drug dealing and drunkenness, are significant concerns[39] (confirmed by practitioners). All GHA doors and windows are installed to 'Secured by Design' (SBD) standards approved by the police to 'withstand reasonable levels of attack from housebreakers'. A recent study of GHA properties reported that housebreaking and attempted housebreaking reduced in areas that had received SBD doors

**Table 5** Associations of housing improvements with SF-12 Physical Component Scores (PCS-12) at T2

| Outcome: PCS-12 at T2 | Kitchen and bathroom (β, (CI)) | Central heating (β, (CI)) | Doors (β, (CI)) | Fabric works (β, (CI)) |
|---|---|---|---|---|
| PCS-12 at T1 | 0.57 (0.50 to 0.64)* | 0.54 (0.46 to 0.62)* | 0.54 (0.46 to 0.61)* | 0.48 (0.41 to 0.54)* |
| Intervention within 1 year of T2 | −0.98 (−3.33 to 1.37) | −2.26 (−5.30 to 0.78) | −4.42 (−9.52 to 0.68) | −0.67 (−2.90 to 1.57) |
| Intervention within 1–2 years of T2 | −0.01 (−1.96 to 1.94) | −0.86 (−3.07 to 1.35) | 0.02 (−2.09 to 2.14) | 2.09 (0.13 to 4.04)* |
| Intervention within 3–5 years of T2 | −0.83 (−3.53 to 1.87) | −2.64 (−5.80 to 0.52) | −0.24 (−3.23 to 2.74) | 1.28 (−1.57 to 4.14) |
| Demolition area | 0.98 (−1.39 to 3.35) | −0.08 (−2.15 to 1.98) | −0.58 (−2.54 to 1.39) | 0.89 (−1.28 to 3.06) |
| Gender (female) | 1.25 (−0.29 to 2.78) | 0.21 (−1.52 to 1.95) | 0.50 (−1.15 to 2.15) | 0.81 (−0.64 to 2.27) |
| Over 65 years | −3.08 (−4.89 to −1.27)** | −4.46 (−6.66 to −2.26)* | −4.30 (−6.32 to −2.27)* | −2.81 (−4.53 to −1.09)* |
| Education qualifications | 1.42 (−0.58 to 3.41) | 1.36 (−0.81 to 3.53) | 1.9 (−0.24 to 4.04) | 1.90 (0.10 to 3.70)** |
| Non-British | 1.90 (−0.86 to 4.67) | 2.76 (0.29 to 5.23)* | 2.59 (0.28 to 4.90)* | 2.36 (−0.13 to 4.84) |
| Remaining in employment | 6.59 (3.82 to 9.36)* | 7.43 (4.44 to 10.42)* | 6.00 (3.17 to 8.84)* | 6.91 (4.60 to 9.22)* |
| Moving out of employment | 0.94 (−2.44 to 4.32) | 0.26 (−3.50 to 4.02) | 0.16 (−3.60 to 3.92) | 0.35 (−2.67 to 3.37) |
| Gaining employment | 7.13 (3.71 to 10.56)* | 7.54 (4.23 to 10.86)* | 7.00 (3.55 to 10.46)* | 7.24 (4.10 to 10.38)* |
| Wave 1—Wave 3 case | −3.61 (−5.88 to −1.34)* | −4.36 (−6.86 to −1.86)* | −3.93 (−6.79 to −1.08)* | −4.11 (−6.17 to −2.06)* |
| Wave 2—Wave 3 case | −2.27 (−4.28 to −0.26)* | −2.94 (−5.14 to −0.74)* | −2.74 (−5.22 to −0.27)* | −2.09 (−4.03 to −0.16)* |
| Constant | 12.57 (7.54 to 17.59)* | 15.35 (9.95 to 20.74)* | 15.36 (10.13 to 20.59)* | 17.39 (12.64 to 22.14)* |
| $R^2$ | 0.338 | 0.387 | 0.365 | 0.303 |
| n | 999 | 694 | 802 | 1122 |

*p<0.05, **p<0.01.



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**Table 6** Associations of housing improvements with SF-12 Mental Component Scores (MCS-12) at T2

| Outcome: MCS-12 at T2 | Kitchen and bathroom (β, (CI)) | Central heating (β, (CI)) | Doors (β, (CI)) | Fabric works (β, (CI)) |
|---|---|---|---|---|
| PCS-12 at T1 | 0.19 (0.12 to 0.25)* | 0.09 (0.00 to 0.17)* | 0.16 (0.07 to 0.24)* | 0.11 (0.05 to 0.18)* |
| Intervention within 1 year of T2 | 0.93 (−1.21 to 3.07) | −0.59 (−3.71 to 2.53) | 5.89 (0.65 to 11.14)** | 0.11 (−1.95 to 2.18) |
| Intervention within 1–2 years of T2 | 2.58 (0.79 to 4.36)* | 1.38 (−0.89 to 3.65) | 0.99 (−1.18 to 3.15) | 1.84 (0.04 to 3.65)* |
| Intervention within 3–5 years of T2 | 2.81 (0.34 to 5.28)* | 3.34 (0.11 to 6.58)* | 1.09 (−1.96 to 4.15) | 0.73 (−1.91 to 3.36) |
| Demolition area | 1.86 (−0.30 to 4.01) | 0.44 (−1.68 to 2.56) | −0.89 (−2.90 to 1.11) | 0.28 (−1.73 to 2.28) |
| Gender (female) | −2.11 (−3.51 to −0.71)** | −1.37 (−3.15 to 0.42) | −1.57 (−3.26 to 0.12) | −1.65 (−2.99 to −0.31)* |
| Over 65 years | 8.19 (6.52 to 9.85)** | 6.92 (4.65 to 9.19)* | 7.74 (5.66 to 9.81)* | 6.73 (5.14 to 8.32)* |
| Education qualifications | −0.99 (−2.79 to 0.81) | −2.34 (−4.55 to −0.13)** | −0.22 (−2.41 to 1.96) | −1.48 (−3.13 to 0.17) |
| Non-British | 3.17 (0.67 to 5.68)* | 3.89 (1.40 to 6.39)* | 4.57 (2.22 to 6.92)* | 4.45 (2.17 to 6.73)* |
| Remaining in employment | 6.77 (4.29 to 9.25)* | 7.15 (4.14 to 10.16)* | 6.21 (3.36 to 9.06)* | 6.86 (4.76 to 8.97)* |
| Moving out of employment | 3.63 (0.59 to 6.68)** | 3.26 (−0.57 to 7.08) | 2.36 (−1.47 to 6.19) | 4.17 (1.42 to 6.93)** |
| Gaining employment | 7.11 (4.01 to 10.22)* | 6.76 (3.37 to 10.14)* | 5.93 (2.40 to 9.46)* | 5.15 (2.27 to 8.03)* |
| Wave 1–wave 3 case | −0.20 (−2.27 to 1.87) | −1.42 (−3.98 to 1.14) | 0.45 (−2.48 to 3.38) | 0.72 (−1.18 to 2.62) |
| Wave 2–wave 3 case | 0.65 (−1.18 to 2.48) | 1.13 (−1.11 to 3.38) | 1.66 (−0.87 to 4.18) | 1.93 (0.15 to 3.71)* |
| Constant | 34.66 (29.76 to 39.56)* | 38.13 (32.16 to 44.10)* | 34.04 (28.37 to 39.71)* | 36.98 (32.26 to 41.71)* |
| $R^2$ | 0.174 | 0.119 | 0.127 | 0.118 |
| n | 999 | 694 | 802 | 1122 |

*p<0.05, **p<0.01.

and windows.[40] A reduction in anxiety about crime and safety may be the source of immediate mental health gains from new doors, although this 'halo' effect appears not to last thereafter.

Our findings that central heating works had a negative association with physical health are curious, although the Cochrane review found 'contradictory effects' of central heating on home satisfaction.[13] Several particularities come to mind. First, installing heating systems is more disruptive to occupants than other works. Second, heating interventions are variable in nature; a large number of heating works were to high-rise dwellings due for later demolition and comprised the installation of electric storage heaters rather than gas central heating, as installed elsewhere. Thus, some heating interventions may be insufficient to counter the underlying trend of worsening physical health. Third, GHA's investment programme aims to install new heating systems to all properties, but the level of need and 'potential to benefit' from this intervention may vary. Past studies that have found positive health effects from central heating have involved groups with an absence of heating beforehand, which was not generally the case in Glasgow. The positive association of central heating with mental health in the medium-term may reflect a period of getting over disruption, becoming used to the new equipment, and allaying concerns about costs, which practitioners thought were issues for occupants and the Cochrane reviewers identified as potential mediators for impacts.[13]

New kitchens and bathrooms had positive associations with mental health 1 year after the intervention and beyond, possibly indicating a cumulative effect after overcoming disruption and a period of adjustment to new facilities. This is the intervention where, according to practitioners, residents had an element of choice (in colour and layout) and therefore psychosocial benefits may be important. Our previous cross-sectional study showed that these internal works were associated with occupants' ratings of the internal quality of their dwellings, which in turn was positively associated with feelings of control and of status.[35]

## Strengths and limitations

The strengths of our study include that it is larger and covers a longer period than most others, and is quasi-experimental with a control group and before-and-after surveys. Furthermore, at the time of first interview, most occupants did not know if or when they would receive housing improvements, and participants also did not know we were specifically studying the effects of improvements to their homes; thus there is an element of 'blinding'.

The main distinctive characteristic of our study is that we separate the effects of different types of housing improvement, for example, dividing warmth interventions into fabric works/insulation and heating systems. We also examine interaction effects between different housing improvements. As far as we are aware, this has not been done before.

A further advantage is that we have been able to examine the effects of different time periods postintervention over a period of 5 years, whereas most past studies have used a uniform follow-up period, often of less than 1 year, and have not examined the issues of timing or duration of effects; indeed, the Cochrane reviewers concluded that 'much remains to be learned about the timescale of impacts'.[13] Nonetheless, further analysis could be done concerning the effects of more sophisticated time variables, using direct and indirect pathways (see below) to help explain why health effects occur at particular times and either endure or erode over time.

We have examined a direct or environmental pathway between improving someone's home and physical and mental health outcomes. We have yet to consider the indirect pathways to these and other health outcomes (including health conditions and behaviours), particularly via perceived changes in housing quality and psychosocial benefits of control and status. These are things we intend to examine in future analyses.

There are other weaknesses we have not been able to overcome here. Issues of sample bias could apply to our study; it also has to be borne in mind that we are studying the poorest communities in a very deprived city. We have not objectively measured housing conditions and thus we know neither the initial potential to benefit in housing terms, nor the extent of change in conditions resulting from improvement works, on a case-by-case basis. Variation in the extent and quality of the intervention has not been measured. The housing improvement programme is generalised and widespread, not targeted or adapted to those most likely to benefit.[13] Accordingly, we have



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focused on the question of *which interventions* provide benefits, rather than conducting subgroup analyses to establish *which households* receive benefits.

Although a key strength of our study is that we study the same individuals in the same households over time, this does introduce a potential source of bias through the migration of treated residents, meaning that those who benefitted most (or least) from housing improvements may have moved home, although we have no reason to believe this is the case.

More generally, our models perform less well at explaining mental health than they do physical health, based on the variation explained ($R^2$), although we find stronger and more frequent associations between the individual interventions and mental health than we do for physical health. Our purpose was not to explain health per se, but rather to explore the relative contribution of different housing improvements, while recognising that health itself is an outcome of a complex set of experiences and exposures over the life course. While we have controlled for the usual confounders in order to examine the impact of housing improvements, there are other life events and external experiences that affect health, particularly within deprived, unstable households and communities, which we have not taken into account.

This raises a question as to how big an effect on health we can realistically expect from a specific housing improvement and highlights that perhaps the modest effects we find here are positive signs of some impact. Despite regular use in a range of studies, there is a question-mark over the extent to which the SF-12 can adequately capture the effects of change through housing improvements. For the PCS-12, we consider that two elements (general health and physical functioning) may be more sensitive to such change than the others (role functional and bodily pain). For the MCS-12, three of the elements (vitality, social functioning and mental health) may be more responsive to housing improvements than the fourth (emotional role). These are issues we may be able to consider in future analyses.

## CONCLUSION

Regeneration programmes are often 'property-led' as in Glasgow, and their insufficiency has been noted.[41] Housing improvements constitute the largest investment item within such programmes, and we have shown that particular improvement works, and combinations thereof, can affect the physical and mental health of occupants. But the gains are generally modest, particularly compared with the benefits on health resulting from gaining employment; yet only a small group of our sample (5.4%) actually gained employment over time, while the vast majority (77.9%) remained out of work. Although housing providers would contend that they are improving homes with the expectation of health gains, they would also argue that their main objective is to improve residential satisfaction and quality of life more generally. Nonetheless, our study highlights the central importance of employment, or rather lack of employment, to the health of residents in deprived areas, and supports a case for more attention to be paid to employment as part of regeneration, whether through economic, employability or health-improvement measures.

### What is already known on this subject

- Warmth interventions can improve respiratory health and general health, but their impacts on mental health are not clear. The effects of rehousing or retrofitting of dwellings on health are unclear.
- Housing improvement works are very variable, often insufficiently targeted to those who will benefit the most and usually assessed in very broad categories.
- Many studies of housing improvement interventions are unable to provide robust or statistically significant findings due to study design weaknesses.

### What this study adds

- Within the 'warmth and energy efficiency' package of housing improvements, external fabric works (including insulation) had positive effects on physical and mental health, but central heating often had no effects or negative effects.
- New 'Secured By Design' front doors had immediate positive effects on mental health.
- Different housing improvements had effects on health at different time periods after intervention.
- For people living in deprived areas, gaining employment has a substantial impact on physical and mental health and thus holistic regeneration may be more appropriate than housing improvements.

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