



# Longitudinal effects of physical and social neighbourhood change on suicide mortality: A full population cohort study among movers and non-movers in the Netherlands

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## ABSTRACT

Associations between the residential neighbourhood environment and suicide mortality are well-established; however, most evidence is cross-sectional and not capable of incorporating place-based and residential moving-related neighbourhood changes. We studied how suicide mortality is associated with changes in the physical and social neighbourhood environment for movers and non-movers. Our retrospective analysis was based on longitudinal register data for the entire Dutch population aged 25–64 years enriched with annually time-varying data on the residential neighbourhood environment between 2007 and 2016. A total of 8,741,021 people were followed-up between 2007 and 2016 of which 10,019 committed suicide. Upward and downward neighbourhood change was measured by comparing neighbourhood conditions separately at two time points. Cox proportional hazard models indicated that movers had a significantly lower risk of suicide compared to non-movers. Suicide risk was lower for people experiencing improvements in social fragmentation and deprivation compared to those remaining in poor conditions. Change from rural to urban conditions also resulted in lower suicide risk, while a gain in green space put people at increased risk. For those stable neighbourhood conditions over time, suicide mortality was lower for men and women in urban vs. rural neighbourhoods as well as for women in neighbourhoods with low vs. high social fragmentation. Stable exposure to high levels of green space resulted in higher suicide risk among women. Interactions and stratification by moving type revealed associations between neighbourhood change and suicide were more pronounced in non-movers. Our findings suggest that neighbourhood improvements might contribute to a lower suicide risk, especially for long-term residents in poor neighbourhood conditions.

## 1. Introduction

It has been recognised that suicide mortality is linked to people's residential neighbourhood environment (Turecki et al., 2019). Associations have been found between higher suicide risk and, for example, rural residence (Hirsch and Cukrowicz, 2014), socioeconomically deprived neighbourhoods (Cairns et al., 2017; Martikainen et al., 2004; Rehkopf and Buka, 2005), high social fragmentation (Agerbo et al., 2007; Congdon, 2013; Hagedoorn et al., 2020; Martikainen et al., 2004), and low social capital (Kunst et al., 2013). However, associations with neighbourhood socioeconomic characteristics (Agerbo et al., 2007), social fragmentation (Collings et al., 2009) and green space (Helbich et al., 2020) were not universally found.

A possible reason for the spurious associations between suicide risk and neighbourhood characteristics is the widespread use of cross-sectional study designs (Agerbo et al., 2007; Hagedoorn et al., 2020; Helbich et al., 2020; Kunst et al., 2013; Martikainen et al., 2004) failing to represent neighbourhood change over time and neglecting that people move home throughout their lifetime (Helbich, 2018). It is unclear whether neighbourhood change and moving to another residential neighbourhood with different characteristics is related to suicide mortality. Longitudinal data covering both moving and neighbourhood change over time is therefore vital to provide more insight into how changes in neighbourhood physical and social characteristics are associated with suicide mortality.

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### 1.1. Residential mobility and suicide

Residential mobility has been associated with adverse health outcomes (Morris et al., 2018), including an increased risk of suicide attempts among young-adolescents (Haynie et al., 2006; Potter et al., 2002; Qin et al., 2009; Webb et al., 2016) and higher rates of poor mental health, substance abuse and behavioural problems (Morris et al., 2018), factors involved in the transition from ideation to suicide attempt (Turecki et al., 2019). However, except a few older ecological studies (Stack, 1980, 1981), research into associations between residential mobility and adult suicide is scarce. Yet, residential mobility can be an important precursor for suicidal behaviour. Following Durkheim's theory of social integration as a determinant of suicide (Émile Durkheim, 1951), the disruption of social ties as a result of residential moving might weaken social connections and regulations that restrain individual actions, such as suicide. Moving might also be a stressful life-event in itself (Morris et al., 2018), often triggered by other life-events such as union dissolution, unemployment or eviction which have detrimental effects on mental health (Tunstall et al., 2015) and suicide (Turecki and Brent, 2016).

### 1.2. Neighbourhood change and suicide

Residential mobility also determines the residential environment to which individuals are exposed (Helbich, 2018). Theories on suicide, including the biopsychosocial model of suicide risk (Turecki et al., 2019) and the integrated motivational model of suicide (O'Connor and Kirtley, 2018), emphasise that suicide is the outcome of a complex interplay of biological, psychological, social, cultural and environmental factors. Following these frameworks, the residential neighbourhood may affect suicide risk through proximal factors such as social context or the presence of stressors. The local social environment plays an important role in suicidal behaviour by providing integration into local communities while regulation provides norms for individual behaviour (Émile Durkheim, 1951). In neighbourhoods with high fragmentation, for example, social integration is low due to the high share of non-family households and high residential turnover (Congdon, 2013). Such environments may provide little social support and lack social norms, reciprocity and trust (Fagg et al., 2008; Ivory et al., 2011), while a safe and supportive environment protects against suicide (Turecki et al., 2019). Socioeconomic deprivation, such as being unemployed or having a low income, is an individual-level risk factor for suicide (Turecki et al., 2019). However, also at the neighbourhood level, deprivation may indirectly influence suicide risk due to a lack of economic opportunities and increased feelings of hopelessness and despair (Denney et al., 2015; Rehkopf and Buka, 2005). Finally, neighbourhoods with social disorder and socioeconomic disadvantage may directly increase emotional distress while characteristics such as green space may buffer stress (Diez Roux and Mair, 2010).

Through the pathways described above, residential mobility changes people's exposure to neighbourhood characteristics, which in turn might induce or protect against suicidal behaviour. At the same time, residential mobility can influence the socioeconomic and demographic composition of neighbourhoods and in that way also change neighbourhoods for non-movers (Hedman, 2011). In addition, non-movers can experience neighbourhood change as the result of public planning or through natural change as inhabitants age or start a family etc. (Blair et al., 2015; Hedman, 2011). Although empirical research on neighbourhood change and suicide risk is scarce, several studies looked into associations between neighbourhood change and mental health, a precursor to committing suicide (Turecki et al., 2019). Increased area-level socioeconomic deprivation was associated with poor mental health among movers (Norman et al., 2005; Tunstall et al., 2014) and non-movers (Blair et al., 2015). In contrast, moving to greener neighbourhoods was associated with mental health improvements (Alcock et al., 2014), although others observed null (Weimann et al., 2015) or

even health-threatening associations (Tunstall et al., 2014).

Studies on neighbourhood change and health either included movers (Alcock et al., 2014; Darlington-Pollock et al., 2018; Green et al., 2017; Shackleton et al., 2018; Weimann et al., 2015) or non-movers (Aretz et al., 2019; Blair et al., 2015; Boyle et al., 2004; Xiao et al., 2018). Little is known on whether health outcomes related to neighbourhood change differ between movers and non-movers. Although movers are restricted by available resources, housing prices and the availability of social housing, their neighbourhood of destination is generally a deliberate choice (Hedman and van Ham, 2012). Neighbourhood change for non-movers, on the other hand, is often caused by external factors, such as changing population composition or planning-induced changes (Hedman, 2011). Lack of control over one's living environment and lack of means and resources to move out might trigger suicidal behaviour as a result of increased stress or feelings of entrapment (Turecki et al., 2019).

### 1.3. Selective residential mobility

If characteristics of movers differ from non-movers, residential mobility can result in geographic inequalities in health and spurious associations between neighbourhood characteristics and health. This happens, for example, if individuals in poor health are more likely to move to disadvantaged neighbourhoods (Jokela, 2014). While some studies suggest that internal migrants are healthier than non-migrants (Norman et al., 2005), others found that adults in poor health are more likely to relocate compared to healthy ones (Larson et al., 2004; Morris et al., 2018). Specifically, people experiencing mental health problems (Lix et al., 2006; Morris et al., 2018; Tunstall et al., 2014) have a higher likelihood of moving. It might thus be possible that higher suicide rates in certain neighbourhoods are the result of selective migration of individuals in poor mental health. Although this has not been empirically studied for suicide before, poor mental health was more common among movers to areas with increased socioeconomic deprivation (Tunstall et al., 2014). Although there is some evidence that poor general (Norman et al., 2005) and mental health (Tunstall et al., 2015) result in selective migration, many studies reported only minor influences of selective migration on neighbourhood-health associations for depressive symptoms (Airaksinen et al., 2016a), and other health outcomes (Darlington-Pollock et al., 2018; James et al., 2015; Martikainen et al., 2008; van Lenthe et al., 2007).

In summary, individual level studies have found an increased suicide risk among adolescents after residential mobility, but the extent to which this holds for adult suicide is unknown. In addition, previous research report associations between neighbourhood characteristics and suicide mortality. However, to our knowledge, effects of changes in neighbourhood characteristics on suicide mortality have not been studied before. To address this gap in knowledge, we took advantage of unique longitudinal population-wide register data over a 10-year period and examined how suicide mortality is associated with changes in the physical and social neighbourhood composition along people's residential mobility across the Netherlands. More specifically, we assessed whether 1) suicide risk differs between non-movers and movers; 2) suicide risk is associated with upward and downward changes in neighbourhood conditions as compared to no change; and 3) associations differ between movers and non-movers. As theorized above, we hypothesize that movers have a higher suicide risk compared to non-movers as a result of a disruption of social ties and increased feelings of distress associated with moving. Following studies on mental health and on neighbourhood effects on suicide risk, we further hypothesize that upward (downward) neighbourhood change is associated with a decrease (increase) in suicide risk. Finally, as movers might have -to a certain degree- more control over which neighbourhoods they are exposed to compared to non-movers, we assume that associations between suicide risk and neighbourhood change are more pronounced for movers compared to non-movers.

## 2. Materials and methods

### 2.1. Study population

We conducted a retrospective register-based cohort study in the Netherlands. Our data comprised the entire officially registered Dutch population. We linked registers on a person-by-person basis through anonymised unique personal identification codes assigned to each resident. Eligible were all residents aged 25–64 years on January 1, 2007 ( $N = 9,069,864$ ). We followed them until suicide, censoring (i.e., death by another cause or emigration), or end of follow-up on December 31, 2016. Death by suicide was coded as X60.0 through X84.9 in the cause of death register according to the International Classification of Diseases.

People in institutionalised homes ( $N = 153,737$ ) during the study period and those with missing individual ( $N = 162,723$ ) and/or neighbourhood ( $N = 12,383$ ) characteristics were excluded. The selection of the study population is shown in Fig. S1 in the Supplementary Materials. In total, our study population included 8,741,021 people; of which 4,367,526 were men and 4,373,459 were women.

### 2.2. Residential mobility

We retrieved information on peoples' residential addresses and date of moving between January 1, 2007 and December 31, 2016 from the population register. People who did not move were categorised as non-movers; those who changed their address (once or multiple times) were movers. For people with multiple address changes during the study period we only considered the last recorded move before suicide, censoring (death by other cause, emigration) or end of follow-up. We assumed that the last residential relocation was most influential for subsequent change in people's health status. We recorded the moving frequency as the number of address changes between January 1, 2007 and December 31, 2016. For movers, we also distinguished between short-distance (within-municipality) and long-distance (between-municipality) moves.

### 2.3. Residential neighbourhood context

Residential neighbourhood characteristics were assessed annually between 2007 and 2016. We used neighbourhoods ('buurten') which represent small-scale administrative units with similar socioeconomic characteristics. To ease analytical complexity, we kept geographical boundaries fixed over time by using the 2007 neighbourhood division. In 2007, there were 11,406 neighbourhoods containing, on average, about 1,400 residents (Statistics Netherlands, 2011).

Following earlier studies (Hagedoorn et al., 2020; Hagedoorn and Helbich, 2021; Helbich et al., 2020), we included four neighbourhood characteristics. Green space was measured with the Normalized Difference Vegetation Index (NDVI) (Pettorelli et al., 2005). Multispectral remote sensing images with a 30 m resolution were retrieved from Landsat 5, Landsat 7, and Landsat 8 obtained via Google Earth Engine. The NDVI ranges from +1 (=green biomass) to -1 (=non-biomass). Per year, we included all available orthorectified and atmospherically corrected scenes covering the Netherlands during May to September; those with >40% cloud cover and a cloudiness score of >25 were excluded. We masked negative NDVI values to avoid distortions when calculating the annual mean NDVI values per neighbourhood.

Urbanicity, social fragmentation and deprivation were computed based on register data for the total Dutch population. We identified all residents living within a neighbourhood on January 1st of each year and aggregated their individual-level data. As done elsewhere (Helbich et al., 2017) urbanicity was operationalized as the number of people per km<sup>2</sup>. In line with previous research (Congdon, 2013; Hagedoorn et al., 2020), we measured social fragmentation through a composite index including three indicators: the share of unmarried; single-person households; and residential turnover (moves into the neighbourhood)

as a percentage of the total adult ( $\geq 18$  years) population. Each indicator was z-scored and summed to create an annual social fragmentation score, with higher scores referring to higher levels of social fragmentation. Neighbourhood deprivation was approximated through area-level unemployment rates calculated as the number of residents who were unemployed as a percentage of the labour force (working and unemployed persons aged 25–75).

### 2.4. Upward and downward neighbourhood change

We assessed neighbourhood change as neighbourhood improvement and deterioration from poor to good conditions and vice-versa (Blair, 2015). First, we categorised each neighbourhood characteristic into annual quintiles. Quintiles were constructed with an equal number of neighbourhoods per quintile, whereby the 1st quintile represents good conditions (i.e., high population density, high levels of green space, low social fragmentation, low deprivation), while the 5th quintile represents poor conditions. Second, we recoded the quintiles of neighbourhood characteristics into a binary variable whereby quintiles 1–3 represent good neighbourhood conditions and quintiles 4–5 represent poor conditions. Finally, for each neighbourhood indicator, we assessed neighbourhood change by comparing neighbourhood conditions at two time points. For non-movers, we compared conditions at baseline with those either at the date of death, date of emigration, or end of follow up. For movers, neighbourhood conditions before and after move were compared. Neighbourhood conditions before moving were assessed at baseline (for those who moved once) or start date of residence before relocation (for frequent movers); characteristics of the neighbourhood after move were assessed at the date of move. This resulted in four categories of neighbourhood change: 1) constant poor conditions (i.e. low population density, low levels of green space, high social fragmentation and high deprivation); 2) constant good conditions (i.e. high population density, high levels of green space, low social fragmentation and low deprivation); 3) change from good to poor conditions; and 4) change from poor to good conditions.

### 2.5. Individual-level characteristics

Next to age (in years) and sex (male, female), we adjusted for covariates associated with suicide risk (Li et al., 2011). Nationality was considered as a dummy variable (Dutch, non-Dutch). Marital status was categorised into married, never married, or not currently married. Household type was grouped as couple with children, couple without children, single parent, or other (i.e., mainly single households). Socioeconomic position was measured through employment status (employed, unemployed, non-working) and standardised household income which was divided into three categories (<€20,000, €20,000–35,000, and >€35,000). As a proxy for affective disorders (e.g., depression), we included antidepressants prescriptions (yes, no) classified as 'N06A' in the anatomical therapeutic chemical system.

We retrieved these register data for non-movers at baseline. For movers, these covariates were obtained at time of residential move to account for changes in individual characteristics that might be related to the residential move.

### 2.6. Statistical analyses

We generated descriptive tables and assessed differences in the distribution of suicide mortality by moving status and neighbourhood change using Chi<sup>2</sup> tests. To assess absolute differences in suicide mortality between non-movers and movers we calculated age-standardized mortality rates (ASMR). We used direct age standardization with the sex-specific age distribution of the Dutch population for 2007 as the standard population. Finally, we fitted Cox proportional hazards regression models (Box-Steffensmeier and Jones, 2004) to assess associations of suicide mortality with moving status and with

neighbourhood change. Person years for the Cox regressions were calculated from baseline to the date of death, censoring, or December 31, 2016, whichever occurred first. We report regression coefficients as hazard ratios (HRs) together with their 95% confidence intervals (CIs). Due to distinct gender differences in suicide (Hagedoorn et al., 2020; Turecki et al., 2019), we stratified all analyses by sex.

We fitted unadjusted and adjusted models controlling for moving status, moving frequency and individual-level covariates. All models were adjusted for age at baseline. To assess neighbourhood change for non-movers and movers, we refitted the adjusted models including an interaction term between moving status and neighbourhood change for each neighbourhood characteristic as well as stratified models by moving status. As sensitivity tests we fitted adjusted models for single and frequent moves and short- and long-distance moves. We also compared the outcomes of our adjusted models with models including neighbourhood conditions at baseline and with multilevel models. Likelihood ratio tests were used to compare the fit between models. Analyses were performed in Stata, version 14.

### 3. Results

#### 3.1. Descriptive statistics

Table S1 shows the distribution of population characteristics by suicide mortality and moving status. The majority of our study population ( $N = 5,728,076$ ; 66%) did not move. Among the movers ( $N = 3,012,967$ ), 64% did so once. Suicide was more common among non-movers. Chi<sup>2</sup> tests indicated that differences in the distribution of suicide mortality by moving status were statistically significant ( $p < 0.05$ ). The distribution across categories of neighbourhood change indicated that most people remained in stable neighbourhood conditions over time. Urbanicity was the most stable indicator as only 4% of the population experienced an upward or downward change. Deprivation changed most over time, with 14% of people experiencing deteriorating conditions, while 14% experienced improvements from high to low deprivation. Concerning green space and social fragmentation, 84% of the population had no neighbourhood change over time. A higher share of suicide deaths occurred in neighbourhoods without changing conditions. Neighbourhood change was more likely for movers compared to non-movers. Among movers, neighbourhood change tended to result in improved living conditions and increased rurality. Chi<sup>2</sup> tests indicated that differences in neighbourhood change by suicide mortality and moving status were statistically significant.

#### 3.2. Residential mobility and suicide risk

The ASMR and hazard ratios (HR) displayed in Table 1 indicate that suicide mortality differs significantly between movers and non-movers. Among men, non-movers have an ASMR of 173 (95% CI: 168–179) per 100,000 persons while movers have an ASMR of 131 (95% CI: 125–138). Among women, the ASMR also indicates absolute differences in suicide mortality between movers (ASMR 68; 95% CI: 63–72) and non-movers (ASMR 76; 95% CI: 72–79). In addition, the HRs indicate significant relative differences in suicide risk between movers and non-movers. In

the adjusted models, movers had a 46% lower risk of suicide than non-movers (HR men: 0.64, 95% CI: 0.59–0.70; HR women: 0.64, 95% CI: 0.57–0.74). Table 1. Hazard ratios of suicide mortality for non-movers and movers, stratified by sex.

#### 3.3. Neighbourhood change and suicide risk

Table 2 shows the associations of suicide with neighbourhood change with and without adjustment for moving status and other

**Table 2**  
Unadjusted and adjusted suicide hazard ratios for neighbourhood change, stratified by sex.

	Men		Women	
	Unadjusted	Adjusted	Unadjusted	Adjusted
<i>Urbanicity</i>				
No change: rural (ref.)	1.00	1.00	1.00	1.00
No change: urban	0.80 (0.72–0.88)	0.81 (0.73–0.89)	0.83 (0.71–0.97)	0.71 (0.61–0.83)
Change: urban to rural	0.68 (0.55–0.83)	0.89 (0.72–1.10)	0.62 (0.44–0.86)	0.70 (0.50–0.98)
Change: rural to urban	0.67 (0.53–0.85)	0.76 (0.60–0.97)	0.67 (0.47–0.96)	0.62 (0.43–0.89)
<i>Green space</i>				
No change: little green (ref.)	1.00	1.00	1.00	1.00
No change: green	1.03 (0.97–1.10)	1.06 (1.00–1.13)	1.06 (0.97–1.16)	1.14 (1.04–1.24)
Change: green to little green	0.96 (0.87–1.06)	1.04 (0.95–1.15)	0.95 (0.82–1.09)	1.00 (0.86–1.15)
Change: little green to green	0.91 (0.83–1.00)	1.06 (0.96–1.17)	1.03 (0.90–1.18)	1.17 (1.01–1.34)
<i>Social fragmentation</i>				
No change: high fragmentation (ref.)	1.00	1.00	1.00	1.00
No change: low fragmentation	0.79 (0.74–0.84)	0.96 (0.90–1.02)	0.66 (0.61–0.72)	0.82 (0.75–0.90)
Change: low to high fragmentation	0.78 (0.70–0.86)	0.94 (0.84–1.04)	0.87 (0.76–1.01)	1.04 (0.90–1.20)
Change: high to low fragmentation	0.63 (0.56–0.69)	0.82 (0.74–0.91)	0.61 (0.52–0.71)	0.78 (0.67–0.91)
<i>Deprivation</i>				
No change: high deprivation (ref.)	1.00	1.00	1.00	1.00
No change: low deprivation	0.85 (0.80–0.90)	0.98 (0.92–1.04)	0.83 (0.76–0.91)	0.97 (0.89–1.07)
Change: low to high deprivation	0.84 (0.78–0.90)	0.93 (0.86–1.00)	0.89 (0.80–1.00)	0.98 (0.88–1.10)
Change: high to low deprivation	0.79 (0.73–0.85)	0.87 (0.80–0.94)	0.84 (0.75–0.95)	0.93 (0.83–1.04)

Unadjusted models control for age; Adjusted models control for age, moving status, nationality, marital status, household type, employment status, income, antidepressant use, and moving frequency; ref. = reference category; 95% CI in brackets.

**Table 1**  
Age-standardized mortality rates (ASMR) and hazard ratios (HR) (95% confidence intervals) for suicide mortality by non-movers and movers, stratified by sex.

	Men			Women		
	ASMR	HR unadjusted	HR adjusted	ASMR	HR unadjusted	HR adjusted
<i>Moving status</i>						
Non-mover (ref.)	173 (168–179)	1.00	1.00	76 (72–79)	1.00	1.00
Mover	131 (125–138)	0.68 (0.65–0.72)	0.64 (0.59–0.70)	68 (63–72)	0.83 (0.77–0.90)	0.64 (0.57–0.74)

ASMR per 100,000 persons, standardized using the sex-specific Dutch population in 2007 as the standard population; Unadjusted models control for age; Adjusted models control for age, nationality, marital status, household type, employment status, income, antidepressant use, and moving frequency; ref. = reference category; 95% CI in brackets.

covariates for men and women. With the exception of green space, unadjusted models show that remaining in stable good conditions as well as experiencing upward neighbourhood change is associated with lower suicide mortality, compared to remaining in stable poor conditions. Including moving status, moving frequency and the individual covariates in the adjusted models attenuated much of these neighbourhood change-suicide associations, although significant associations remained. Neighbourhood change from rural to urban is associated with significant reductions in suicide risk compared to those remaining in rural conditions, just as urban to rural change for women. Further, men and women experiencing no change in urbanicity have a 19% and 29% lower suicide risk in urban compared to rural neighbourhoods (HR men: 0.81, 95% CI: 0.73–0.89; HR women: 0.71, 95% CI: 0.61–0.83). Women living in neighbourhoods with high levels of green or experiencing an increase in green space have a 14% (HR: 1.14, 95% CI: 1.04–1.24) and 17% (HR: 1.17, 95% CI: 1.01–1.34) higher suicide mortality respectively, compared to those having stable low levels of green. Men and women experiencing neighbourhood improvement from high to low social fragmentation have a 18% and 22% lower risk of suicide respectively compared to those remaining in poor conditions (HR men: 0.82, 95% CI: 0.74–0.91, HR women: 0.78, 95% CI: 0.67–0.91). Women without neighbourhood change but low levels of social fragmentation have significantly lower suicide mortality as well. Compared to remaining in deprived neighbourhood conditions, improvements in deprivation are associated with a lower suicide risk for men (HR: 0.87, 95% CI: 0.80–0.94). Adding baseline neighbourhood conditions to the models did not alter our findings and resulted in collinearity with neighbourhood change. Multilevel analyses gave similar results and did not show substantially improved model fits compared to regular models (results not shown).

### 3.4. Neighbourhood change and suicide risk by moving status

Interactions between neighbourhood change and moving status were significant (results not shown), so we stratified the adjusted model for neighbourhood change by moving status (Fig. 1; Table S2). Stratifications revealed that several of the aforementioned associations between neighbourhood change and suicide mortality are observed for non-movers but not for movers. Suicide mortality among non-movers experiencing no neighbourhood change was significantly lower in urban vs. rural neighbourhoods and significantly higher in green vs. non-green neighbourhoods. In addition, female suicide mortality was 20% lower

for non-movers with unchanged high vs. low levels of fragmentation (HR: 0.80, 95% CI: 0.72–0.89). For those in socially fragmented neighbourhoods, neighbourhood improvements were associated with a 26% and 35% lower risk of suicide among men and women respectively (HR men: 0.74, 95% CI: 0.63–0.86; HR women: 0.65, 95% CI: 0.51–0.82). Compared to those living in constant deprivation, men experiencing neighbourhood improvement had a 18% lower suicide mortality (HR: 0.82, 95% CI: 0.74–0.91), while those experiencing deterioration had a 12% lower suicide risk as well (HR: 0.88, 95% CI: 0.81–0.97). With the exception of deprivation, suicide was not associated with neighbourhood change among movers. For those moving to neighbourhoods with similar levels of deprivation, female suicide risk was 19% lower if the move was between affluent vs. deprived neighbourhoods (HR: 0.81, 95% CI: 0.67–0.98). Interactions between neighbourhood change and moving frequency or moving distance were non-significant (results not shown).

## 4. Discussion

### 4.1. Main findings

Our study showed that movers had a significantly lower absolute and relative risk of suicide mortality compared to non-movers, which contrasted our first hypothesis. Confirming our second hypothesis, compared to people remaining in neighbourhoods with high social fragmentation and deprivation, neighbourhood change towards low social fragmentation and deprivation was associated with lower suicide mortality. Continuous residence in green neighbourhoods and an increase in green space was unexpectedly associated with a higher risk of death by suicide among women. We observed significant interactions between neighbourhood change and moving status. Associations between neighbourhood change and suicide were more pronounced among non-movers, rejecting our third hypothesis.

### 4.2. Explanation of findings

Residential mobility has been associated with an increase in suicide risk, although previous studies either looked at adolescent suicide attempts (Haynie et al., 2006; Potter et al., 2002; Qin et al., 2009; Webb et al., 2016) or used ecological study designs (Stack, 1980, 1981). Contrary to these findings, our study on adult suicides observed a 46% lower suicide risk among movers compared to non-movers, after

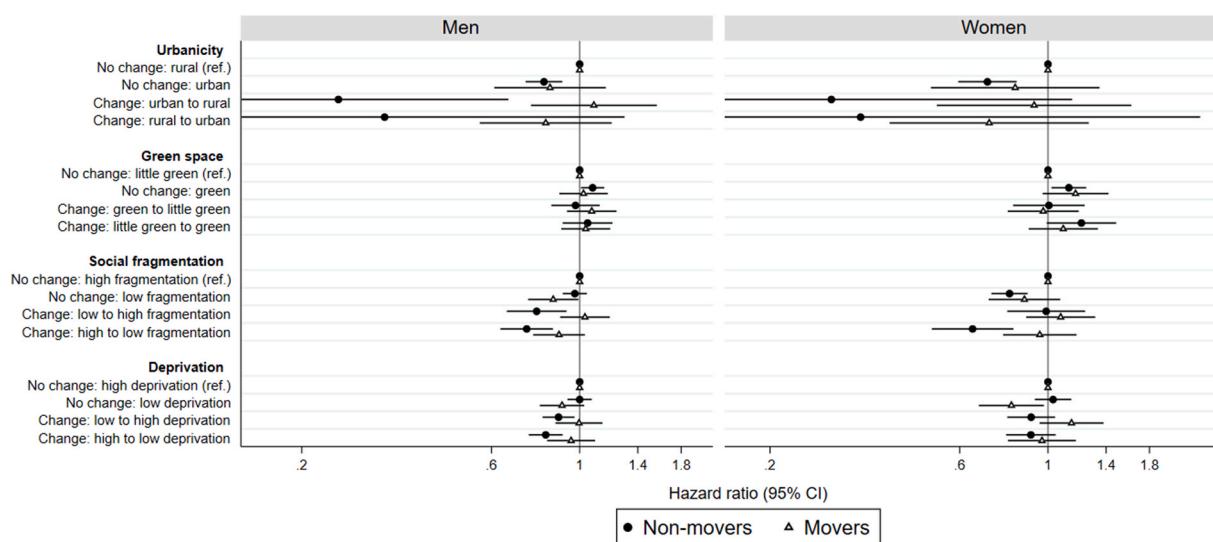


Fig. 1. Adjusted suicide hazard ratios for neighbourhood change stratified by moving status and sex. Models were adjusted for age, nationality, marital status, household type, employment status, income, antidepressant use, and moving frequency; ref. = reference category.

adjusting for individual-level confounders and antidepressant use at baseline. Yet, this is unlikely due to a “healthy migrant effect” (Morris et al., 2017) as our descriptive statistics showed a higher proportion of antidepressant users among movers, complementing previous findings that movers were more likely to have poor mental health (Lix et al., 2006; Tunstall et al., 2014). Although this seems contradictory, it might be explained by temporal changes in subjective wellbeing associated with residential mobility (Nowok et al., 2013). Preceding their residential move, movers experienced a decline in subjective wellbeing, possibly related to changes in life circumstances or dissatisfaction with their place of residence (Nowok et al., 2013; Tunstall et al., 2014). After moving, their subjective wellbeing received a boost which restored their happiness to the original level (Nowok et al., 2013).

Movers have the capacity to move out of negative life circumstances or undesired neighbourhood environments (Nowok et al., 2013; Tunstall et al., 2014), which might explain why they have a lower suicide risk compared to non-movers. Experiencing residential ‘entrapment’, i.e. wanting to move but not being able to, puts people at risk for mental disorder (Woodhead et al., 2015). As feelings of entrapment are among the determinants of suicidal behaviour (O’Connor and Kirtley, 2018), residential entrapment might contribute to the observed differences in suicide risk between movers and non-movers. Further, ‘selective entrapment’ might occur if non-movers cannot make a desired move as a result of poor (mental) health (Woodhead et al., 2015) or lack of socioeconomic resources (Coulter et al., 2011), factors which are also associated with an increased suicide risk (Turecki and Brent, 2016).

Our findings indicated that positive changes in neighbourhood conditions were related to a lower risk of suicide mortality, albeit only for non-movers. Therefore, it seems unlikely that social selection of movers into better neighbourhood conditions played a major role in the lower suicide risk observed for movers. We further observed that for non-movers in stable neighbourhood conditions, suicide mortality depended on whether they lived in neighbourhoods with poor or good conditions. This suggests that long-term exposure to certain neighbourhoods might have mental health effects, as implied by social causation (Jokela, 2014). Compared to those in neighbourhoods with high social fragmentation, suicide mortality was lower for men and women experiencing a decrease in social fragmentation and for women living in neighbourhoods with stable low social fragmentation. This might indicate that these neighbourhoods provide more opportunities for social support and local social contacts (Ivory et al., 2011). We further observed that men experiencing a decrease in neighbourhood deprivation had a 18% lower suicide risk. This corroborates earlier research indicating that improvements in neighbourhood deprivation among non-movers resulted in better health and lower mortality (Boyle et al., 2004; Xiao et al., 2018) and a lower risk of mental disorders (Kivimäki et al., 2021). However, contrary to our findings for suicide, Blair et al. (2015) observed no association between distress and improved material conditions or with decreased social deprivation. Lower suicide mortality in neighbourhoods with urban vs. rural conditions and among movers from rural to urban neighbourhoods might be related to established rural risk factors for suicide such as social isolation, access to means, stigmatisation, and lower access to mental health care facilities (Hirsch and Cukrowicz, 2014). For suicide-green space associations the pathways are under debate, with insufficient evidence suggesting null associations (Helbich et al., 2020; Mitchell and Popham, 2008). Although there is some evidence of beneficial effects of green space on mental health (Yang et al., 2021), our findings suggest a significantly higher suicide risk among women living in green vs. non-green neighbourhoods and women experiencing an increase in neighbourhood green space. This is in line with previous research reporting poor mental health among movers to neighbourhoods with improved physical conditions (Tunstall et al., 2014). As urban-rural differences in suicide as green space and urbanicity were correlated ( $r = 0.7$ ;  $p < 0.01$ ), we cannot exclude that this association reflects low levels of green space in urban neighbourhoods where suicide risk is

significantly lower among women.

The favourable effect of neighbourhood improvement on suicide for non-movers might indicate that this group is less able to escape from poor neighbourhood conditions and may benefit from planning-induced neighbourhood change. Further research is necessary to explore why non-movers have a higher suicide risk and to what extent factors such as entrapment, moving desires and neighbourhood preferences play a role. In addition, more research is necessary into underlying mechanisms that gain insight into what drives neighbourhood-suicide associations.

#### 4.3. Strengths and limitations

Our study has several strengths. While it is well-established that the residential neighbourhood context is intertwined with suicide (Cairns et al., 2017; Rehkopf and Buka, 2005), we are not aware of any other study looking into the effects of neighbourhood change on suicide mortality. A key analytical strength is the use of detailed longitudinal register data over 10 years for the entire Dutch population with nationwide movement patterns. The large dataset ensured that our models were statistically well-powered, which is key for rare events like suicide (Gibbons, 2013). Although our observational design cannot rule out residential self-selection, the availability of several individual-level variables and the inclusion of multiple neighbourhood exposures minimised the risk. Our neighbourhood characteristics comprised the full spectrum of physical, social, and socioeconomic contextual circumstances identified previously (Cairns et al., 2017; Diez Roux and Mair, 2010; Hirsch and Cukrowicz, 2014). Although each domain is often studied independently (Diez Roux and Mair, 2010), we acknowledged that multiple facets of the neighbourhood environment are spatially correlated (Rugel and Brauer, 2020) possibly having synergistic effects (Diez Roux and Mair, 2010). Continuously recorded residential address histories allowed us to reconstruct people’s residential address trajectories, to classify moving status, and number of moves accurately. By studying both movers and non-movers we differentiated between effects of neighbourhood change as a result of residential moving and changes in residential environments itself. While some studies excluded frequent movers (Green et al., 2017; van Lenthe et al., 2007), we maintained them in our analyses which reduced the risk of selection bias as frequent moving was associated with poor health and socioeconomic disadvantage (Larson et al., 2004).

Notwithstanding these strengths, our study had limitations. Administratively collected register data are constrained by the number of individual-level variables. Because we lacked data on moving reasons, residential preferences, etc., we cannot rule out that residential self-selection might be at play, although effects were found to be minor (James et al., 2015). Although we adjusted for baseline mental health based on prescribed antidepressants, we lacked data on other diagnosed and undiagnosed mental health problems. Mild and non-diagnosed mental health problems remained unrecognized. Consequently, we were only partially able to adjust for health-related selective migration. However, previous research reported higher rates of residential mobility among people with mental illness (Lix et al., 2006; Tunstall et al., 2014) which would not explain the lower suicide risk among movers. In addition, selective migration based on poor mental health was deemed to be minor (Airaksinen et al., 2016b; Larson et al., 2004; Tunstall et al., 2014). As individual characteristics were assessed at baseline, we cannot exclude that changes in socioeconomic characteristics occurred over time. Future research should incorporate changes in antidepressant use over time to assess mental health changes before and after moving as well as changes in mental health over time for non-movers. We defined neighbourhood change by comparing neighbourhood characteristics across two time points, neglecting more complex long-term neighbourhood dynamics. Future studies might apply latent class analysis or trajectory analysis in order to model neighbourhood trajectories, although these can also misclassify complicated trajectories and frequent movers (Shackleton et al., 2018). In addition, trajectories might differ by

neighbourhood characteristic, complicating the assessment of multiple aspects of the neighbourhood environment. Despite our full population analysis, a more fine-grained change in neighbourhood conditions (e.g. going from medium to good conditions) led to insufficient statistical power for some categories and model convergence partially failed. Finally, criticism concerning the meaningfulness of administrative neighbourhoods to delineate the geographic context remains (Flowerdew et al., 2008; Helbich, 2018). However, earlier work demonstrated no substantial differences between administrative neighbourhoods and individualised buffers centred on address locations (Hagedoorn et al., 2020).

## 5. Conclusion

This study indicated that suicide mortality was associated with both residential mobility and neighbourhood change. We observed a significantly lower suicide risk for movers and for people experiencing improvements in neighbourhood social fragmentation and deprivation, as well as increased urbanicity, compared to people remaining in poor and rural conditions. For those with stable neighbourhood conditions, suicide mortality was lower in neighbourhoods with high urbanicity and low social fragmentation. Stratification by moving type revealed that associations between neighbourhood change and suicide were more pronounced in non-movers. Non-movers might be more reliant on external or policy-induced neighbourhood improvements for health gains. Neighbourhood regeneration programmes and public health policies should aim especially at improving the social and socioeconomic environment in neighbourhoods with long-term poor conditions in order to improve mental health and reduce suicide mortality among residents.

## CRedit

Paulien Hagedoorn: Data Curation, Conceptualization, Methodology, Formal analysis, Visualization, Writing - Original Draft. Marco Helbich: Conceptualization, Methodology, Writing - Review & Editing, Project administration, Funding acquisition.

## Data availability statement

The data used in this analysis cannot be shared with third parties as per the policies of Statistics Netherlands. Dutch privacy legislation permits, under strict conditions, the use of linked microdata for statistical and scientific research.

## Declaration of competing interest

The authors have no conflict of interest to declare.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.socscimed.2021.114690>.

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