INTRODUCTION

Environmental exposures during early life can influence the development and health of a child. While numerous studies have shown the harmful effects of environmental chemical exposures on children’s development and health, the impacts of housing environments—such as which storey of the building the residence is located on—are remarkably under-examined. This is despite the fact that the home environment is critical to children’s development and health, since they spend most of their time at home.

In Japan, the development of super high-rise buildings—defined as buildings with 20 or more storeys—has begun specifically in the greater Tokyo area. From 1990 to 2003, the proportion of super high-rise buildings to the total number of residential buildings and units increased nearly six-fold. In addition, approximately one in four of the families living in a super high-rise building had a child below the age of 12.
ever, thus far, the impact of high-rise living has mainly been investigated among the elderly and adult female populations from the perspective of mental health\textsuperscript{12–18}). These studies have indicated that high-rise living led to inactivity, deteriorated their social life and mental health\textsuperscript{13}).

Thus, it has been hypothesized that children living in a high-rise building or in the upper storey of a building might have development and health problems. More specifically, the height of living environment itself might have an effect on child development as early exposure in the high-rise living can be considered as spatial neglect of ground and thus might affect on spatial cognition\textsuperscript{19}). Further, high-rise living environment might induce reluctance to going out for parents and children, which leads to inactivity and less social life. The present paper reviews the literature on the relationship between high-rise living and children’s development and health.

**METHODS**

We conducted two separate searches for relevant, original articles in English and Japanese. For English articles, we used PubMed to search MEDLINE and identified studies from 1960 to 2008 which focus on high-rise living and the associated child development problems or diseases. The primary key word used to extract the relevant articles was ‘high-rise’. The title, abstract, and text of each article were examined to determine whether it was relevant. The references listed in the extracted articles were also searched to collect additional studies. To obtain original Japanese studies, we used the key word ‘ko-so’ (Japanese word for ‘high-rise’) to search ‘Ichushi-Web’ for studies dated 1983–2008, excluding meeting reports. Only original papers (not review articles) were selected.

**RESULTS**

We retrieved 253 English articles from PubMed, of which 2 were considered to be relevant\textsuperscript{12,20}). Three additional studies were obtained through the references listed in the articles\textsuperscript{13,21,22}). Finally, another 5 studies were collected from the references listed in these 3 studies\textsuperscript{23–27}). Of the 10 articles, 8 papers met the criteria (i.e. original paper which investigate the impact of high-rise living) for the literature review\textsuperscript{20–27}). For Japanese studies, we retrieved 55 papers from Ichushi-Web, of which 2 were found to be relevant\textsuperscript{28,29}). In total, 10 original English and Japanese studies were selected for the review (see Table 1).

The relationship between high-rise living and child development was first indicated by Fanning in a 1967 paper published in British Medical Journal\textsuperscript{21}). Thereafter, several papers on this subject were published in the 1970s\textsuperscript{23–25}) and 1980s\textsuperscript{20,22,26,27}); however, only 2 papers—both of which are in Japanese—have been published since the 1990s\textsuperscript{28,29}). The countries covered by these studies include the U.K. the U.S.,\textsuperscript{22}) Israel,\textsuperscript{26}) Australia,\textsuperscript{27}) and Japan\textsuperscript{20,28,29}). These studies surveyed children from infants to 13-year-old teenagers, and they employed cross-sectional analyses as the study design. The studies adopted 2 perspectives: the effect of living in a high-rise building as compared to that of living in a low-rise building or detached house\textsuperscript{21–26,29}) and the effect of the storey on which the flat is located\textsuperscript{20,27,28}). The children’s development and health measured in the studies included incidences of illness, development, and play habits.

The evaluation methods varied from study to study: they were largely based on mothers’ reports or objective evaluations using established scales. Only 1 study adjusted for socioeconomic factors\textsuperscript{27}) and 2 studies adjusted for the socio-
<table>
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<tr>
<th>Author, year</th>
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<th>Measured outcome</th>
<th>Main results</th>
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<tr>
<td><strong>Living in high-rise buildings vs. living in low-rise buildings</strong></td>
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<td>Fanning, 1967(21)</td>
<td>U.K.</td>
<td>Mothers and children (aged 0–4, 5–9) living in 3- or 4-storey flats (A) and detached houses (B)</td>
<td>1,163 (A) and 445 (B)</td>
<td>Cross-sectional</td>
<td>Flats vs. detached housing</td>
<td>Total number of consultations with a doctor</td>
<td>Children living in flats consulted with a doctor more often (odds ratio: 2.6, 95% CI: 1.7–3.9). With other confounding factors are not adjusted for, the direct effects of living in a flat are unclear.</td>
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<td>Ineichen &amp; Hooper, 1974(23)</td>
<td>U.K.</td>
<td>Married mothers</td>
<td>262</td>
<td>Cross-sectional</td>
<td>High-rise vs. non-high-rise flats</td>
<td>Children’s behaviour problems reported by mothers</td>
<td>43% of mothers living on upper storeys recognized behaviour problems in their children, double the rate for other residence types (odds ratio: 3.6, 95% CI: 1.9–6.8). With other confounding factors not adjusted for, the direct effects of living in a flat are unclear.</td>
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<tr>
<td>Richman, 1974(24)</td>
<td>U.K.</td>
<td>3-year-old children in families with 2 children aged &lt; 5 years</td>
<td>75</td>
<td>Cross-sectional</td>
<td>Comparisons among high-rise flats (≥ 4 storeys), low-rise flats (≤ 3 storeys), or detached housing</td>
<td>Semi-structured interviews (Behaviour Screening Questionnaire)</td>
<td>Behaviour problems exhibited by 16% of children living in high-rise flats; 28%, in low-rise flats; and 29%, in detached houses ($\chi^2 = 1.5$, not significant) Although socioeconomic factors were not different between the 3 groups, other possible confounders, such as social support, were not adjusted for.</td>
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<tr>
<td>Richman, 1977(25)</td>
<td>U.K.</td>
<td>Families with 3-year-old children; random sampling from total population</td>
<td>705</td>
<td>Cross-sectional</td>
<td>High-rise flats vs. all residence types</td>
<td>Semi-structured interviews (Behaviour Screening Questionnaire)</td>
<td>Behaviour problems were prevalent among 30% of the children living in high-rise flats as compared to 14% of the children in the total sample ($p &lt; 0.01$). With other confounding factors not adjusted for, particularly socioeconomic status, the direct effects of living in a flat are unclear.</td>
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<tr>
<td>Saegert, 1982(22)</td>
<td>U.S.</td>
<td>Elementary school children from low-income families</td>
<td>312</td>
<td>Cross-sectional</td>
<td>High-rise (14-storey) vs. low-rise (3-storey) flats; random assignment</td>
<td>1. Behavioural adjustment rate by teachers (on a behaviour rating scale) 2. Reading achievement scores from school records</td>
<td>1. Among boys, the total behavioural disturbance score of those living in high-rise and low-rise flats was 17.9 and 11.7 respectively for buildings in low-density areas, and 22.5 and 16.3 respectively for building in high-density areas. 2. No single pattern was observed between children living in high-rise and low-rise flats with respect to reading achievement scores. Among low-income families, high-rise living may be associated with behaviour problems among boys.</td>
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</table>
Table 1. (continued) Results of a systematic review of the literature on the relationship between high-rise living and children’s health, development, and play habits (sorted by study perspective and publication year)

<table>
<thead>
<tr>
<th>Author, year</th>
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<tr>
<td>Churchman &amp; Ginsberg, 1984(26)</td>
<td>Israel</td>
<td>Mothers and children (aged 2–13) in middle-class neighbourhoods</td>
<td>168</td>
<td>Cross-sectional</td>
<td>High-rise (8 to 20 storeys) vs. low-rise (3 to 5 storey) flats</td>
<td>Playing time outdoors, structured interview with the mothers</td>
<td>For those living in high-rise flats, only children aged 4–5 went outdoors alone to play: 33% of those living in an 8-storey building, 42% of those living in a 12-storey building, and 62% of those living in a 16–20-storey building did not play alone outdoors.</td>
<td>High-rise living imposes behavioural restrictions only on children of an age at which they are allowed to go outside alone.</td>
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<tr>
<td>Oda et al., 1999(29)</td>
<td>Japan</td>
<td>Elementary school children aged 10–12</td>
<td>94 residents of high-rise flats and 339 residents of non-high-rise flats</td>
<td>Cross-sectional</td>
<td>High-rise flats (mean number of storeys: 9.2) vs. non-high-rise flats (mean number of storeys: 2.5)</td>
<td>Consciousness on playing</td>
<td>Those living in non-high-rise flats expressed a desire for more playtime (80.5%) in comparison with those living in high-rise flats (73.1%, p &lt; 0.05). Similarly, a greater number of those in the former group (60.2%) expressed a desire for playmates as compared with those in the latter group (51.0%, p &lt; 0.05).</td>
<td>Outcome measurements were not objective, and possible confounders were not adjusted for in the statistical analysis.</td>
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<tr>
<td>Homel &amp; Burns, 1989(27)</td>
<td>Australia</td>
<td>Children aged 9–11 (stratified random sampling from an overall sample)</td>
<td>321</td>
<td>Cross-sectional</td>
<td>1st floor vs. 2nd or higher floors</td>
<td>Emotional/social adjustment (on the basis of a scale developed by the U.S. Foundation for Child Development)</td>
<td>There was no difference between residents of different storeys in terms of emotional/social adjustment.</td>
<td>Given the study's adjustment for socioeconomic factors and the generalizability of its sample, the results are convincing. However, the effects of living in a high-rise building (e.g. a 20-storey building) remain unclear.</td>
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<td>Oda et al., 1989(20)</td>
<td>Japan</td>
<td>Mothers with infants or kindergarteners</td>
<td>169 infants and 876 kindergarteners</td>
<td>Cross-sectional</td>
<td>Comparisons among lower (1–5), middle (6–13), or upper (14–23) storeys</td>
<td>Independence of children with respect to fundamental daily customs</td>
<td>Infants living on the upper storeys had greater inability to greet people, go to the toilet, brush their teeth, gargle, or get dressed than those living on the lower storeys (p &lt; 0.05). No significant difference was observed among the kindergarteners.</td>
<td>With other confounding factors not adjusted for, the direct impact of the storey on which flat is located is unclear.</td>
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High-rise living and child health: Review

Table 1. (continued) Results of a systematic review of the literature on the relationship between high-rise living and children’s health, development, and play habits (sorted by study perspective and publication year)

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<tbody>
<tr>
<td>Oda et al., 1999(28)</td>
<td>Japan</td>
<td>Mothers of 1-year-old to 12-year old children living in 30-storey buildings</td>
<td>176</td>
<td>Cross-sectional</td>
<td>Comparisons among lower (1–5), middle (6–13), and upper (14–29) storeys</td>
<td>Consciousness on playing</td>
<td>1. Among the children aged 10–12, 6.5%, 13.0%, and 29.4% of those living on the lower, middle, and upper storeys, respectively. 2. Average playtime for children living on the lower, middle, and upper storeys was respectively 92.7, 88.9, and 84.7 min daily.</td>
<td>While the results were compared on the basis of the storey on which a resident’s flat was located, sufficient statistical analyses were not performed.</td>
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</table>

Economic status of the subjects by limiting the sample to people from low- or middle-income classes22,26. In brief, 8 of the papers suggested that living in a high-rise building or on the upper storeys might impair children’s health, development, or play habits20–23,25,26,28,29 whereas 2 rejected the relationship24,27.

High-rise buildings vs. low-rise buildings or detached houses

Fanning21 reported that for children aged 0–4, the doctor consultation rate was higher for those living in high-rises than for those living in detached houses (668.4 vs. 438.0 per 1,000 children, respectively). The odds ratio, although not presented in Fanning’s paper but calculated by the author (TF), was 2.59 with a 95% confidence interval (CI) of 1.70–3.93, indicating a significant difference ($P < 0.001$). However, Fanning didn’t adjust for socioeconomic factors. It is well known that poor people are more likely to live in flats and that poverty leads to illness30. Moreover, it has been indicated that the incidence of neurosis is higher in mothers who live in flats (rather than detached houses) and on the upper storeys of a building, which might be due to the loneliness caused by the restrictions arising from living in a flat12. In particular, this might make them more sensitive to their children’s symptoms, which leads them to take their children to a hospital more often.

The effect of high-rise living on the development of behaviour problems in children has also been investigated. Ineichen and Hooper23 showed that mothers living in a high-rise more likely recognized behaviour problems in their children than mothers living in other types of residences (OR: 3.63, 95% CI: 1.82–6.83; TF calculated this on the basis of relevant data provided in the reference section)31. However, several limitations of the study should be noted. First, the type of high-rise building in which the subjects lived remained unclear. Second, the study did not consider those living on the lower storeys in the same buildings. Finally, the study did not adjust for socioeconomic factors.

In 2 papers24,25 focusing on the effect of high-rise living on the development of behaviour problems in children, Richman used a validated scale (Behaviour Screening Questionnaire [BSQ]) instead of mothers’ reports for the analyses. In one study24, there were no significant differences among three groups (high-rise building, low-rise building, or detached house). However, it should be noted that the study found the overall incidence of behaviour problems to be 21.4%,
higher than the 13% found by other studies using the same interview method\(^3_2\), suggesting the possibility of selection bias.

Using a previously conducted population-based survey, Richman’s next study investigated the effects of familial and social factors—including those of high-rise housing—on problematic behaviour in 3-year-old children\(^2_5\). The study reported that behaviour problems were prevalent among 30% of the children living in high-rises as opposed to among 14% of the children in the total sample (\(P < 0.01\)). However, since the main explanatory variable in the study was not high-rise housing, its description and analysis were insufficient for our review. Further, the study did not adjust for socioeconomic and other confounding factors, including mothers’ mental health.

Saegert\(^2_2\) measured behaviour problems on the basis of teachers’ ratings. One of the strengths of this study was that by taking advantage of the fact that new residents were randomly assigned to vacant buildings by the government for low-income families, it achieved successful randomization of residential environments. The study found that at least among low-income families, high-rise living may be associated with behaviour problems in children. That is, among boys, the total behavioural disturbance score of those living in high-rise and low-rise flats was 17.9 and 11.7, respectively, for buildings in low-density areas, and 22.5 and 16.3, respectively, for buildings in high-density areas (statistical analysis unavailable). Girls did not show a similar pattern.

Churchman and Ginsberg\(^2_6\) examined the impact of high-rise living on Israeli children’s play habits. In Israel, people below the middle-income class cannot afford to live in high-rise buildings. Therefore, the study could adjust for socioeconomic factors by simply selecting subjects who lived in high-rises. The results revealed that the greater the number of storeys, the more restricted were the children with respect to playing outdoors: 33%, 42%, and 62% of the children living in 8-storey, 12-storey, and 16- to 20-storey buildings had some restriction imposed on them. The significance of the differences is unknown.

In Japan, Oda \textit{et al.}\(^2_9\) reported the demand for playtime by children: the children not living in high-rises (80.5%) expressed the desire for more playtime than those living in high-rises (73.1%, \(P < 0.05\)). In addition, the demand for playmates was higher in the former group (60.2%) than in the latter group (51.0%, \(P < 0.05\)). However, the study did not adjust for socioeconomic status or other possible confounders such as the number of friends.

**Number of storeys**

Unlike the studies discussed above, Homel and Burns\(^2_7\) evaluated the health effects of high-rise residences on the basis of the storey on which a flat was located. In Sydney, Australia, they selected 321 families with 9- to 11-year-old children by using a stratified random sampling method. The results showed no relationship between living on the second or upper storeys and the presence of emotional/social adjustment problems.

Oda \textit{et al.}\(^2_9\) showed infants living in the upper storeys are likely to show delayed development with respect to basic daily customs. Similar study reported that the both mothers and children tended to become more reluctant to go outdoors as the number of storeys increased\(^2_8\). However, socioeconomic factors were not adjusted.

**DISCUSSION**

On the basis of 10 studies from the 1960s to the 1990s, we conducted a systematic review of the literature on the relationship between high-rise living and children’s development and health. No paper on this theme has been
published in the past 10 years. All of the above studies had adopted a cross-sectional design, but only one study adjusted for socioeconomic factors through multivariate analysis. Moreover, the children’s development and health were measured largely on the basis of mothers’ reports. Notwithstanding the limitations, 8 of the papers suggested that high-rise living impairs a child’s health, development, and play habits. It has also been suggested that this relationship is particularly notable in boys but becomes weak with increasing age. Specifically, in one randomized study,22) behavioural disturbance was more likely found among boys living in high-rise and low-rise flats, but not among girls.

First, since many of these studies were conducted in the 1970s and used samples from Western countries, it is necessary to identify the value that was placed on “living” in the 1970s in such countries. In Japan, this decade corresponded to a period of rapid economic growth, when many people regarded a high-rise residence as a status symbol.33) According to one paper, a similar trend was observed in Israel.26) Thus, given the possibility that the decision to live in a high-rise was a result of social trends, it is necessary to investigate how individuals’ decision to live in a high-rise building was affected by social trends. For instance, it is likely that those who lived in a super high-rise building owing to its significance as a status symbol (i.e. those susceptible to social trends) would be able to easily identify problems regarding the social development of their children. In this case, high-rise housing itself would not have directly affected child development. In short, the previous studies did not sufficiently adjust for confounding factors such as the reason why people chose to live in a high-rise. Another confounding factor to take into account is the effect of high-rise living on mothers’ mental health, a theme that was addressed in various papers.12,13)

Furthermore, since the studies adopted a cross-sectional design, they could not adequately determine causal relationships because the results may have represented reverse causation: the delayed development or introverted personality of a child may have caused the family to live in a high-rise building. Thus, it is necessary to conduct a prospective study that follows newly married couples over 3 or 4 years to observe their newborns’ development; the storey on which their flat is located should be designated as the exposure. Nevertheless, since there will still remain a possibility that the parents’ preference for living on an upper storey will genetically affect the development of their children, a decisive causal relationship cannot be established. While a randomized, controlled study can be considered, it would not be acceptable from an ethical standpoint. In this sense, Saegert22) — in which subjects living in high- or low-rise buildings were randomly chosen — may be a good example to follow. However, in the situation studied by Saegert, the subjects tend to belong to low-income families, which inevitably lead to sampling bias. Practically speaking, the only alternative is a prospective cohort study to demonstrate the relationship between the storey on which a flat is located and child development and health.

Ideally, children’s development and health should be directly measured on the basis of validated scales. While mothers’ reports are essential in the case of very young children, validated scales should be used concurrently even in such a case. Specifically, behaviour problems in children should be quantitatively evaluated by employing scales such as the Child Behavior Checklist (CBCL), which is a gold standard for assessing 2- to 3-year-old children’s behaviour.34) Other scales have also been developed which should be considered when evaluating children’s develop-
ment and health. These include the Early Coping Inventory (ECI), which is used to evaluate children’s daily customs\textsuperscript{35}, and the Bayley Scales of Infant Development (BSID), an international standard pertaining to child development\textsuperscript{36}. Additionally, it is necessary to examine children’s athletic performance, since high-rise living might lead them to have a sedentary lifestyle\textsuperscript{28}.

The previous studies confused the effects of living in a high-rise building with those of living on an upper storey. In the future, the impacts of living in high-rises—which may be dependent on the density of the area where the building is located—should be first evaluated in comparison with the impacts of living in low-rise buildings. This can be accomplished by investigating the health impacts per storey within a single high-rise building. Further, previous papers did not present the definition of high-rise buildings or the minimum number of storeys required to designate a building as a high-rise. Since certain studies were based on the hypothesis that living on an upper storey makes people reluctant to go outdoors, “high-rise” should be defined precisely and the minimum number of storeys required to make residents feel reluctant to go out should be discussed.

RECOMMENDATION

In light of these findings, future studies should adopt a design that meets the following criteria:
- A prospective cohort study (preferably with follow-up starting before pregnancy) is carried out.
- Socioeconomic factors are adjusted.
- Mothers’ mental health is measured and adjusted on an established scale.
- Reasons underlying the decision to live in a high-rise building are included.
- A valid definition of “high-rise” is presented.
- Preferably, data on the temperament of the parents are included.
- Residents in low-rise buildings and detached houses are recruited as the control group.
- The children’s development and health are evaluated using an established scale such as CBCL, ECI, or BSID.

In conclusion, our systematic literature review indicates that there is insufficient evidence showing the impacts of high-rise living on children’s health and development. Further investigations are necessary to determine whether living in high-rise residences—particularly super high-rise residences, which are increasing in number in Japan—affects children’s development and health.

ACKNOWLEDGEMENT

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REFERENCES

High-rise living and child health: Review