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Title: Current and future research on the influence of parental physical activity on children’s physical fitness

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Abstract

Physical fitness in childhood consequently affects and determines the risk of acquiring non-communicable diseases in adulthood. Therefore, it is important for children to acquire adequate physical fitness during childhood. It has been reported that children’s physical fitness is related to environmental factors, and one of this is their parents’ health-related lifestyle. This review introduces the findings of the association between parental physical activity and children's physical fitness. Additionally, we introduced the research conducted by our laboratory on mothers’ physical activity, which is expected to have a greater impact than that of the fathers. Finally, we provide a research plan in progress on the association between maternal physical activity and children’s physical fitness through an adjunct study of the Japan Environment and Children’s Survey, in which our laboratory is participating.

Keyword

physical fitness, children, parental physical activity, pregnancy
タイトル：子どもの体力に対する親の身体活動の影響についての研究の現状とこれから

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抄録:
子どもの頃の体力は、成人期以降の体力の規定因子となるとともに、将来の生活習慣病の危険因子であるため、子どもの頃に十分な体力を獲得することが重要である。子どもの体力は、環境要因と関連することが報告されており、環境要因の一つとして親の生活習慣がある。本レビューでは、初めに親の身体活動と子どもの体力の関連についてこれまで得られている知見を紹介する。さらに、父親と比べてより影響が大きいことが予想される母親の身体活動について、我々の研究室が行った研究を紹介する。最後に、我々の研究室が参画している「子どもの健康と環境に関する全国調査」（エコチル調査）の追加調査における母親の身体活動と子どもの体力に関する研究について、現在進行中の研究計画を述べる。
Introduction

Physical fitness (PF) is one of the most important health markers. Childhood PF is associated with cognitive function and academic performance as well as the risk of non-communicable diseases in later life. Although it has been shown that it is important to improve children’s PF, it continues to decline worldwide over the past few decades and currently remains at a low level.

Numerous studies have been conducted to identify the determinants of children’s PF. The determinants of children’s PF are classified into intrapersonal and environmental factors. Previous studies showed that children’s age, sex, physical activity (PA) level, and body mass index (BMI) were independent and strong intrapersonal factors of PF. Older age, being male, more PA time, and lower BMI were significantly associated with better fitness levels. Previous studies have reported that family status is associated with children’s PF. For example, children with high socioeconomic status (SES) have better muscle strength and cardiorespiratory fitness (CRF). Furthermore, Erkelenz et al. showed that maternal smoking has a significantly negative effect on children's CRF, suggesting that a healthy parental lifestyle also affects children’s PF. Given that family is the first community for children, parents should be important role models. Hence, it is possible that parents’ health-related lifestyles are transferred to their children, and their
In this review, we first conducted a short narrative review of the association between parents’ PA and their children’s PF. Next, we summarized the findings regarding the association between maternal PA during pregnancy and children’s PF, because there has been much attention in recent years regarding the impact of prenatal exposure on child development. Moreover, maternal PA, which is associated with children’s PF\cite{13,14}, can change with pregnancy and child growth; thus, we show our data describing the longitudinal change in maternal PA before and after pregnancy based on an adjunct study of the Japan Environment and Children’s Study (JECS). In the last section, we provide our research plan on maternal behavior and children’s PF using panel data from the JECS.

**Parental PA behavior and PF in children**

To the best of our knowledge, there are only five studies that have examined the association between parental PA and exercise habits and children’s PF\cite{13,14,16-18} (Table 1). Sallis et al. reported the first study investigating the association between parental PA and children’s PF in 1992\cite{16}. In this study, parental PA was assessed using a self-reported questionnaire, and children’s CRF was measured using a mile run/walk test. They found no association between parental PA and CRF in children. Moreover, McMurray et al. also
reported that there was no difference in children’s CRF between those with parents who
did not exercise at all or exercised only once a month and those who exercised three or
more times a week\(^\text{17}\). In contrast, Cleland et al. showed a positive association between
child-reported parental exercise habits and children’s CRF measured by the mile run/walk
and a cycle ergometer\(^\text{18}\). One of the potential explanations for this discrepancy is the
difference in the method of measurement of parental PA. It is possible that children’s
perceptions of their parents’ PA have a greater impact on children’s PA and PF than the
parents’ own assessment of PA. In recent studies, other components of PF, such as muscle
strength, speed/agility, and coordination, were also targeted\(^\text{13,14}\). Martin-Matillas et al.
showed that a mother’s PA engagement was positively associated with her children’s
muscular strength\(^\text{13}\). Moreover, a recent study indicated that a higher level of maternal
PA was associated with a higher performance of CRF and coordination in boys but not in
girls\(^\text{14}\). Although no direct reason was found for this gender difference, the authors
speculated that parental educational level may be a potential reason. In this study, a higher
parental educational level was also associated with a higher children’s PF only among
girls. Based on this finding, the authors hypothesized that girls’ parents with higher
educational levels may have supported the health behaviors of their children, resulting in
a higher PF, whereas the parents of boys placed importance on their children’s PA and PF
regardless of the parents’ educational level.

Although some previous studies have shown positive associations between parental PA and children’s PF, the number of previous studies is limited, and their results are inconclusive. In addition, because all five studies had a cross-sectional design, longitudinal studies are needed to clarify the causal relationship between parental PA and children’s PF.

Table 1

Maternal PA before and during pregnancy and children’s characteristics

The impact of pre- and perinatal exposure on child development and future disease has been a topic of interest in recent years\textsuperscript{[19]}. Pivarnik et al. examined the influence of PA during pregnancy on CRF in children aged 8–10 years in a small group of participants (n=20). No association was found between maternal PA and CRF\textsuperscript{[20]}. Although this is the only report on maternal PA before and during pregnancy and child fitness\textsuperscript{[20]}, some studies have reported an association between maternal PA before and during pregnancy and children’s PA. For example, Xu et al. found a positive association between mothers’ PA levels before pregnancy and their children’s outdoor playtime in early childhood, indicating that each 1 h increase in mothers’ PA time before pregnancy was associated
with 4 min more daily outdoor playtime among children\textsuperscript{21}). Furthermore, maternal PA during pregnancy has also shown a positive association with children’s PA\textsuperscript{22}). Given these findings, the level of pre- and perinatal PA in mothers may be positively associated with children’s PF. However, a limited number of studies have examined the influence of maternal PA before and during pregnancy on children’s PF and PA. To address this objective, there is a need to assess pre- and perinatal PA. This type of study is generally called a birth cohort study, and there are not many cohorts worldwide. The Avon Longitudinal Study of Parents and Children (ALSPAC) in the United Kingdom\textsuperscript{23}), Norwegian Mother and Child Cohort Study (MoBA) in Norway\textsuperscript{24}), and GECKO Drenthe study in the Netherlands\textsuperscript{25}) are well-known birth cohorts that have continuously evaluated mothers’ and children’s exercise-related indicators from the mother’s pregnancy to the child at school age. In Japan, an adjunct study of the JECS conducted by the Miyagi Unit Center is an ongoing birth cohort in which data on maternal PA are collected at multiple points from pre-pregnancy until the child reaches school age. Because the social and cultural background of Japan is different from that of European countries, it is necessary to conduct studies focused on the Japanese population.

In the following sections, we provide an overview of the adjunct study conducted by the JECS and Miyagi Unit Center, and report our data describing the longitudinal change
in maternal PA from pregnancy to child rearing.

JECS

The JECS is a nationwide birth cohort study of 100,000 parent-child pairs funded by the Ministry of the Environment. This study aimed to investigate the effects of chemical exposure and living environment factors on children’s health and development. The participants were recruited between January 2011 and March 2014 and were followed up until they reached the age of 13 years. This study was conducted at 15 regional centers across Japan, located in Hokkaido, Fukushima, Chiba, Kanagawa, Koshin, Toyama, Aichi, Kyoto, Osaka, Hyogo, Tottori, Kochi, Fukuoka, South Kyusyu/Okinawa, and Miyagi. In addition to the JECS main study, adjunct studies were conducted by each regional center with their own planning and funding. Proposals for adjunct studies were approved by the Ministry of the Environment.

Adjunct study of Miyagi Unit Center (MUC)

The MUC covers 14 municipalities in Miyagi prefecture, including mountainous areas (Osaki, Wakuya, Misato, Kami, Shikima, Kurihara, and Tome) and coastal areas (Kesennuma, Minamisanriku, Ishinomaki, Onagawa, Iwanuma, Watari, and Yamamoto).
The latter includes areas that were severely damaged by the Great East Japan Earthquake in March 2011. A total of 9,031 participants were registered in a nationwide study. Among them, 3,578 participated in the adjunct study of the MUC. The eligibility criteria for the adjunct study were similar to those for the JECS: (1) expected date of delivery between August 1, 2011, and mid-2014, (2) residence in the study area, and (3) no difficulty in participating in the study. This adjunct study covers premenstrual syndrome, maternal lifestyle (i.e., fish-eating habits and PA), and oral and urinary development of children. It also collected information about the experience of disaster damage in 2011.

**Longitudinal change in maternal PA before and after pregnancy**

Our laboratory participated in the adjunct study of MUC to determine the influence of parental PA patterns on children’s PA and PF. Mothers’ PA was measured at the time of registration, during pregnancy, at 1.5, 3.5, and 5.5 years after childbirth. Children’s PA was also measured at 5.5 years. In addition, MUC also assessed the PF of the mother and child when the child was in second grade (8 years old) for some participants. Mothers and children’s PF assesses muscle strength and balance, with muscle strength assessed by grip strength and balance assessed by standing on one leg.

As mentioned above, although pre- and perinatal PA in mothers is potentially
associated with children’s PF or PA, it is unclear to what extent can pregnancy and childbirth change mothers’ PA. Pregnancy and childbirth are major life events for women, and they are also times when their physical, mental, and social environments dramatically change. These changes are expected to force changes in lifestyle, including physical activity. Previous studies have reported that maternal PA decreases during pregnancy and increases after childbirth\textsuperscript{28-31). These studies have focused on the changes over the course of pregnancy and the first year postpartum; however, the changes in the mothers’ PA as their children grew were not clear. Therefore, we conducted a study to describe the longitudinal change in maternal PA from pre-pregnancy to child-rearing period, with the aim of clarifying the changes in PA due to women’s life events.

We collected data on the PA of 1,874 mothers. PA was assessed using the shortened Japanese version of the International Physical Activity Questionnaire (IPAQ) at four time points: pre-pregnancy, during pregnancy (in mid to late pregnancy), and when the child was 1.5 and 3.5 years old. The amount of PA per week (METs/week) was calculated and divided into two categories, namely “low physical activity” and “moderate-high physical activity”, according to the guidelines for data processing and analysis of the IPAQ\textsuperscript{32). We calculated the proportion of each category and classified the changes in PA into 16 patterns throughout the four time points.
The results showed that 51.7% of the participants were classified as low physical activity at pre-pregnancy, 64.5% during pregnancy, 92.0% at 1.5 years, and 65.3% at 3.5 years, respectively (Fig. 1). Among the participants with low physical activity at 1.5 years, 66.5% maintained low physical activity level at 3.5 years. In addition, 32.1% of the participants were classified as having low physical activity during the measurement period, which was the most common pattern. These results suggest that the opportunity afforded by pregnancy resulted in the decrease of PA, and that this change may become established as a lifestyle during the child-rearing period. As described above, since maternal PA changes significantly with life events, the timing of assessing maternal PA should be considered when examining the impact of maternal PA on children’s PA and PF. Furthermore, since PA consists of daily accumulation, the influence of the mother’s total amount of PA and the pattern of change on the children’s PA and PF during the observation period should also be considered.

**Research plan on maternal PA and children’s PF**

Our previous study has only described the changes in PA of mothers from pregnancy...
to child rearing, and we are currently analyzing the data on PA of children aged 5.5 years. Based on our data, a mother’s PA changes dramatically within a short period of time from pregnancy to child rearing. Therefore, we set the following four questions: (1) at what time point, from before conception to the same time as the child’s PF assessment, does the mother’s PA most affect the child’s PA and PF?; (2) does the total amount of maternal PA during the observation period affect the PA and PF of the child?; (3) does the pattern of change in maternal PA during the observation period affect the child’s PA and PF?; (4) is maternal PA associated with children’s PF independent of children’s PA? The answers to these questions will provide details of the interaction between the mother’s PA and the child’s PA and PF. The previous studies mentioned above reported fragmented findings on the association between mothers’ PA and children’s PA and PF because these studies used the data at a single point in time\textsuperscript{13,14,16-18,20}. Therefore, by answering these questions, it will be possible to summarize the previous fragmented findings on the association between maternal PA and children’s PF.

As mentioned above, we are in the process of measuring maternal PF along with the child’s PF in the survey at age 8. By measuring the PF of the mother, it is possible to consider the heritability of PF. In addition, the MUC adjunct study has information on the mother’s lifestyle, biological changes (through blood tests), physiques, and diseases.
Therefore, it is also possible to explain the factors that mediate the relationship between PA and PF in mothers and their children.
Conflict of Interests

The authors have no conflicts of interest directly relevant to the content of this article.

Acknowledgment

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Author Contributions

The contributions of each author were as follows. AY and HM drafted the manuscript and prepared the figures. All authors edited and revised the manuscript and approved the final manuscript.


Figure. 1 Changes in physical activity categories from pre-pregnancy to 3.5 years postpartum.
Figure 1 shows the number of individuals in each physical activity category (n) and the percentage of individuals moving between the two time points (%) to be considered as participants in the adjunct study by the Miyagi Unit Center of the Japan Environment and Children’s Survey. (Reproduced from Yamada et al. 2021 Research in Exercise Epidemiology)
Table 1. Overview of previous studies examining the association between parental physical activity and children’s physical fitness.

<table>
<thead>
<tr>
<th>Author (year) country</th>
<th>Study design</th>
<th>Sample</th>
<th>Age (years)</th>
<th>Parental PA measurement</th>
<th>Children’s PF measurement</th>
<th>Main results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sallis et al.16)</td>
<td>Cross-</td>
<td>297</td>
<td>9</td>
<td>Parent self-administered questionnaire</td>
<td>CRF (mile run/walk)</td>
<td>Parents’ PA score (frequency of exercise multiplied by MET value) was not associated with children’s PF.</td>
</tr>
<tr>
<td>(1992) USA</td>
<td>sectional</td>
<td>50.2% boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McMurray et al.17)</td>
<td>Cross-</td>
<td>1,253</td>
<td>8.8±0.8</td>
<td>Parent self-administered questionnaire</td>
<td>CRF (submaximal cycle ergometer test)</td>
<td>Parents’ PA engagement was not associated with children’s PF.</td>
</tr>
<tr>
<td>(1993) USA</td>
<td>sectional</td>
<td>47.0% boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleland et al.18)</td>
<td>Cross-</td>
<td>6,414</td>
<td>9-15</td>
<td>Self-administered questionnaire answered by the child</td>
<td>CRF (mile run, physical work capacity (PWC170))</td>
<td>Parental exercise involvement was positively associated with 1.6 km run/walk time and, in girls only, PWC170.</td>
</tr>
<tr>
<td>(2005) Australia</td>
<td>sectional</td>
<td>50.8% boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Martin-Matillas et al.13)</td>
<td>Cross-</td>
<td>3,288</td>
<td>12.5-17.5</td>
<td>Self-administered questionnaire answered by the child</td>
<td>(1) CRF (20m shuttle run)  (2) Muscular strength (stand long jump) (3) Speed/agility (4×10m shuttle run)</td>
<td>(1) Parents’ PA engagement was positively related to children’s CRF. (2) Mothers’ PA engagement was positively associated with children’s muscular strength.</td>
</tr>
<tr>
<td>(2012) Europe</td>
<td>sectional</td>
<td>48% boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erkelenz et al.14)</td>
<td>Cross-</td>
<td>1,875</td>
<td>7.1±0.6</td>
<td>Parent self-administered questionnaire</td>
<td>(1) CRF (6-min run)      (2) Whole body coordination and muscular endurance (lateral jumping)</td>
<td>High levels of maternal PA were positively related to PF in boys, but not in girls.</td>
</tr>
<tr>
<td>(2014) Germany</td>
<td>sectional</td>
<td>51.4% boys</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CRF: cardiorespiratory fitness. PA: physical activity. PF: physical fitness.