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Health risks of early swimming pool attendance

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Abstract

Swimming pool attendance and exposure to chlorination by-products showed adverse health effects on children. We assessed whether early swimming pool attendance, especially baby swimming, is related to higher rates of early infections and to the development of allergic diseases. In 2003–2005, 2192 children were analysed for the 6-year follow-up of a prospective birth cohort study. Data on early swimming pool attendance, other lifestyle factors and medical

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history were collected by parental-administered questionnaire. Bivariate and multivariate logistic regression analyses were used to evaluate associations.

Babies who did not participate in baby swimming had lower rates of infection in the 1st year of life (i) diarrhoea: OR 0.68 CI 95% 0.54–0.85; (ii) otitis media: OR 0.81 CI 95% 0.62–1.05; (iii) airway infections: OR 0.85 CI 95% 0.67–1.09. No clear association could be found between late or non-swimmers and atopic dermatitis or hay fever until the age of 6 years, while higher rates of asthma were found (OR 2.15 95% CI 1.16–3.99), however, potentially due to reverse causation.

The study indicates that, in terms of infections, baby swimming might not be as harmless as commonly thought. Further evidence is needed to make conclusions if the current regulations on chlorine in Germany might not protect swimming pool attendees from an increased risk of gastrointestinal infections. In terms of developing atopic diseases there is no verifiable detrimental effect of early swimming.

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Keywords: Swimming pool attendance; Baby swimming; Early infections; Atopic diseases

Introduction

Baby swimming, which became more and more popular since 1970, showed to increase the risk of recurrent respiratory tract infections and otitis media (Nystad et al., 2003) as well as to lead to airway changes potentially predisposing to respiratory diseases later in life (Bernard and Nickmilder, 2006b; Bernard et al., 2007). Chlorine compounds used for the disinfection of swimming pools do react with organic matter (e.g., urine, sweat) of swimmers resulting in potentially harmful inhalable by-products at the water surface. Although chlorine itself and most of its derivatives are known toxic agents, it was pronounced as being safe as water disinfectant. Detailed analyses and extended studies only started recently, when more concern came up regarding their potential influences on human health. Chlorinated swimming pool attendance was found to increase lung hyperpermeability, exercise-induced bronchoconstriction (EIB) and asthma (Bernard et al., 2003). Thus, the hypothesis was generated that a repeated or chronic disruption of the lung epithelial barrier could facilitate the penetration of allergens in the lung (Bernard et al., 2003) and therefore could result in increased rates of allergic sensitization and atopic diseases. Furthermore, chlorine in bathing water showed to change the dermal barrier function, especially of atopic skin (Seki et al., 2003). Official directives on chlorine differ between countries, e.g., German maximum chlorine levels are 10 times lower than those in Belgium. The objective of this study was to assess whether early swimming pool attendance in Germany, especially baby swimming, could be related to higher rates of a variety of early infections and to the development of allergic diseases.

Methods

Study population and questionnaire

Study participants were evaluated in the framework of the LISA study (influence of life-style related factors

on the immune system and the development of allergies in childhood), a prospective cohort study in four regions of Germany (Munich, Leipzig, Wesel, Bad Honnef). 3097 children born between November 1997 and January 1999 were recruited at birth and followed-up on a regular basis by parental-administered questionnaires (aged 6, 12, 18 months and 2, 4, 6 years). For the 6-year follow-up in 2003–2005, a total of 2192 children providing information on socioeconomic factors, medical history, and lifestyle factors could be included. The study was approved by the local ethics committees of each study center. Swimming pool attendance was used as a proxy of contact to chlorination by-products and potential exposure to microbial water pollutants. At age 6 years, questions asked for the age of first pool attendance and for the frequency of pool attendance during the past 12 months stratified for spring/summer and autumn/winter (A: At what age did your child for the first time attend an outdoor or indoor swimming pool (no lake or river)? regularly 1st year of life (baby swimming)/occasionally 1st year/between ages 1 and 3/between ages 3 and 6/up to now never. B: How often did your child attend an outdoor or indoor swimming pool during the past 12 months? At least once per week/at least once per month/more rarely/never). For the analyses, we summarised the age of first pool attendance to the following groups: (a) 1st year baby swimming, (b) 1st year occasionally and (c) later or never. Health outcome data was assessed anew for the baseline and each follow-up evaluation. Information used for calculations concerning early infections (1st year of life) and atopic diseases were physician-diagnosed illnesses: did a doctor diagnose the following diseases during the past 6 months (for ages 6, 12, 18 and 24 months)/at ages 3–6: asthma, hay fever, eczema, diarrhoea, airway infection, otitis media.

Statistical analyses

Statistical analyses were carried out using SAS, version 9.13. First, descriptive methods were used to

evaluate differences in the prevalences of infectious diseases in the 1st year of life related to swimming pool attendance during that year. Furthermore, atopic diseases depending on the age of first swimming pool attendance and depending on the frequency of recent pool contact were analysed. Logistic regression models were then applied adjusting for sex, study center, parental education, parental atopy, older siblings and daycare attendance.

Results

The characteristics of the study population are given in Table 1.

Throughout the 2192 children included into this follow-up study, 30.1% started attending swimming pools before the age of 1 year (baby swimming) and more than 90% before 3 years of age. Only 0.7% of all participants had never had any contact to chlorinated pools up to age 6. Early swimming pool attendance (1st year of life) was not associated with higher rates of atopic diseases (Table 2) later in life. Related to the

frequency of pool attendance during the past 12 months at age 6 years, neither for atopic diseases nor for infections acute effects or clear trends could be seen. Diarrhoea in the 1st year of life was related to early swimming pool attendance. Not swimming at all did show a protective effect (Table 3). Adjusting for potential confounders such as gender, study center, parental education, parental atopy, older siblings and daycare, only slightly changed the odds ratios. Similar logistic regression models were applied for atopic diseases. No swimming during the 1st year of life was associated with higher rates of asthma (Table 3). However, the probability of reverse causality has to be taken into account (see discussion). Results were similar when additionally adjusted for early infections.

Discussion

The results of this study revealed a potential association between swimming pool attendance, especially baby swimming in the 1st year of life, and higher rates of diarrhoea. The suspected effect of early pool attendance

Table 1. Characteristics of the LISA study population 2003–2005

Participants with data on swimming pool attendance	Munich <i>n</i> = 1170	Leipzig <i>n</i> = 561	Bad Honnef <i>n</i> = 239	Wesel <i>n</i> = 222	Total <i>n</i> = 2192
Males	614/1170 (52.5)	273/561 (48.7)	115/239 (48.1)	111/222 (50.2)	1113/2192 (50.8)
Age of first pool attendance					
1st year (baby swimming)	273/1170 (23.3)	242/561 (43.1)	82/239 (34.3)	63/222 (28.5)	660/2192 (30.1)
1st year occasionally	395/1170 (33.8)	113/561 (20.1)	64/239 (26.8)	83/222 (37.6)	655/2192 (29.9)
Later or never	502/1170 (42.9)	206/561 (36.7)	93/239 (38.9)	72/222 (34.2)	877/2192 (40.1)
Hay fever doctor diagnosed (after 1st year of life)	66/1170 (5.6)	26/561 (4.6)	11/239 (4.6)	8/222 (3.6)	111/2192 (5.1)
Asthma doctor diagnosed (after 1st year of life)	36/1170 (3.1)	18/561 (3.2)	8/239 (3.6)	8/222 (3.6)	70/2192 (3.2)
Ekzema doctor diagnosed (after 1st year of life)	241/1170 (20.6)	136/561 (24.2)	47/239 (19.7)	42/222 (18.9)	466/2192 (21.3)
Airway infections (1st year of life)	864/1139 (75.9)	455/551 (82.6)	182/228 (79.8)	143/210 (68.1)	1644/2128 (77.3)
Otitis media (1st year of life)	189/1091 (17.3)	120/539 (22.3)	56/226 (24.8)	38/201 (18.9)	403/2057 (19.6)
Diarrhoea (1st year of life)	347/1096 (31.7)	185/537 (34.5)	76/228 (33.3)	66/202 (32.7)	674/2063 (32.7)
Parental atopy	717/1165 (61.6)	242/561 (43.1)	116/239 (48.5)	89/221 (40.3)	1164/2186 (53.3)
Higher parental education ^a	1013/1162 (87.2)	389/557 (69.8)	186/238 (78.2)	143/219 (65.3)	1731/2176 (79.6)
Older siblings #	538/1170 (46.0)	242/561 (43.1)	137/239 (57.3)	128/222 (57.7)	1044/2192 (47.6)
Daycare attendance (1st year of life)	23/1023 (2.3)	60/495 (12.1)	0/203 (0)	0/186 (0)	83/1907 (4.4)

Data presented as *n/N*, with % in parentheses.

^a10th grade or higher # ≥ 1.

Table 2. Doctor-diagnosed atopic diseases in relation to swimming pool attendance

Age of first pool attendance	Doctor diagnosed after the 1st year of life up to age 6		
	Asthma <i>n</i> = 70	Hay fever <i>n</i> = 111	Atopic dermatitis <i>n</i> = 466
1st year baby swimming	14/660 (2.1)	30/660 (4.6)	139/660 (21.1)
1st year occasionally	17/655 (2.6)	27/655 (4.1)	135/655 (20.6)
Between ages 1 and 3	32/686 (4.7)	40/686 (5.8)	143/686 (20.9)
Later or never	7/191 (3.7)	14/191 (7.3)	49/191 (25.7)

Table 3. Infections and atopic diseases in relation to pool attendance in the 1st year of life

Swimming pool attendance	Crude		Adjusted model 1 ^a	
	OR	CI 95%	OR	CI 95%
(a) Airway infections				
1st year baby swimming	1		1	
1st year occasionally	1.03	0.79–1.35	1.02	0.76–1.38
Later or never	0.85	0.67–1.09	0.79	0.61–1.03
(b) Otitis media				
1st year baby swimming	1		1	
1st year occasionally	0.95	0.72–1.24	0.94	0.69–1.29
Later or never	0.81	0.62–1.05	0.76	0.57–1.02
(c) Diarrhoea				
1st year baby swimming	1		1	
1st year occasionally	0.80	0.63–1.01	0.84	0.65–1.09
Later or never	0.68	0.54–0.85	0.72	0.57–0.93
(d) Asthma				
1st year baby swimming	1		1	
1st year occasionally	1.23	0.60–2.52	1.42	0.65–3.10
Later or never	2.15	1.16–3.99	2.35	1.21–4.56
(e) Hay fever				
1st year baby swimming	1		1	
1st year occasionally	0.90	0.53–1.54	1.18	0.64–2.16
Later or never	1.38	0.87–2.18	1.55	0.92–2.62
(f) Atopic dermatitis				
1st year baby swimming	1		1	
1st year occasionally	0.97	0.75–1.27	1.02	0.76–1.38
Later or never	1.05	0.82–1.34	1.01	0.77–1.32

Significant values indicated in bold.

^aGender, study center, parental education, parental atopy, older siblings, daycare.

on the development of atopic diseases later in childhood could not be confirmed. In contrast late- and non-swimmers even showed higher rates of asthma.

Chlorination by-products constitute potentially harmful inhalable irritants reaching their highest concentration at the water surface. The extent of exposure depends on temperature, number of bathers and ventilation systems used (Stav and Stav, 2005). Especially inadequately maintained pools with either too high doses (chlorine accidents, poorly controlled standards) or too low concentrations (resulting in microbiological contamination) imply several health hazards.

For a long time considered health aspects due to swimming pool contact were mainly irritant skin, eye, nasal, and throat symptoms (Massin et al., 1998; Momas et al., 1993; Penny 1983; Powis and Hazzard, 1984; Shusterman et al., 2003; Small and Murray, 1987; Varraso et al., 2002). First concerns came up as soon as 1979 regarding airway obstructions in young swimmers (Mustchin and Pickering, 1979), but extended investigations only started recently. By now, most important and intensively studied health effects are respiratory outcomes related to contact to chlorination by-products (Bernard et al., 2003, 2006a; Bernard and Nickmilder,

2006b; Helenius et al., 2002, 1998; Kohlhammer and Heinrich, 2007; Mustchin and Pickering, 1979; Nickmilder and Bernard, 2007; Penny, 1983; Stav and Stav, 2005; Thickett et al., 2002; Varraso et al., 2002; Zwick et al., 1990). In recent studies of Bernard et al., exposure-response-related increases of cellular markers indicating lung damage (surfactant proteins SP-A and SP-B, CC16) could be seen and were consistent for short term and chronic contact to chlorination products (Bernard et al., 2003; Carbonnelle et al., 2002). Associations were strongest when exposure to chlorination products started early, e.g., in those participating baby swimming (Bernard et al., 2003; Bernard and Nickmilder, 2006b). They came up with the hypothesis that repeated or chronic disruption of the lung epithelial barrier could facilitate the penetration of allergens in the lung (Bernard et al., 2003) with potentially predisposing to allergic sensitization or the development of atopic diseases. Our data, however, do not show any clear association between attendance of chlorinated swimming pools and allergic outcomes. Though, one important difference between Belgium (where most of the swimming pool studies were performed) and Germany is the difference of maximum recommended levels for combined chlorine. In Belgium with a maximum of 2 ppm, the level is 10 times higher than German standards, where limits of water concentrations of 0.3–0.6 mg/l for free chlorine, 0.2 mg/l for bound chlorine and a pH of 6.5–7.6 have to be maintained (Kohlhammer et al., 2006). Therefore, lower exposure levels in German children may result in minor health effects in terms of atopic diseases what would be in line with our results. The higher risk for diarrhoea in baby swimmers may indicate an insufficient disinfection and incomplete protection against waterborne pathogens.

We adjusted our logistic regression models for older siblings and daycare as potential risk factors and therefore confounders for the analysed health outcomes. Earlier analyses could show higher rates of infectious diseases among children attending daycare centres or having siblings. Participation in baby swimming itself constitutes a further form of social contact that could lead (even without contact to water) to higher infection rates.

Baby swimming became more and more popular, with increasing frequencies from around 6% when born in the early 1980s (Nystad et al., 2003) to 13% in the early 1990s (Bernard and Nickmilder, 2006b) and up to 30% today. Young children inhale and swallow more water, and in the case of small pools highly polluted water. In the US, CDC reported on poor pool maintenance and associated outbreaks of gastroenteritis, especially in young children (MMWR, 2003). Regarding other infections, a study of Nystad et al. (2003) could state an increased risk of recurrent respiratory tract infections and otitis media in children attending baby swimming.

Against common belief water contact in the youngest has no relevant influence on learning to swim (American Academy of Pediatrics, 2000). Nevertheless, it might reduce the fear of water. Though, at the same time, it may encourage children to enter the water without supervision (American Academy of Pediatrics, 2000).

Some studies found exceptional high rates of atopic sensitizations (measured by specific IgE and prick tests) or reported apparent allergies in routine swimmers (Helenius et al., 1998; Small and Murray, 1987; Zwick et al., 1990). Thus, the question remains, if toxic or irritant agents (e.g., chlorine and its by-products) are themselves risk factors for atopic diseases or if subjects who are already sensitised to allergens are just more sensitive to exposures. In our study, we could find higher rates of asthma among those not starting to swim in the 1st year of life. However, there is a high probability of reverse causality, with allergic children tending to go swimming less frequently than non-atopic children. In a recent evaluation, we, Kohlhammer et al. (2006), have revealed an association between higher rates of hay fever and frequent and early contact to chlorinated swimming pools when analysing age of first pool contact and frequency of recent swimming pool attendance in adults. This evaluation did cover pool attendance at times, when the present regulations on chlorine were not yet introduced. That would even strengthen our hypothesis of the updated chlorination dosage (DIN 19643, 1997) being low enough to avoid lung impairment and a predisposition to atopic diseases, but being too low to avoid waterborne infections.

A further hypothesis one could come up with would be in line with the so-called hygiene hypothesis. A higher rate of infections during the 1st year of life would then protect from the development of atopic diseases and would fit to the results presented, though hypothetical. As we do not believe in a 'protective' effect of baby swimming itself, we can only speculate on the interpretation of the results (concerning asthma and hay fever) in the direction of chance finding, finding due to uncontrolled confounding, consequence of reverse causation, or relation to the hygiene hypothesis.

This study has several limitations. While the study did collect outcome data regularly the exposure data were only collected years later. Thus, recall bias could be another reason for not finding the hypothesised effects, but we consider this as not likely. For the mainly questionnaire-based evaluation, subjective answers with a potential over- or under-estimation of results have to be accounted for. The main problem for the long-term evaluation was the fact that a proper reference or control group of children without any contact to chlorinated swimming pools up to 6 years of age is lacking (only 0.7% of the study population). In contrast to other studies we do not have data on short-term effects and specific markers potentially indicating early

effects of swimming pool attendance. However, cumulative effects might be more important, but the resulting health effects might not yet be apparent at the age of 6 years. One further problem was the evaluation strategy of information on the frequency of swimming pool attendance. Data on the frequency was only assessed for the 6th year of life, while especially for evaluating long-term effects of early pool attendance, it would have been more important to have a more specific frequency of early pool attendance, not only for the 1st year, but also later on. Thus, we only have the information when pool attendance started, but, e.g., children who swam for the first time at age 2 and never again and children who started swimming at age 2 and from there on attended pools weekly would end up in the same group. That was the reason why we mainly focussed our analyses on effects of early pool attendance (1st year of life). There, we have the information whether they swam regularly or occasionally. A further limitation is the lack of data on chlorine and microbial concentrations in the public pools of the study areas. No data could be collected retrospectively. Therefore, we only were able to use pool attendance as surrogate for exposure to chlorination by-products and microbial pathogens. What we did not ask for was the maintenance of private swimming pools. Too high or too low concentrations of chlorine and its by-products could influence the health effects in both directions. However, the term baby swimming is not likely to be used for private swimming, but rather for public swimming courses. As our main interest lay on early exposure, the results are unlikely to be strongly influenced by attending private pools. Main strength of the study is a big study population covering four different study areas. It uses a prospective cohort design, while exposure data was collected retrospectively.

Conclusion

Relying on our results, we cannot give a definite conclusion whether baby swimming is safe in terms of atopic diseases. Frequent swimming pool attendance might make up a contribution to the development or the aggravation of infections (especially diarrhoea) and other diseases. However, the results are only significant for diarrhoea. We might speculate that the low concentrations of chlorine in German swimming pools or early frequent pool attendance or a combination of both could be reasons for higher rates of early infections. Even if the evidence regarding risks given by German swimming pools is not clear, we at least have hints for health hazards while we do not see any reason to recommend baby swimming. Therefore our opinion is to stay with German regulations on chlorine, but to only start swimming at a time point where the child's immune

system and lung development is on a more advanced level. Further follow-ups or studies with a more detailed exposure assessment should follow. Important general implications should include control of temperature, water quality, and air quality, especially for those with long term and repeated exposure, as well as for the youngest.

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