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SCIENTIFIC NOTE

CHILD OUTDOOR PHYSICAL ACTIVITY IS REDUCED BY PREVALENCE OF THE ASIAN TIGER MOSQUITO, *AEDES ALBOPICTUS*

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ABSTRACT. We tested the hypothesis that day-biting mosquitoes contribute to child obesity by reducing opportunities for summer outdoor play. The influence of Asian tiger mosquito (*Aedes albopictus*) prevalence on child outdoor physical activity was compared in 2 matched urban communities, one treated for mosquito abatement and one untreated. More time was spent outdoors by children where abatement took place.

KEY WORDS *Aedes albopictus*, obesity, physical activity, mosquitoes

The Asian tiger mosquito, *Aedes albopictus* (Skuse), is a highly anthropophilic species that has adapted to use artificial containers as larval habitats in urban areas. The Asian tiger mosquito is a day-biter that prefers large mammals including humans (Benedict et al. 2007). The public health threat posed by *Ae. albopictus* via disease is enormous as this mosquito transmits chikungunya, dengue, and other harmful arboviruses (Enserink 2007). However, in the USA the more immediate public health issue is degradation of human environmental quality from bites, with the hyperaggressive *Ae. albopictus* regarded as among our most important nuisance mosquitoes.

The availability of outdoor physical activities is an important metric of human environmental quality, and annoyance from mosquitoes seriously inhibits outdoor activities. The median number of bites forcing Minnesota (Sjogren 1977) and Virginia (Ratigan 2008) residents indoors was only 3, yet *Ae. albopictus* has biting rates of 30–48/h (Cancrini et al. 2003). In short, biting mosquitoes impact quality of life by reducing outdoor recreation.

Physical activity is critically important for managing health. Sedentary behaviors increase the risk of obesity, heart disease, stroke, diabetes, depression, and some cancers (Riddoch and Boreham 2000). The connection between physical activity and child obesity is especially well documented. Obesity in children is a national epidemic, with obesity rates having tripled for US children 6–11 years of age over the last 30 years, increasing from 7% in 1980 to almost 20% in 2008 (Ogden et al. 2010). Given the rapidity with which obesity has increased, it is reasonable to attribute this change to nongenetic causes. Aside from nutritional considerations, child obesity is associated with low levels of physical activity. While factors such as less time for physical education in schools and more time spent in sedentary pursuits (e.g., video games) have been blamed (Anderson and Butcher 2006), the physical environment itself may present barriers to adequate physical activity by children. "Things that bite you" (e.g., mosquitoes) have been cited by adolescents as "issues beyond your control" that they perceived to reduce their physical activity (Ries et al. 2008). Children's outdoor physical activity is greater in the summer (Beighle et al. 2008), making the seasonal appearance of mosquitoes particularly salient. From this perspective, we hypothesize that mosquitoes indirectly contribute to child obesity by reducing summer outdoor play.

A US Department of Agriculture (USDA) area-wide pest management project, designed to develop control strategies against *Ae. albopictus* in 2 New Jersey communities, provided an opportunity to explore whether mosquitoes were a barrier to childhood outdoor physical activity. The 2 towns were matched geographically (2 mi distant in Monmouth County), socioeconomically, demographically, and in *Ae. albopitcus* abundance (Unlu et al. 2011). In summer 2009, a group of 1,000 contiguous private resident yards in one town, Cliffwood Beach, was selected as our treatment site, and an equivalent number of yards in the matching town, Union Beach, were untreated for comparison. In 2011, treatment and untreated communities were reversed.

Adult mosquito populations were monitored with BG-Sentinel™ traps (Biogents AG, Regensburg, Germany). In 2009, the treatment had 18 and the untreated area 21 traps, whereas in 2011 the treatment had 22 and the untreated area 20 traps. Traps were deployed once for 24 h at each

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site during the study, and trap counts were averaged.

The 2009 abatement program is detailed in Fonseca et al. (2012) and included: 1) door-to-door source reduction and hand-larviciding with the insect growth regulator methoprene (Altosid® Pellets; Wellmark International, Schaumburg, IL) or a monomolecular film (Agnique® MMF G; Cognis Corp., Cincinnati, OH); 2) distribution of educational brochures; and 3) a July 30 application of Duet™ Dual-action Adulticide (1% prallethrin, 5% sumithrin, 5% piperonyl butoxide; Clarke Mosquito Control, Roselle, IL) at the maximum label rate of 1.24 fl oz/acre using a truck-mounted Clarke Cougar ULV cold aerosol sprayer. In 2011, we conducted truck-mounted applications with Altosid liquid larvicide at the maximum label rate on April 21, May 6, and June 24. Adulticide applications were conducted in parallel with methoprene larvicide on June 10, July 7, and July 28.

In July of 2009 and 2011, we distributed recruitment flyers door-to-door in both communities that advertised interest in studying how children spend their time in the summer. Protocol approval was obtained from the Rutgers University Institutional Review Board. Parents and their children were asked to attend a meeting in their respective towns on a Saturday. In 2009, 4 children from the treated town and 8 from the untreated town participated, whereas in 2011 the treated and untreated towns enrolled 18 and 8 children, respectively. Children ranged in age from 8 to 12 years (mean 10.1). The study procedures were explained, consent forms were signed, and a paper-and-pencil log booklet was issued to each child. Children were instructed to keep a 5-day diary of their indoor and outdoor activities from a preset list of activities, and to record the time they spent engaged in each. Activity logs were maintained from August 4 to 9 in 2009 and from July 31 to August 5 in 2011. Logs were returned 1 wk later and $25 gift cards were provided as compensation.

Participant knowledge of where our intervention efforts were occurring could influence our results. Accordingly, we did not reveal to participants which site was being treated and which was merely surveyed. Surveillance was conducted with equal intensity in both treated and untreated sites. All 2011 intervention activities were performed at night so the visible presence of mosquito control personnel was equivalent in both sites. Reversing the treated and untreated sites between 2009 and 2011 added an additional layer of security.

The 2009 study found no difference in time spent outdoors between children from the 2 towns; however, *Ae. albopictus* prevalence was unusually low in both towns in July of that year (mean 4.9 $\pm$ 1.2 adult *Ae. albopictus* in the treated and 5.79 $\pm$ 1.2 in the untreated site, $F = 0.28$, $P = 0.6$), presumably due to a cool spring and early summer. As the control and treated towns had comparable *Ae. albopictus* numbers, the corresponding equivalence in time spent outdoors met our prediction. By contrast, in 2011 mean trap counts were significantly higher in the untreated than in the treated test site (12.0 $\pm$ 1.85 *Ae. albopictus* captured per trap in the untreated town compared to 6.86 $\pm$ 0.88 in the treated town). As evidence to the effectiveness of the abatement effort, the treated town's trap counts were as low as in 2009. Because mosquito pressure in both sites in 2009 was the same as in the treated site in 2011, and to boost the statistical power of the analysis, the children's 2009 outdoor time estimates were combined with the 2011 estimates from the treated town, and compared to those from the 2011 untreated town. Time reported outdoors was significantly higher for the children from the treated town where mosquito prevalence had been reduced ($F = 4.43$, $P = 0.046$, repeated-measures analysis of variance performed in the context of a multivariate analysis of variance in JMP 8.0.1 [SAS Institute, Cary, NC]). On a per-day basis, children in the treated area averaged 228.94 min of outdoor play, compared to 99.4 min in the untreated control. In short, *Ae. albopictus* creates a "toxic" environment that discourages child outdoor physical activity, a finding bolstered by a comprehensive associated study (also part of our USDA area-wide project) that included hundreds of homes, and demonstrated adult outdoor activities increased by 113.4 min/wk in abatement sites (Shepard et al. 2012).

Study limitations include small sample size and child self-report data collection, making our results suggestive, but stated simply: children residing in the community where effective abatement took place spent more time outdoors in play. To reverse childhood obesity, experts stress the importance of "overcoming neighborhood barriers" in developing health-promoting environments that support outdoor physical activity (Jilcott et al. 2007). We submit that *Ae. albopictus* is a neighborhood barrier that promotes indoor sedentary behaviors rather than outdoor activities. Therefore, creation of Asian tiger mosquito–free environments may positively impact children's physical activity by encouraging daytime outdoor activities.

Outdoor physical activity is an important metric of human environmental quality, although mosquitoes, long considered a public health threat due to their disease transmission potential, have never been previously considered as a childhood obesity risk factor. We propose an expanded definition of environmental (nongenetic) contributors to obesity that includes biting mosquitoes. Because obesity is difficult to treat, public health efforts need to be directed toward prevention, which could include mosquito abatement since physical activity protects against obesity. We hope our findings will encourage others to test the hypothesis that *Ae. albopictus* abatement can result in enhanced health benefits via increased physical activity.

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