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Using epidemiology and neurotoxicology to reduce risks to young workers

Diane S. Rohlman [a,*], Iman Nuwayhid [b], Ahmed Ismail [c,d], Basema Saddik [e]

[a] Center for Research on Occupational and Environmental Toxicology, Oregon Health and Science University, Portland, OR 97239, USA
[b] Faculty of Health Sciences, American University of Beirut, Beirut, Lebanon
[c] Public Health and Community Medicine Department, Menoufia University, Egypt
[d] Family and Community Medicine Department, Jazan University, Saudi Arabia
[e] College of Public Health and Health Informatics, King Saud bin Abdulaziz University for Health Sciences, Saudi Arabia

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ABSTRACT

Children around the world are working in hazardous or unsafe conditions and they are at risk to injury through manual labor and susceptible to poisoning due to chemical exposures in the work place. Because of their behavior and the developmental changes occurring throughout childhood and adolescence children are more vulnerable to injury. Often children work because of economic necessity, coming from families living in extreme poverty, with poor housing conditions, unsafe water supplies, poor sanitation, and inadequate food supplies making them even more vulnerable to poor developmental outcomes. This presents a multifaceted problem that can be challenging to address. Although many studies have examined occupational risks among adults very few studies have examined the impact of these risks on children. This paper reflects a summary of the talks from the symposium "Using Epidemiology and Neurotoxicology to Reduce Risks to Young Workers" presented at the 13th International Neurotoxicology Association Meeting and the 11th International Symposium on Neurobehavioral Methods and Effects in Occupational and Environmental Health in Xi'an China in June 2011. Epidemiological studies have demonstrated that children are exposed to various neurotoxicants, show increased symptoms and health problems and are working in hazardous conditions with minimal safety restrictions. Other studies have identified neurotoxicology effects in children from occupational exposures. Prevention methods have potential for reducing risks to young workers short of eliminating child labor and should be addressed to multiple stakeholders, parents, employers and children.

1. Introduction

The International Labor Organization (ILO) estimates that 218 million children are employed around the world, with over half working in hazardous or unsafe conditions. This is cause for concern because of the high vulnerability of children compared to adults, due to both their behavior and the developmental changes occurring throughout childhood and adolescence. Children are at risk to injury through manual labor and susceptible to poisoning due to chemical exposures in the work place. Often children work because of economic necessity, providing a significant portion of their family's total income. Furthermore, working children often come from families living in extreme poverty, with poor housing conditions, unsafe water supplies, poor sanitation, and inadequate food supplies making them even more vulnerable to poor developmental outcomes. This presents a multifaceted problem that can be challenging to address.

Developmental changes occurring throughout childhood, particularly during adolescence, may make working children more vulnerable (or more resilient) to subsequent neurotoxic exposures (Spear, 2000). The process of puberty, which typically occurs between ages 12 and 18, is associated with hormonal and physiological changes and a large growth spurt. There is also an increase in novelty seeking and risk taking behavior. Evidence from addiction studies indicate that brains may be at enhanced risk during this time (Spear, 2002). In addition, adolescents face a greater need for sleep than adults. Working over 20 h a week has been associated with daytime sleepiness and the ability of the child to stay awake during school. Furthermore, excessive sleepiness is associated with increased risk of injury, poor performance at both work and school and psychological problems (Davis et al., 2000; Salazar, 1997). Epidemiological studies also demonstrate that children have higher susceptibility to lead, silica and benzene (ILO, 1998, 2000; Fassa et al., 2000) and also to noise, heat and ionizing radiation (Bequele and Myers, 1995; Committee on the Health and Safety Implications of Child Labor, 1998). Research in the United

* Corresponding author. Tel.: +1 503 494 2513.
E-mail addresses: rohlmand@ohsu.edu (D.S. Rohlman), nuwayhid@aub.edu.lb (I. Nuwayhid), aa-ismail@hotmail.com (A. Ismail), saddikba@ngha.med.sa (B. Saddik).

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States has shown that children have a higher risk of injuries than adults; adolescents between 15 and 17 have an injury rate of 4.9 per 100% fulltime equivalent workers, while the rate is 2.8 for all workers (Committee on the Health and Safety Implications of Child Labor, 1998).

This paper reflects a summary of the talks from the symposium "Using Epidemiology and Neurotoxicology to Reduce Risks to Young Workers" presented at the 13th International Neurotoxicology Association Meeting and the 11th International Symposium on Neurobehavioral Methods and Effects in Occupational and Environmental Health in Xi'an China in June 2011. The summaries will report on the characteristics and exposure of working children in general with a focus on known neurotoxicants (e.g., pesticides and solvents) in work settings, reviewing the literature from less developed countries (Egypt and Lebanon) and a more developed country (United States of America). Although many studies have examined occupational exposures and risks among adults, very few studies have examined the impact of these risks on children. Studies examining working children in Egypt provide information about the hazards faced in children and demonstrate the limited work examining occupational exposures in a developing country. Studies in Lebanon are presented to describe the unique characteristics of working children and the impact of occupational solvent exposure on working children. Adolescents working in agriculture in the US provide an example of the risks faced by adolescents in a more developed country and offer potential solutions to reduce exposures in working children.

2. Young workers in Egypt

The majority of the child workers live in the developing countries of Latin America, Asia and Africa, but there are also pockets of child labor in many industrialized countries (ILO, 1998; Parker, 1997). In Egypt (population approximately 80 million), an estimated 2–2.5 million children between the ages 6 and 15 are working as agriculture laborers, factory workers, street vendors, domestic workers, laundry workers and helpers for mechanics (Egyptian Center for Women's Rights, 2008).

There are three sets of international legal standards that establish the framework for defining, identifying and addressing child labor in Egypt: the United Nations Convention on the Rights of the Child (ratified in 1990); the ILO Convention No. 138, Concerning Minimum Age for Admission to Employment (ratified in 1999); and the ILO Convention No. 182, Concerning the Worst Forms of Child Labor (ratified in 2002). These standards are combined in the law No. 126 of 2008, which forbids the employment of children below the age of 15 for permanent employment and prohibits any person under 18 from being employed in the worst forms of child labor. The Labor Law explicitly excludes domestic workers and members of the employer's family and children working in agricultural labor from these regulations. However, adaptation of these international standards into national law and implementation at a national level are poor and currently Egypt does not have a fully functioning and coherent government policy on child labor. This lack of effective governmental monitoring is of concern (Mosallem, 2011).

Several studies have addressed health hazards among young workers, mostly males of 16–17 years of age, across a range of industries in Egypt, including carpentry, mechanic, spray painters, blacksmith, autobody repair, dry cleaning, construction, and clothes ironing shops. One study reported that injuries were significantly higher among working children compared to the control group and medical examinations revealed a significantly higher prevalence of nail, hand, eye, mouth, throat and chest problems among working children. More than one third of the working children (38%) were suffering from fatigue and significantly more working children report smoking or drug use compared to controls. Results of blood analysis revealed that lead toxicity was higher among working children (42%) compared to the control group (21%). Working children also reported both low job satisfaction (46%) and dissatisfaction with working conditions (58%). Perhaps most troubling is that, more than half of the children (52%) report high physical or verbal abuse from their current employer (El-Laithy et al., 2008).

Noweir et al. (1993) surveyed working children in various industries. They reported that young workers had significantly higher prevalence of the following manifestations compared to controls: (a) respiratory system complaints; (b) cardiovascular abnormalities; (c) gastrointestinal abnormalities including dyspepsia and parasitic infestations; (d) neuropsychiatric complaints; and (e) other health problems including urinary tract infections, backache, visual impairment, hernia and nocturnal enuresis. The authors attributed these health effects to the impact of work on health and to the low socioeconomic background that requires the children to work, and they recommended the use of primary health care approach to child labor, emphasizing the importance of pre-employment and periodical medical examinations for protecting this vulnerable group from work hazards (Noweir et al., 1993).

Children can be employed year round or only during the summer when school is not in session. El-Gilany et al. (2007) surveyed secondary school students and reported that 28% of the students worked only during the summer and 9% report working throughout the year. Working students had a significantly higher prevalence of physical disorders including back pain, fatigue or weakness, visual disorders, chronic diarrhea, bronchial asthma, skin problems, and chronic headache, than non-working students (El-Gilany et al., 2007). The authors concluded that lower social status, attending vocational school, male sex, large family size and rural residence were significant predictors of students working while in school. It is noteworthy that vocational school students were reported to have a higher prevalence of lead toxicity (urinary lead > 80 μg/L) than students in regular schools (Osman et al., 2005). Elevated lead levels were associated with an increase in neurological signs and lower scores on the Wechsler Adult Intelligence Scale (WAIS).

Kotb et al. (2011) examined work activities among rural school students between the ages of 6 and 15 years old. They reported that more than half of the students (53%) worked in agricultural jobs and 73% of them began this work at an early age, less than 10 years old. Boys were more often involved in labor activities than girls. Approximately half of the working students reported helping their fathers in their work. More than one third of the working students had a history of injuries; the most common type of injuries was cut wounds (62%), followed by back pain, general weakness and fatigue and headache (35%, 21%, and 19%, respectively). Besides the previous physical manifestations, working students also demonstrated more psychological symptoms, and lower school performance (Kotb et al., 2011).

Other research has examined health outcomes in children working in agriculture. Children and adolescents are hired to work seasonally applying pesticides to the cotton crop. Male children working as applicators between the ages of 9 and 18 completed a neurobehavioral test battery, work, health, and exposure questionnaires, and medical and neurological screening exams (Abdel Rasoul et al., 2008; Ismail et al., 2010b). Blood samples were collected for cholinesterase screening and laboratory investigations. Children not working in agriculture, matched on age and education, and socioeconomic level served as controls. This study revealed significant health effects in children who work as pesticide applicators by comparison with control children. Children who apply pesticides showed impaired neurobehavioral performance, reported more symptoms, and had lower acetyl

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cholinesterase levels than children from the same communities that do not apply pesticides. This study also found a significant correlation between days worked during the current season and increased symptom reports and also with decreased neurobehavioral performance. Later research with a similar population of adolescent pesticide applicators found elevated metabolite levels of applicators and decreased neurobehavioral performance compared to control (Ismail et al., 2010a; Rohlman et al., 2011).

In addition to the lack of enforcement of the child work laws in Egypt, these young workers also report little use of protective equipment that could be used to decrease potential exposures (Abdel Rasoul et al., 2008; Farahat et al., 2003). There is also a lack of social support and health insurance that should provide care for the working children, both socially and medically. About 27% of paid child workers are employed in workshops, where environmental conditions are hazardous, hot, and dirty, toilets may not be available, and children may be badly treated by owners (WHO, 2005). Over 80% of working children are currently enrolled in schools and thus, in theory, have access to health care. However, they may not be able to access this care, as they report that, when they have an accident at work, on at least half of the occasions the family pays for medical care, while in just over a quarter of the cases the employer pays. Children injured at work may be reluctant to use the school health service, as they are technically working illegally (WHO, 2005).

3. Working children in Lebanon: an example of solvent exposure

Child labor is also a problem in Lebanon (population approximately 4 million), especially in underserved urban neighborhoods in the major cities and in rural areas. It has been reported that in spite of several national laws and international agreements which ban child labor, more than 40 thousand children under 18 years of age are active participants of the labor force in Lebanon (accounting for 4.6% of the labor force) (Issa and Houry, 1997). Unfortunately not many studies exist on child labor in Lebanon and therefore the scope and reasons for employment are limited to a number of descriptive studies. However from the studies available, it is clear that the majority of working children have low school enrollment rates, consequently dropping out of school as a result of failure in their studies. UNICEF (1995) reported that 37.5% of working children in Lebanon were illiterate or had not finished their elementary education. UNICEF (1995) and the ILO International Programme on the Elimination of Child Labor Lebanon (2002) found that working children primarily come from poor families having a low educational level. Children were usually employed in the same type of work as their fathers and had a lower educational level than non-working children of the same age. Issa and Houry (1997) also reported that almost all (92%) of the working children in their study, aged 10–13 years, were from families whose head of household had received only primary education or was illiterate. Similarly, another study found that 50% of children report working due to economic reasons, 33% in order to learn a profession and 14% because they had failed in their studies (Hamdan, 1997). The majority of working children in Lebanon are paid very low salaries. Hamdan (1997) also revealed that 65% of children get less than half the minimum wage rate. The same study also found that 90% of working children worked for more than 10 h a day and were not registered by employers in the National Social Security Fund (NSSF); therefore they were not covered by health or medical insurance. Nuwayhid et al. (2005) found that 80% of children who had been working for two or more years were receiving less than half the Lebanese minimum wage, at that time about US$50 (equivalent to 75,000 Lebanese pounds) per week, which would barely meet the family's basic needs for housing, food or education.

The Central Administration of Statistics (CAS) and UNICEF (2002) report that in the 10–14 year age group, most working children were employed in artisan production (49%) followed by trade and service (23%), whereas 57% worked in artisan production and 19% as unskilled employees in the 15–18 year age group. Eleven percent of working children were employed in the agriculture sector, and 5% were working in construction (ILO, 2002). The report also found that children in urban areas were employed in jobs predominantly trade-related whereas in the rural sector, agricultural work predominated. The kind of work a child did is likely linked to the availability of employment for children in their region, rather than intended selection of sectors. Although, it may also be argued that children preferred specific sectors because of their own or their parents desire for them to learn a trade.

Most children work in small industrial workshops with minimal control of hazards and practically total absence of protective measures or equipment. An investigation of the work environment and work activities of children working in mechanical, carpentry, autobody repair and spray-painting workshops in Lebanon (Nuwayhid et al., 2001), found that the workplaces visited lacked basic hygienic necessities including washing basins, soaps and toilets. Children reported using chemicals to "wash" grease and paints from their hands. Furthermore, the use of protective personal equipment was almost non-existent and missing from the majority of the 98 workplaces visited. An investigation of the physical and mental health of working children in Lebanon (Nuwayhid et al., 2005) revealed that working children are disadvantaged compared to non-working children. It was found that the nutritional intake of the working children was poorer than non-working children. Working children also reported more health problems and injuries. Physical examination and laboratory tests showed that more working children were anemic and had a higher blood lead level than non-working children and the condition of their skin reflected the jobs they were involved in, showing a clear indication of working with tools or chemicals. No differences were noted between the two groups of children regarding anxiety, hopelessness, and self-esteem. The drawings of the working children, however, revealed a higher tendency to place themselves outside home and a wider deficit in developmental age when compared to non-working children.

3.1. Solvent exposure in working children

In the absence of workplace control measures, children working in mechanical and other trade workshops are at significant risk of exposure to organic solvents, and as a result, at risk to develop clinical and subclinical signs of neurotoxicity. There have been relatively few studies examining neurobehavioral toxicity in working children, especially children from developing countries. A study was conducted in 2001 in Lebanon to compare the impact of solvent exposure on neurobehavioral performance in three groups of children, working children exposed to solvents, working children not exposed to solvents, and school children not working. All of the children were from the same community.

Demographic data, social habits, general health data and work history were collected through a questionnaire. Neurotoxic effects were assessed through a modified version of the Q16 neurotoxic questionnaire and the child's performance on a selection of neurobehavioral tests. Workplace exposure to a mixture of solvents was measured using personal indirect passive samplers. Analysis of the computerized neurobehavioral tests showed that, working children exposed to solvents had significantly slower mean reaction time than working children not exposed to solvents and to school children. Furthermore, the non-computerized tests demonstrated that working children exposed to solvents performed significantly worse than the other two groups on the motor

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dexterity and memory tests. These differences between working children exposed to solvents and the other two groups remained when the analysis controlled for potential confounding variables such as age and education. Workplace exposure measures showed that children working in environments where solvents were used had significantly higher levels of solvents than the school children and the children working in areas without solvent exposure, indicating occupational exposure to solvents. Furthermore, analysis of the relationship between workplace exposure and performance on the neurobehavioral tests showed that children with exposure levels above the hygienic effect threshold performed worse on a number of tests, specifically those which assessed functional domains in reaction time and memory functions (Saddik et al., 2003, 2009, 2005).

Overall the results of these studies indicate serious health and social problems in children working in Lebanon and especially those exposed to solvents. These are greater than the effects of simply working and need to be addressed especially since some of these effects are sub-clinical and only found on investigation. More information is still needed about the work hazards, work exposures and conditions to which working children in Lebanon and other developing countries are exposed to and about the types and frequency of physical activities they do at work. These are important to guide any policy action that aims to prevent child labor and to promote awareness of it. Moreover, there is a need to investigate particular problems among working children be it mental health, exposure to heavy metals, neurophysiological and neurobehavioral impairment, injuries and the like.

4. Adolescent farmworkers in the United States

Agricultural work is considered to be one of the most hazardous industries in the United States (CDC, 2011). In addition to long and strenuous work hours, there are many types of hazards in agriculture that put workers at risk to injuries and exposure to pesticides and other hazardous chemicals. Although many protections are in place for adolescent workers in the United States, including regulation of hours of employment and limiting exposure to dangerous machinery and hazardous exposures, these protections are more lenient when applied to children working in agriculture. Children working in agriculture can work at younger ages, including working in hazardous jobs, and there are no restrictions on the number of hours children can work on farms owned or operated by their parents. Agriculture is the second most common employer of youth in the US and the most dangerous industry for young workers. The risk of injury for child agricultural workers is four times higher than for children in other industries (NIOSH, 2010a). Although many employers provide basic safety and health training to these new and younger workers (e.g., the Worker Protection Standard; Environmental Protection Agency US, 1992), few currently implement programs are designed to address the special needs of a young or adolescent workforce.

Adolescent agricultural workers in the US include children living in agricultural communities, either working or living on a farm, children of migrant workers, and emancipated minors who work and travel without their families. The National Agricultural Workers' Survey (NAWS), reported that most adolescent farmworkers are male (84%) and live and work on their own without a parent (47%). In addition, between 1992 and 2000, 76% of fatal injuries to agricultural workers under the age of 16 involved work in a family business (Gabbard et al., 1999). There are many unique characteristics of these adolescents in the US that may put them at risk. Often they are new immigrants in an unfamiliar country, living and working without parents or other family members, with limited ability to read or speak English. This may be their first time working in agriculture and they have limited knowledge about work safety. Furthermore, adolescents perform the same work as adults and are exposed to the same risks as adults. Adolescents also tend to be risk takers who do not comprehend the long-term implications of disease, injury or disability.

4.1. Research examining adolescent farmworkers in the US

The majority of studies with adolescent farmworkers have focused on agricultural injuries. A range of data sources including, emergency room records, poison control records, and workers compensation claims, have been used to calculate injury rates and prevalence. Primarily injuries are related to work with tractors or other heavy machinery, hearing loss, falls and other orthopedic injuries (cuts, sprains, broken bones). The majority of fatalities (23%) associated with children working in agriculture are due to accidents with machinery (NIOSH, 2010b). The inexperience of children working in agriculture, their smaller size which often make equipment and safety protections designed for larger adults ineffective, as well as the fatigue that comes from long hours of physical labor, increase their risk for both fatal and non-fatal injuries (Cooper et al., 2005).

Adolescents working in agriculture are also at risk of exposure to pesticides. The incidence rate of acute occupational pesticide related illness in adolescents is significantly higher (197 per billion hours worked) compared to adolescents not working in agriculture (7 per billion hours worked) (Calvert et al., 2003). However, few studies have examined the impact of occupational pesticide exposure on adolescent health. These studies have identified deficits on neurobehavioral performance in adolescents working in agriculture compared to controls. These deficits are associated with increased years working in agriculture and working with pesticides (Rohlman et al., 2007, 2001). Gender differences have also been reported (Rohlman et al., 2007). However, it is unclear if adolescents are more vulnerable than adults to pesticide exposure.

The primary method of exposure to pesticides occurs by working in fields recently sprayed with pesticides. The Worker Protection Standard requires training for agriculture workers on the hazards of pesticide exposure. The Environmental Protection Agency requires retraining at 5-year intervals for all agricultural workers. Several studies have indicated that a low percentage of adolescents report receiving training about the dangers of pesticides, safety measures or what to do in case of exposure. A recent community-based survey evaluated pesticide knowledge, health beliefs and agricultural work practices in community members living in an agricultural community (Hohn, 2010). Approximately half of the 113 youth (18–25) completing the survey report working in agriculture (48%). Their scores on pesticide knowledge questions were significantly lower compared to older adults ($p < 0.05$). Furthermore, only 14% report receiving any pesticide safety training, although the majority (86%) report being exposed to pesticides while working. Supervisors (51%) or fellow workers (32%) are the primary source of information about pesticides or other chemicals in the workplace.

4.2. Interventions to reduce injuries

Recent work in the US has focused on reducing agricultural injuries in children and adolescents, focusing on training addressed to various stakeholders, including parents, employers and young workers. The North American Guidelines for Children's Agricultural Tasks (NAGCAT) was developed by the National Children's Center for Rural and Agricultural Health and Safety (Lee and Marlenga, 1999). These guidelines provide information about specific tasks and are designed to assist adults in assigning safe and appropriate jobs to children taking into account the capabilities of the child, and the hazards, risks and level of supervision required

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for specific tasks. An evaluation of the NAGCAT through a randomized control trial demonstrated a reduction in injuries on intervention farms compared to control farms and an increase in safety related behaviors (e.g., limiting time children work between breaks and delaying ATV use; Gadomski et al., 2006). Materials have also been developed specifically for supervisors of adolescent farmworkers, "Safety Guidelines for Hired Adolescent Farmworkers." Other methods have targeted adolescents working in agriculture (LOHP, 2010). This school-based intervention was designed to be administered to adolescent farmworkers in ESL or English as a Second Language classes. Adolescents who received the training demonstrated increases in knowledge and self-reported safety behaviors (Teran et al., 2008). These studies demonstrate the effectiveness of interventions targeted to various stakeholders. Recent reports on injury estimates for youth farmworkers have demonstrated a decline in injury rates between 1998 and 2009 (NIOSH, 2010b). These methods suggest that targeting interventions toward various stakeholders, taking into account the capabilities of the child and addressing specific risks associated with tasks may provide effective interventions to reduce risk and injuries in young workers. Future interventions need to focus on reducing chemical exposures in the workplace.

5. Conclusions

Child labor remains an acute global social and health problem, which is not limited to poor and under-resourced countries. It is feared that child labor will be on the increase in light of the growing global economic crisis. According to the ILO, although there was a decrease in child labor of 10% for the age group 5–14 years, there was an increase in child labor of 20% for the age group 15–17 years (Zaracostas, 2010). In spite of this, very few studies have examined the impact of these risks on children. Epidemiological studies have demonstrated that children exposed to various neurotoxicants, show increased symptoms and health problems and are working in hazardous conditions with minimal safety restrictions. Fewer studies have identified neurotoxicology effects in children from occupational exposures. These risks are frequently underreported, if reported at all. Safeguards in place for adults in the workplace are often not appropriate for children. There are multiple ways to reduce risk to young workers, including delaying the start of children entering the workforce, removing children from hazardous work, improving working conditions, providing adequate training, and identifying appropriate exposure limits for this vulnerable population. In order to find effective methods to reduce these risks and create safer working environments, researchers must confront the inherent challenges of working with this population and fully understand the unique risks faced by working children.

Some may pose the question whether more epidemiological research is needed to document the health effects of work hazards, including known neurotoxicants, on working children. We believe that more studies are needed but there is a need to adhere to strict methodological and ethical principles while conducting them and to look for converging evidence from animal models and through physiologically based pharmacokinetic/pharmacodynamic (PBPK/PD) modeling studies. For example, methodological issues including gender differences and timing of puberty need to be examined in order to determine the vulnerability of adolescents to exposure. In addition, the long-term effect beyond adolescence of exposure to neurotoxicants and other work hazards need to be examined. Studies that facilitate the removal of children from work and assess the impact of regulations and preventive measures on their exposure and health are also critical. Prevention methods have potential for reducing risks to young workers and should be addressed to multiple stakeholders, parents, employers and children. Identifying knowledge and beliefs in young workers allows the development of training and work practices to reduce workplace risks. Training should be geared toward the capabilities of the children and occur frequently.

In all of the above, public health professionals cannot escape the ethical dilemma that faces them when dealing with the issue of working children. Public health professionals cannot stay silent while watching millions of children being exposed to worst conditions of labor on a daily basis. However, the balance between "objective" assessment of exposure and health impact and "advocacy and activism" reminds us all of the thin line between scientific objectivity and ethical misconduct.

Conflict of interest

OHSU and Dr. Rohlman have a significant financial interest in Northwest Education Training and Assessment, LLC, a company that may have a commercial interest in the results of this research and technology. This potential conflict of interest was reviewed and a management plan approved by the OHSU Conflict of Interest in Research Committee was implemented.

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