



National Institute on Drug Abuse

Can Physical Activity and Exercise Prevent Drug Abuse? Promoting a Full Range of Science to Inform Prevention

June 5–6, 2008

Meeting Summary

**National Institutes of Health
Bethesda, MD**

**National Institute on Drug Abuse (NIDA)
National Institutes of Health (NIH)**

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Promoting a Full Range of Science to Inform Prevention**

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Meeting Summary

DAY ONE, THURSDAY, JUNE 5, 2008

Welcome and Overview of the Meeting

Physical Activity: A Remarkable Research Opportunity for NIDA; Wilson Compton, M.D., M.P.E., Director, Division of Epidemiology, Services, and Prevention Research, NIDA, Bethesda, MD

Dr. Compton welcomed the participants to the meeting and thanked the NIDA staff involved in bringing together practitioners and basic, clinical, and translational researchers from various disciplines to share ideas that will facilitate recovery from addiction. He explained that initial studies show that physical activity may have a significant role to play in recovery from substance use disorders (SUDs) because both drugs and exercise evoke similar responses in the brain reward system. In addition, both provide psychosocial rewards that increase the attractiveness of the behavior. These findings make exercise an intriguing and logical subject for SUD prevention and treatment research.

The Future of Physical Activity and Substance Use Research at NIDA; Nora Volkow, M.D., Director, NIDA, Bethesda, MD

Dr. Volkow welcomed the group and encouraged them to assist NIDA in the search for effective and inexpensive interventions to promote recovery from drug addiction. She reported that some current studies indicate that exercise may promote recovery from alcohol addiction. She also noted that larger and long-term studies are needed to identify and understand possible significant associations between exercise and addiction. Research might include cross-institute and interdisciplinary collaborations to explore the benefits of exercise on the neurological, chemical, and clinical levels. The identification of strong associations would have a definite impact on policy development and the promotion of exercise as an inexpensive intervention.

In her conclusion, Dr. Volkow noted that NIDA will soon promulgate a request for applications (RFA) providing \$4 million to support research on links between physical activity and addiction. She encouraged the meeting participants to provide bold ideas that will help shape the RFA and that will lead to meaningful breakthroughs and advance the field of prevention.

Meeting Logistics

Augusto Diana, Ph.D., Health Scientist Administrator, Prevention Research Branch, Division of Epidemiology, Services, and Prevention Research, NIDA, Bethesda, MD

Dr. Diana welcomed the group and thanked them and the NIDA staff for making the meeting possible. He explained that the basic format for the 2 days would consist of panel presentations followed by general discussions. In the interest of time, he asked the group to refer to the speaker biographies in their packets for information about the presenters' backgrounds and expertise. He also noted that a Webcast of the meeting would be archived and available at <http://videocast.nih.gov>.

Setting the Stage for the Meeting

Moving Toward Exercise as Substance Abuse Prevention—Learning From Smoking Cessation Programs; Bess Marcus, Ph.D., Professor of Community Health, Brown University, Providence, RI

Dr. Marcus reviewed recent findings concerning the benefits of physical activity for overall health. She noted that available data indicates that exercise can have a positive impact on nicotine use. She also reported that:

- Studies have found that middle school children who participate in sports are less likely to use alcohol, cigarettes, and marijuana than students who do not participate. However, when children reach high school, they are less likely to participate in sports and more likely to experience peer pressure to use drugs. The results are increased use of alcohol, cigarettes, and marijuana as well as use of cocaine. Nonetheless, some studies show that these increases are lower among students participating in sports.
- Some recent interventions produced long-term positive effects on alcohol and cigarette use among teens by promoting physical activity and providing brief consultations on the negative consequences of substance use. This finding may be linked to various effects of exercise that reduce risk for SUDs. Exercise provides a healthy outlet for energy and aggression, improves feelings of well-being, reduces anxiety and depression, and increases positive social interactions.
- Programs that promote exercise as an alternative to drug use must be attractive to the target audience. To that end, projects for teens should incorporate elements from the growing field of sports technology.
- Additional studies are needed to learn more about how exercise might be beneficially incorporated into recovery and prevention efforts.

Discussion

In response to questions, Dr. Marcus noted that:

- Researchers should be encouraged to collaborate with community organizations in providing interventions at convenient, low-cost sites. For example, smoking interventions provided at YMCAs have been successful in attracting participants.
- Physical activity can be part of both treatment and prevention efforts. In either case, exercise should be made an exciting option.
- Team sports may not provide enough exercise to be protective factors. Communities need to be encouraged to use multiple methods to increase exercise for children, teens, and adults. For example, the built environment might be

adjusted to include more sidewalks and municipal policies might be changed to encourage students to walk by moving bus drop-off points further from schools.

Panel One: Physical Activity in Prevention Interventions: Understanding the Concept

Moderator: Shirley Gerrior, Ph.D., National Program Leader, U.S. Department of Agriculture, Washington, DC

Adolescents and Healthy Leisure Contexts: The HealthWise and TimeWise Interventions; Linda L. Caldwell, Ph.D., Professor of Human Development and Family Studies, Pennsylvania State University, University Park, PA

Dr. Caldwell provided an overview of research on physical activity and leisure-time use among adolescents. She began by summarizing two NIDA-supported programs that promote physical activity as a leisure-time option and provide prevention messages.

- TimeWise: Taking Charge of Leisure Time provided rural students in grades 7–9 with core lessons and advanced skill-builders to promote the healthy use of leisure time. Results indicated that, in comparison with a control group, participants increased their intrinsic motivation and decreased their amotivation and boredom. In addition, boys in the intervention group had slightly lower rates of inhalant and cannabis use. Furthermore, although boys in both groups used alcohol at increasing rates, the increase was lower among boys in the program.
- HealthWise South Africa: Life Skills for Young Adults targets substance use, sexual risk-taking, and the co-occurrence of these behaviors. Thus far, the sessions offered to eighth grade girls appear to be useful in motivating them to make protective leisure-time choices.

Dr. Caldwell also reviewed three other similar studies, noting that each provided evidence that leisure education can help adolescents make protective decisions and select leisure-time activities that are linked to reductions in substance use. However, she also observed that all of the studies underscore the need for greater research, particularly to develop: (1) consistent measurements for cross-study components and (2) methods for sustaining programs.

Translating Drug Use Prevention to Obesity Prevention; Mary Ann Pentz, Ph.D., Professor of Preventive Medicine, University of Southern California, Alhambra, CA

Dr. Pentz noted that translational research allows investigators to apply lessons learned about one risky behavior to others. She explained that prevention research on SUDs and impulsive eating may have relevance for each because both behaviors share specific risk factors. These include low impulse control, sensation seeking, emotional dysregulation, poor executive cognitive functions, inappropriate peer and parental modeling, and substance use in response to stress/arousal.

The Midwestern Prevention Project, a multicomponent community-based prevention trial, incorporates two evidence-based models for drug use and violence prevention into the Pathways to Health (PATHWAYS) program for control of impulsive eating. Various

PATHWAYS interventions—all of which involve students in grades 4–6 and their families—are being used to test four hypotheses:

- The regulation hypothesis states that a PATHWAYS intervention targeting improved emotional regulation will lead to increased executive cognitive function; in turn, this will lead to increased physical activity and decreased impulsive eating.
- The prosocial bonding hypothesis states that a PATHWAYS intervention promoting increased physical activity will lead participants to seek a prosocial environment and then to decrease impulsive eating.
- The regulation hypothesis states that a PATHWAYS intervention focusing on increased physical activity will lead to alternative leisure-time use and, in turn, decreased impulsive eating.
- The pleasure hypothesis states that a PATHWAYS intervention focusing on increased exercise and decreased eating will increase dopamine responses and lead to better impulsive eating control.

Using the Behavioral Rating Inventory for Executive Function and the Neighborhood Physical Activity Questionnaire, Dr. Pentz has thus far found relationships supporting the regulatory control hypothesis. The other hypotheses will be tested.

A Model for Preventing Substance Abuse and Promoting Physical Activity in High Schools; David Wyrick, Ph.D., Associate Professor of Public Health Education, University of North Carolina at Greensboro, Greensboro, NC

Dr. Wyrick described the NIDA-supported Crossroads prevention program. Crossroads employs partnership between health teachers, high school peer educators, and college mentors. It is a multicomponent program designed to complement existing health instruction and is grounded in evidence-based prevention strategies. The targeted mediators are positive social norms, beliefs about consequences, decisionmaking, and resisting pressure.

One of the key Crossroads components is HOPSports, a multimedia program for high school students designed to promote exercise, good nutrition, and healthy decisionmaking about drug use. HOPSports is compliant with age-appropriate physical education standards and uses a cyber gym, as well as actual exercise equipment, to train students in skills specific to sports, dance, and exercise. HOPSports targets knowledge, self-efficacy, normative beliefs, attitudes, and perceived behavior control. It attracts students by providing activities that are fun and involve cutting-edge sports technology. Challenges in disseminating the program include its cost and difficulties gaining support from high school physical education teachers who may not be comfortable with technology.

Contributions of Public Parks to Physical Activity in Low-Income and Diverse Communities; Myron F. Floyd, Ph.D., Professor, College of Natural Resources, North Carolina State University, Raleigh, NC

Dr. Floyd discussed recent studies about the use of parks by low-income and minority populations and identified pertinent research needs and implications. He noted that:

- Fourteen of 20 recent studies found consistent evidence that parks increase opportunities for physical activity.
- All 20 studies emphasized the need for access to programs, as well as facilities, and for aesthetically appealing space.
- Park use patterns and setting preferences seem to vary by race/ethnicity. For example, African Americans tend to favor parks with more developed facilities.

Dr. Floyd also reviewed his research about park use in Chicago census tracts with different ethnic compositions. He found that with the exception of the playground areas, adults were more likely to use the parks than children. In addition, having a park close to home was linked to more time spent in vigorous physical activity, especially among girls. He also found that:

- Parks commonly used by children and adult males were associated with the conduct of more vigorous physical activity.
- Women were more likely than men to make use of the playgrounds and walking paths.
- In African-American neighborhoods, access to a park and the prevalence of children were predictors of engaging in vigorous activity.
- There is clear gender and age segregation among Latino park users.
- Some sports (such as soccer) require more vigorous activity than others (such as baseball).

Dr. Floyd recommended that parks provide space designed for more, as well as less, vigorous activities. He also recommended establishing a theoretical framework employing a socioecological model to examine ways that parks can promote SUD prevention. To be effective, this framework should include standardized and culturally sensitive methods for measuring physical activity, leisure time, and park environments. In addition, he stressed the importance of conducting research on the relationships between prevention outcomes and parks and other built environments, with particular attention to variables such as gender, race/ethnicity, age, and park quality.

Positive Action for Today's Health (PATH): A Community-Based Trial for Improving Safety and Access for Physical Activity; Dawn K. Wilson, Ph.D., Professor of Psychology, University of South Carolina, Columbia, SC

Dr. Wilson discussed the PATH program and its implications for SUD prevention. PATH is designed to determine whether an intervention involving patrolled walking and social marketing will result in:

- Greater increases in moderate-to-vigorous activity (MVPA) after 12 months, and
- Greater maintenance of increased MVPA after 18 and 24 months.

As a first step in implementing PATH, a formative study was undertaken to examine differences in exercise participation and perceptions of neighborhood safety within low and high socioeconomic status (SES) communities in Sumner County, South Carolina. Findings indicate that:

- Residents in neighborhoods with lower SES were more sedentary than residents in higher SES neighborhoods.

- Although the miles of sidewalk, access to facilities, and crime rates were similar across the neighborhoods, residents' perceptions of these factors and lack of awareness of existing facilities appeared to influence physical activity levels.

Based on this formative study and other PATH-related preliminary research on topics such as nutrition and family views of exercise, Dr. Wilson concluded that more research is needed to address community, family, and individual issues related to physical activity. She also concluded that:

- Health promotion programs should be flexible and include components that respond to local issues.
- Local advocacy should be highly encouraged as a method for improving access to healthy foods and places to exercise.
- Studies should consider the differing needs of parents and adolescents.
- A positive approach to health improvement might focus on healthy behaviors rather than weight loss.

Discussion

Meeting participants agreed that sustainability is the key to success for individual and community physical activity programs. Although patients get exercise prescriptions from their health care providers, long-term exercise adherence on the individual level requires internal motivation and the use of leisure activities. Participants also noted that:

- Innovative social marketing techniques could be used to build ongoing enthusiasm for physical activity on the community and individual levels; however, more research is needed to identify the most effective social marketing messages and channels for delivering them.
- Lifelong learning might provide a context for individual efforts to start and sustain exercise programs.

In further discussion, participants noted that longitudinal studies are needed to more fully examine linkages between the built environment and physical activity and to examine the social implications of various built environments. Further research also is needed about:

- The relationship between physical activity and exposure to nature.
- The restorative qualities of being outdoors and of low-intensity exercise such as yoga.
- Methods for promoting student involvement in extracurricular and leisure-time exercise to compensate for the reduced time allowed for physical activity during school hours.
- The mediating factors linked to making positive lifestyle changes.

Furthermore, to ensure that the research is replicable and generally applicable, more precise definitions are needed for key terms such as physical activity, intense activity, and leisure.

Participants also discussed the RFA process. They recommended that the RFA encourage research ideas from various disciplines and asked that application review committees understand the interdisciplinary nature of the field, the multiple types of research required

to move forward, and the various approaches available for incorporating physical activity into prevention and treatment interventions.

Panel Two: Technological Tools for Assessing Physical Activity--Product Demonstrations

Moderator: Audie Atienza, Ph.D., Behavioral Scientist, Division of Cancer Control and Population Sciences, National Cancer Institute, Bethesda, MD

Overview: Issues Involved in the Assessment of Physical Activity; Audie Atienza, Ph.D.
Dr. Atienza provided an overview of current assessment tools and a snapshot of products under development with NIDA support. Prototypes of these products should be available in 2011.

The most current assessment tools fall into one of two categories: self-reports or objective monitors. At present, about 100 self-report surveys and questionnaires are available; however the accuracy of self-reports remains questionable. Inaccuracies are created by faulty recall, time decay, and the influence of social pressures. Studies comparing self-reports and objective monitors find that individuals are likely to report more activity at greater intensity and for longer durations than is recorded on the monitor.

Objective monitors generally are either pedometers or accelerometers. Studies of pedometers, also called step counters, indicate that these tools have moderate intertest reliability and a moderate correlation with energy expenditure. Their use also is inversely related to sedentary behavior. Pedometers are inexpensive and easy to use; however, they may under-measure activity, and they do not provide data on activity intensity. Tests of accelerometers indicate that these instruments have varying levels of reliability, depending on the type that is used. They tend to underestimate energy expenditure. In addition, although they do measure intensity and duration of activity, results for light and vigorous activity may be inaccurate.

Physiological measures of fitness have been used in activity studies. However, these tools are expensive and obtrusive and are not easily used for real-time measures across populations. In addition, fitness, unlike physical activity, has a genetic component; this critical definitional difference limits the value of comparisons.

NIDA is committed to moving assessment technology to the next stage of sophistication, and the industry is responding. New integrated monitoring tools are being created with improved reliability and validity and a focus on real-time measurement. Empirical peer-reviewed evaluations of these tools will be conducted and further work will be done to resolve issues related to product cost, data storage and analysis, patient confidentiality, and Institutional Review Board approval. In addition, NIDA will promote the development of technical training and technology coordination programs that keep up with the rapid pace of product development.

Assessment of Physical Activity Using Wearable Monitors: Novel Analytic Techniques and Multiple Sensor Devices; Patty S. Freedson, Ph.D., Chair and Professor, Department of Kinesiology, University of Massachusetts, Amherst, MA

Dr. Freedson discussed problems with traditional data processing systems used to interpret accelerometer information, outlined novel methods for analyzing these data, and reported on the development of integrated multisensor devices.

Traditional data processing systems use disparate regression models for information interpretation. Not only do these methods vary, they seldom incorporate all of the data made available by the accelerometer, and they often do not allow for adequate measurements of intensity levels. In response to these problems, investigators have developed intelligent data processing methods, such as neural networking, for analyzing information. Recent research findings indicate that neural networks use the entire sequence and pattern of accelerometer signals, are flexible and powerful, and are capable of “learning” by example. They also are better than traditional data processing solutions for predicting energy expenditures linked to specific activities. In addition, neural networking reduces errors in estimating energy expenditures and eliminates the use of count averaging over specified time intervals.

Dr. Freedson is currently conducting research to develop and evaluate a multisensor device for assessing physical activity that incorporates the findings from neural networking research. Novel features include the use of: (1) a physiological variable (ventilation) that responds to activity and (2) environmental context assessments to determine whether the activity is occurring indoors or outdoors. The ultimate goal is to develop a fully integrated suite of sensors that will make use of pattern recognition to evaluate the volume (amount and intensity) and type of activity. This suite will be an ecological assessment monitor housed in a small unit to be worn on the wrist or belt. The monitor will conduct surveillance of physical activity and inactivity and evaluate changes in activity in response to interventions. It also will quantify physical activity doses by intensity, frequency, duration, type, and bout.

Discussion

In response to questions, Dr. Freedson explained that:

- Better data interpretation methods are being developed to inform evaluations; and
- Controls are included in the research to address data variations caused by individual/specific anomalies.

Towards Real-Time Recognition of Type, Duration, Intensity, and Location of Physical Activity on Mobile Phones; Stephen S. Intille, Ph.D., Technology Director, Department of Architecture, Massachusetts Institute of Technology, Cambridge, MA

Dr. Intille discussed research being undertaken to develop a system capable of detecting physical activity type, intensity, and duration in real-time using miniature wireless accelerometers. As part of this project, the research team has developed an open-source and low-cost hardware and software system for detecting physical activity exploiting common mobile phones. The current challenge is to develop context-sensitive electronic

sampling software on phones that can trigger self-reports based on physical activity and subject characteristics.

As each component is developed, it is evaluated for validity, usability, and acceptability. The goal is to create a complete system that permits population-scale studies to be deployed and run for months. Early results suggest that the final system will include two or three body sensors for detecting real-time activity type and intensity. In addition, energy expenditure will be detected by identifying activity types and linking them with data from an intensity table. The system will run on laptop computers and mobile phones modified to include software for collecting information about the subjects' activity, heart rate, location and related self-reports about behavior.

Physical Activity Location Measurement System (PALMS); Kevin Patrick, M.D., Professor of Family and Preventive Medicine, University of California, San Diego, CA
Dr. Patrick discussed the development of PALMS, an integrated suite of hardware and software that supports continuous analysis of data needed for the understanding of physical activity/environmental exposure. PALMS brings a geospatial perspective to data collection and analysis and can support information gathering from multiple participants within and across various studies. It also is uniquely suited for measuring epigenetic expression.

The three PALMS elements are the sensor, the core architecture for data collection and coordination, and the system for accessing results and linking to other tools. The sensor feeds data of interest to the computers linked through the core architecture, which also deploys the data for use by the researchers. Studies thus far have found that PALMS can successfully map heart rates in various localities and link heart rates to land uses, creating spatial representations of physical activities.

Recently, researchers have combined cell phone and PALMS technology to create eBalance™. This product helps scientists make real-time measurements of energy expenditures and collect data tailored to their specific research. The cell phone provides a user-friendly interface and enables subjects to move over a relatively wide area while still participating in studies. Data are collected via the Internet and a Web site is available for technical computations by researchers and for two-way communications with subjects. Studies of health interventions using eBalance™ have demonstrated its usefulness. For example, a nutrition intervention found that subjects kept more accurate food diaries and were able to receive intervention information in a more timely manner when eBalance™ was employed.

Discussion

In response to questions, Dr. Patrick noted that further research will be conducted on safety and social interaction issues as areas related to PALMS. He also hopes to get funding to create multimedia plug-and-play PALMS applications that complement 21st century learning modalities.

Restorative Benefits of Outdoor Recreation; Chad Pierskalla, Ph.D., Associate Professor, Division of Forestry and Natural Resources, West Virginia University, Morgantown, WV

Dr. Pierskalla reviewed research findings linking stress and boredom with drug use among teens and discussed his work exploring the use of restorative activity—specifically time spent outdoors—as a stress reducer. His current primary foci are: (1) identifying a recommended “dose” of time spent in natural surroundings that will be restorative for highly stressed youth and (2) defining the dose in terms of magnitude, frequency, and duration. Research challenges include developing (1) standards and criteria for levels of restorative activity and (2) tools for simultaneously measuring psychological and physiological restoration indicators.

Although traditional research on nature and stress often uses pictures of landscape to simulate the outdoors for subjects, richer data are generated from studies that employ videos and/or involve participants in real-time outdoor experiences. Dr. Pierskalla used continuous audience response technology to confirm this finding with college students. His future research plans include conducting studies of stress reduction among middle school students using video and real-time outdoor experiences.

Panel Three: Physical Activity and Mood—Implications for Prevention

Moderator: Frank Perna, Ph.D., Ed.D., Program Director, Division of Cancer Control and Population Sciences, National Cancer Institute, Bethesda, MD
The Physiology/Neurobiology of Stress and Physical Activity in Animal Research; Stephen Suomi, Ph.D., Chief, Laboratory of Comparative Ethology, National Institute of Child Health and Human Development, Bethesda, MD

Dr. Suomi summarized the results of his studies of the impact of early environmental and genetic factors on later substance use among Rhesus monkeys. He found that:

- Biological and highly heritable variations do appear among very young Rhesus monkeys; about 10 percent are unusually impulsive and about 15 percent are unusually fearful.
- The unusually impulsive monkeys played too aggressively with their peers and, as a result, were avoided. These monkeys also had lower serotonin levels and, when offered alcohol, were most interested in imbibing and more likely to binge drink.
- Monkeys removed from their mothers’ care shortly after birth and not provided with surrogates were more fearful and engaged in less complex play than monkeys who remained with their mothers. The experimental group also had higher cortisol and lower serotonin-bonding levels and consumed more alcohol than the monkeys not taken from their mothers.

Monkeys removed from their mothers and provided with surrogates (pads of soft material connected to a food source and an artificial nipple) are currently being studied. Results are pending, but it appears that these monkeys have lower cortisol levels and vary in other ways from the control group of monkeys raised by their mothers.

Based on these and other findings, Dr. Suomi concluded that genetic variants exist among Rhesus monkeys, which increase their risk for substance use; however, these are not

expressed until the animals are deprived of nurturance. He also suggested that stress makes genetic polymorphisms more important, and that environment is more important than genetics for monkeys and humans.

Proposed Mechanisms Underlying the Exercise and Depression Relationship: Relevance to Drug Abuse; Lynette L. Craft, Ph.D., Assistant Professor, Department of Preventive Medicine, Northwestern University, Chicago, IL

Dr. Craft explained three mechanisms that appear to justify using exercise to help treat SUDs. She also highlighted the pertinent cognitive and neurobiological changes associated with these mechanisms.

Dr. Craft summarized the research on physiological and psychological mechanisms that might explain the antidepressant effects of exercise and identified the three hypotheses with the most relevant evidence. However, she cautioned that the second and third had limited research support. The three hypotheses were:

- The monoamine hypothesis—exercise raises the levels of brain monoamines (norepinephrine, serotonin, and dopamine) that reduce depression. Animal data support this hypothesis, indicating that cocaine, methamphetamine, and alcohol use alters dopamine levels. Newer imaging techniques may enable scientists to collect pertinent data about humans.
- The self-efficacy hypothesis—the mastery of important health-related behaviors is associated with an enhanced sense of self-efficacy. Greater self-efficacy, in turn, is associated with reduced catecholamine responses to stress, lower perceived vulnerability to threat, reduced anxiety, and increased cognitive control. Some studies link higher self-efficacy to abstinence among teenage drug users and indicate that self-efficacy may be a predictor of future drinking behavior.
- The anxiety sensitivity hypothesis—repeated exposure to anxiety-related sensations through exercise may contribute to a reduction in anxiety sensitivity. The reduction may translate into greater tolerance of stressful stimuli that would otherwise lead to drug use. In addition, exercise may reduce anxiety sensitivity by teaching effective coping skills.

Dr. Craft recommended conducting research to validate these hypotheses. She also suggested using a biopsychosocial approach to apply any pertinent findings to the field.

Exercise Dose and Mood in Drug Use: Extrapolation From Tobacco Dependence; Taru Kinnunen, Ph.D., Section Editor, Tobacco Dependence Treatment and Research, Harvard School of Dental Medicine, Boston, MA

Dr. Kinnunen reviewed studies of nicotine cessation, including his own, and summarized their possible implications for understanding relationships among exercise, mood, and drug use treatment. He began by reviewing pertinent findings from studies of exercise and affect:

- Exercise dose intensity has an impact on adherence and affective responses. Moderate intensity exercise appears to be linked with greater adherence than high or low intensity exercise. It also is linked to consistently positive postexercise affect.

- Nicotine cessation studies have found that people with negative affect are most likely to start and continue using nicotine. In addition, self-administration increased when negative affect was present, and negative affect is a common withdrawal symptom.

Dr. Kinnunen's study of the relationships between exercise, mood, and nicotine cessation involved measuring the impact of exercise and wellness interventions on women between ages 18 and 55 who were receiving nicotine replacement therapy to stop smoking. He also studied the relationships between various aspects of the interventions and negative affect before and after the women quit smoking. The data collected thus far indicate that:

- Smokers who exercised at higher intensities were more successful at quitting.
- Smokers who were depressed at the beginning of the study seemed to experience consistent reductions in negative affect that were linked to exercise.
- Exercise intensity appears to have different impacts before and after quitting. High intensity before quitting was associated with more negative affect, while high intensity after quitting was not.

Based on these data, Dr. Kinnunen suggested that research be conducted to investigate:

- Whether higher intensity exercise leads to better cessation outcomes in large randomized trials;
- How exercise intensity affects withdrawal; and
- The acute (immediate) effects of exercise on affective responses.

He also recommended conducting further study to identify populations for which exercise would be an effective treatment component. In addition, he suggested that investigators consider the role of exercise in drug treatment science, with special attention to:

- Examining when and where exercise science findings might be translated into SUDs treatment; and
- Identifying the factors that are feasible, most relevant, and essential for assessing the impact of exercise on SUDs.

Prevention of Adolescent Depression and the Potential Role of Exercise; Paul Rohde, Ph.D., Senior Research Scientist, Oregon Research Institute, Eugene, OR

Dr. Rohde reviewed depression prevention meta-analyses and related studies, including his most recent randomized control trial of depression prevention among youth. He extrapolated findings that might be relevant for understanding the associations of depression with exercise and SUDs treatment.

The meta-analysis results indicated that prevention programs were successful 49 percent of the time, which compared well with success rates for programs targeting HIV, eating disorders, and obesity, all of which had success rates between 20 and 25 percent. Trials that significantly reduced risk for depression onset were more likely to involve cognitive behavioral or interpersonal therapy, with the former being more successful. Bibliotherapy and supportive-expressive groups did not appear to be effective. However, the positive effects of depression prevention programs were small. Dr. Rohde's most recent

depression prevention study confirmed the effectiveness of cognitive behavioral therapy when compared to the other three therapeutic techniques for adolescents.

Recent studies indicate that the positive effects of exercise on depression and anxiety may be generated by various psychological and physical mechanisms. For example, exercise may increase confidence, self-efficacy, and sense of achievement; improve coping and control skills; and promote increased positive social interactions. Exercise also may improve the quality of sleep, distract subjects from cognitive rumination, decrease cognitive dissonance, and increase the availability of neurotransmitters that regulate mood. These factors, especially those associated with self-efficacy, are inversely associated with depression, self-medication, and SUDs. Furthermore, depression and SUDs are often comorbid and recent findings suggest that recovery from one condition is related to recovery from the other.

Dr. Rohde recommended conducting more research to better understand these linkages and their operant mechanisms. Particular attention should be paid to: (1) the role of gender, (2) developing techniques that will increase exercise among depressed adolescents, and (3) the temporal relationships between depression and exercise.

Discussion

The discussion focused on affect responses generated by exercise and building supports for exercise programs. Additional remarks also were made about the use of neuroimaging to increase scientific understanding of the relationships between brain activation, exercise, and mood.

Participants summarized findings about the relationships of affect and exercise. Postexercise affect was positive, possibly because the exercise was finished; however, affect during exercise was mixed. Initial affect during exercise might be the best adherence predictor. More research is needed about the impact of sustained exercise on mood.

Participants also noted that research is needed about ways to help people feel good while exercising because enhanced positive feelings should increase program adherence. Any supports should ultimately build intrinsic self-motivation for exercising. They also should be creative and individualized. Social supports, such as coaching and mentoring, might make exercise more enjoyable. Some of the findings about play among Rhesus monkeys may be relevant for building appropriate social supports for children and adolescents.

In further remarks, the group agreed that neuroimaging shows great promise for increasing scientific understanding of the brain systems involved in mood alteration related to SUDs. A key challenge is teasing out the brain structure activation caused by the impact of exercise on mood, independent of the impact of exercise on general body regulation. Another challenge is using the neuroimaging findings to develop programs that build the neuroplasticity associated with depression reduction.

Wrap-Up of Day One

Augusto Diana, Ph.D.

Dr. Diana highlighted some of the key issues raised during the day. He noted that definitions are needed for physical activity and its components, including exercise and sports. He added that more research is needed about factors that make exercise attractive and that promote adherence, particularly social supports.

In his conclusion, Dr. Diana thanked the group for their active participation and stimulating ideas. He asked them to maintain their level of enthusiasm during the next day's session, which would include more thought-provoking presentations. Dr. Diana also thanked all of the NIDA and contractor staff involved, respectively, in developing the meeting themes and implementing the meeting logistics.

DAY TWO, FRIDAY, JUNE 6, 2008**Set-Up for Day Two**

Aleta Meyer, Ph.D., Health Scientist Administrator, Prevention Research Branch, Division of Epidemiology, Services, and Prevention Research, NIDA, Bethesda, MD

Dr. Meyer summarized Friday's themes and the key points made on Thursday. She noted that the upcoming panels would focus on epidemiology, attention and cognitive processes, and rewards and motivation. They provided perspectives on current findings and promising research. The previous day's highlights included Dr. Volkow's request for input for the upcoming exercise RFA and participants' creative responses, which ranged from novel applications of theoretical constructs to reports on new measurement tools and products. Before concluding, Dr. Meyer encouraged the participants to maintain their high level of involvement in the sessions and to continue providing NIDA with ideas that will shape its exercise research priorities.

Panel Four: Informing Drug Abuse Prevention Through Research on the Epidemiology and Etiology of Physical Activity and Substance Use

Moderator: Marsha Lopez, Ph.D., Health Scientist Administrator, Prevention Research Branch, Division of Epidemiology, Services, and Prevention Research, NIDA, Bethesda, MD

The Neurobiology of Exercise; Rod K. Dishman, Ph.D., Professor of Exercise Science, University of Georgia, Athens, GA

Dr. Dishman provided an overview of pertinent epidemiology and etiology research. He began with a review of the literature from both mental health and exercise studies that might be useful for shaping research on physical activity as an intervention. He concluded that these studies had limited usefulness, noting that additional investigations are needed about applying findings from animal research to humans, gene/environment interactions, and mechanisms that might explain changes in behavior, cognition, mood, and stress resistance.

In further remarks, Dr. Dishman recommended conducting additional studies of:

- Voluntariness in physical activity. Most exercise studies involve forced physical activity, which may generate different neurobiological, physiological, and behavioral responses than voluntary exercise. Studies of play may provide some

of the missing data, but the pertinence of these results may be limited because play for children must be developmentally appropriate, unlike fitness training for adults; in addition, play has smaller effects on the key variables of interest to researchers.

- Exercise and neural plasticity. Greater understanding is needed to build on recent findings, especially those indicating that both drug use and exercise stimulate key neurotransmitters (serotonin, norepinephrine, and dopamine) involved in the nucleus accumbens/limbic reward system.

The Association of Exercise and Sports Participation With Various Forms of Substance Use in Adolescence: Findings From Monitoring the Future; Lloyd D. Johnston, Ph.D., Distinguished Research Scientist and Research Professor, University of Michigan, Ann Arbor, MI

Dr. Johnston reported on findings from *Monitoring the Future*, a large-scale epidemiological study sponsored by NIDA since 1975. This annual survey includes a nationally representative sample of 50,000 students in grades 8, 10, and 12.

Based on findings from 1991–2007, Dr. Johnston reported that the four survey measures of drug use (smoking, binge drinking, marijuana use, and use of other illicit drugs) have an ordinal, negative, and cross-sectional relationship with self-reported levels of exercise, especially in eighth grade. However, the association:

- Weakens for marijuana by 12th grade, particularly among females;
- Reverses for binge drinking by 12th grade; and
- Weakens for all drugs among African-American and Hispanic females in 12th grade.

Other key findings included the following:

- Levels of exercise declined considerably by 12th grade for all students.
- The amount of exercise reported by 8th and 10th grade males increased between 1992 and 2007.
- Although females' participation in school athletic teams rose considerably since 1992, reported levels of vigorous exercise did not change much.
- Cross-time trends in amounts of vigorous exercise among the surveyed students did not correlate particularly well with cross-time trends in substance use.

Dr. Johnston concluded by urging the meeting participants to consider epidemiological information, especially trend data, when designing programs. He also recommended conducting further research on the neurobiological connections between drug use and exercise.

Neighborhood Built and Social Environments and Physical Activity; Ming Wen, Ph.D., Assistant Professor of Sociology, University of Utah, Salt Lake City, UT

Dr. Wen explained that studies of the build and social environments are being conducted more frequently as scientists become more aware of the influence of communal factors on individual decisions. She described two NIDA-supported environmental studies she conducted and suggested possible implications of the findings for future research.

Dr. Wen's first study looked at the relationship between neighborhood environments and individual decisions to walk for transportation or leisure in California. Her second study explored the contextual effects of built and social environments in Chicago neighborhoods on residents' levels of physical activity. Findings from the first study indicated that neighborhood social cohesion and access to a park, playground, or open space were significant environmental correlates of walking at recommended levels for good health, independent of sociodemographic factors. The second study found that a neighborhood's social and built environments were factors in individuals' decisions to engage in leisure-time physical activity. The research limitations of both studies included the lack of data about causality, limited generalizability across multiple settings, and a reliance on self-reports.

Based on her findings, Dr. Wen recommended that programs promoting behavioral change should consider participants' social and built environments. In addition, she suggested that more research be conducted to learn which neighborhood factors are most significant in individual decisions related to exercise.

Obstacles for Reaching Underserved Populations; Leo Nolan, M.Ed., Senior Policy Analyst, Indian Health Service, Rockville, MD, and Ron Gurley, M.S., Project Manager, FirstPic, Inc., Crofton, MD

Mr. Nolan explained that few exercise intervention studies target the relatively small but highly diverse and dispersed Native American population. However, developing low-cost interventions for this population is especially important because Native American youth have disproportionately high death rates from alcoholism when compared to other ethnic groups.

Mr. Gurley described Together Raising Awareness for Indian Life, a program to reduce the prevalence of diabetes among American Indian youth. This program is based in Boys and Girls Clubs because they are convenient, safe, and clean locations where teens go to have fun. Multiple community institutions—including local schools, food banks, and tribal health agencies—provide various types of support. National organizations, including Nike, Inc., also are active supporters. Program components address participants' mental, physical, emotional, and spiritual well-being. Cultural awareness is incorporated into all of the components. For example, physical activities include stomp dancing and stickball as well as basketball and baseball.

Mr. Gurley suggested that the inclusion of spiritual well-being, the development of community and national partnerships, and the selection of convenient, safe, and popular program sites were particularly important contributors to the program success. He recommended that these factors be considered in developing exercise interventions for SUDs.

Discussion

The discussion ranged across the topics raised by the presenters. Key comments included the following:

- Leisure and occupational activity—A dose-dependent relationship appears to exist between leisure activity and lower symptoms of depression; however, more research is needed to understand this link and to determine whether a similar relationship exists between lower depression symptoms and occupational activity.
- The built environment—Dr. Wen reported that recent research has found a link between the built environments that promote physical activity. They may lead to reduced alcohol use: alcohol users may become more accustomed to exercise and develop related positive social networks. Mr. Nolan added that playing lacrosse, an indigenous sport, is related to lower alcohol consumption among Native Americans.
- Measurement—Research is needed to develop more precise measurements and more sensitive trend assessment tools that reflect real-time changes in behavior, such as the growing use of hookahs for drug ingestion. However, Dr. Johnston cautioned that the need to collect detailed data must be balanced against potential burden on subjects. He suggested that the “trip question” approach be used to measure specific trends.
- The impact of fitness training—Studies link training to acute variations in neurobiological factors among adults and older youth. However, further research is needed to create developmentally appropriate fitness training programs for testing the associations among youth.

Panel Five: The Potential Role of Physical Activity on Attention and Other Cognitive Processes—A New Paradigm for Drug Abuse Prevention?

Moderator: Karen Sirocco, Ph.D., Health Scientist Administrator, Behavioral and Brain Development Branch, Division of Epidemiology, Services, and Prevention Research, NIDA, Bethesda, MD

Science and Physiology of Exercise in Children; Sharon Wigal, Ph.D.

Dr. Wigal focused her presentation on critical issues in pediatric studies of physical activity. She provided data from various studies—including her research on the effect of exercise on children who were healthy, obese, or had attention deficit hyperactivity disorder—that substantiated challenges to the field.

One of the key challenges is developing operating definitions of key terms. Definitions she used in her research included:

- Exercise bout: A brief profound perturbation of cellular homeostasis caused by muscular activity.
- Physical activity: The pattern, tempo, and type of exercise in the daily lives of adults and children.
- Fitness: The summed physiological, behavioral, and genetic adaptation to repeated bouts of exercise.
- Training: The systematic application of a program of individual exercise activities designed to elicit a change in exercise-sensitive elements of the human physiome.

Other research challenges include controlling the setting for exercise studies and timing measurements to determine acute and chronic effects of exercise. In addition, research

studies should move beyond assessing peripheral effects of exercise to understand how it promotes positive behavioral effects among specific patient groups.

Physical Activity and Cognition Across the Lifespan; Charles H. Hillman, Ph.D., Associate Professor, Department of Kinesiology and Community Health, University of Illinois, Urbana-Champaign, IL

Dr. Hillman explained his recent findings about associations between physical activity and cognition. He focused on the similarities between the degradation in these associations that occur with aging and SUDs.

Dr. Hillman's recent investigations found small but positive effects on cognition that were linked to exercise. The area of cognition most affected by exercise was executive function, a subset of processes associated with the selection, scheduling, and coordination of the mental activities responsible for working memory, cognitive flexibility, and inhibitory control linked to more focused attention. Neuroimaging studies suggest that the neural network underlying executive functions undergoes significant changes in both structural architecture and organization over time. During aging, these changes tend to lead to degradation of the system. However, physical activity can improve executive functions among older adults. SUDs are linked to similar degradation of aspects of executive function and that exercise appears to have similar positive effects.

In his conclusion, Dr. Hillman recommended conducting further research to better understand the impact of exercise on executive function. He also expressed his appreciation to NIDA for pursuing ideas about incorporating physical activity into SUD interventions.

Improving Children's Lives, Discipline, and Cognitive Skills Through Dance; Adele Diamond, Ph.D., Canada Research Chair and Professor of Developmental Cognitive Neuroscience, University of British Columbia, Vancouver

Dr. Diamond explained that dance combines movement and exercise to promote spiritual, cultural, mental, and physical balance. She provided handouts and presented a video about the benefits of dance for overall functioning. She also suggested incorporating dance therapy in SUD interventions because dance is linked with the same psychosocial changes as other programs that reduce substance use. For example, dance:

- May reduce the social isolation associated with SUDs and help program participants to develop healthier social relationships based on the respect, sharing, and trust necessary to perform in unison and as a soloist.
- May help improve executive function because it is a form of exercise.
- Builds a work ethic, encourages persistence, and requires participants to focus their attention and master new skills. All of these changes build self-efficacy.

Before concluding, Dr. Diamond reported on studies of the effectiveness of dance therapy in improving behavior among preschool and elementary school students. She suggested that additional research be conducted regarding the incorporation of dance into SUD interventions.

A Potential Enhancement for Substance Abuse Prevention: Promoting Self-Control Through Basketball and Martial Arts; Howard Stevenson, Ph.D., Associate Professor and Chair, Applied Psychology and Human Development, University of Pennsylvania, Philadelphia, PA

Dr. Stevenson discussed Preventing Long-Term Anger and Aggression in Youth (PLAAY) a culturally sensitive intervention for young African-American males designed to buffer rejection sensitivity and to mediate stress related to racism, especially in the school system. The program included various forms of physical exercise, including basketball and martial arts, as well as other activities that build cultural pride and link participants to positive African-American male role models. All of the program components focused on building self-efficacy and improving decisionmaking skills rather than providing additional external control/patrol mechanisms. Evaluation results indicate that participants improved their academic performance and reduced their aggressive behavior in the classroom. In addition, participants better understood the mechanisms and effects of racism and had mastered the skills required to respond in positive ways.

Dr. Stevenson reported that culturally appropriate SUD interventions for African-American males must address existing social challenges as they are perceived by the participants (e.g., how African-American men are portrayed in the media) as well as individual characteristics (e.g., hypermasculinity) linked to responses to racism. He recommended that research be conducted to identify culturally appropriate SUD interventions that maintain their effectiveness over time.

Discussion

Much of the discussion focused on executive function and exercise. Participants noted that:

- More research is needed to better understand links between executive function and exercise, especially aerobic activity.
- Programs for children should encourage them to pursue a physical activity that they like because focus and persistence are required to master the activity and improve executive function.

In addition, Dr. Diamond asked that further research on dance be conducted, with particular attention to the effects of music and group exercises on improving executive function.

Concerns about research requirements also were raised. Participants noted the need for uniform operational definitions of key terms. They also observed that conducting replicable trials may be a challenge, especially when interventions are unstructured. Participants suggested developing more structured interventions that include, for example, training to ensure that staff delivers a standard intervention that can be consistently measured across subjects.

Physical Activity and Health: What Readers Want to Know; Sally Squires, Health and Nutrition Columnist, The Washington Post, Washington, DC

Ms. Squires writes the nationally syndicated “Lean Plate Club” column, which helps individuals translate advice about nutrition and exercise into positive action. Information in the column and related materials also are disseminated via the club’s Web site, Internet social networks, Web chats, and e-mail newsletters.

Ms. Squires noted that certain barriers to engaging in physical activity have remained constant over time: lack of time and money, safety concerns, and uncertainty about how to prepare for an activity. Ms. Squires urged meeting participants to find ways to use technology to promote physical activity by making it safer, more convenient, and less expensive. She also invited participant to visit the Club Web site, www.leanplateclub.com, and to contact her at squires@washpost.com.

Panel Six: Physical Activity and Reward Mechanisms—A Model for Prevention Intervention Treatment

Moderator: Minda Lynch, Ph.D., Chief, Behavioral and Cognitive Science Research Branch, Division of Basic Neuroscience and Behavioral Research, NIDA, Bethesda, MD

The Effect of Enriched Environment on Drug-Seeking Behavior; Michael T. Bardo, Ph.D., Professor and Director, Department of Psychology, University of Kentucky, Lexington, KY

Dr. Bardo’s presentation focused on the impact of environmental enrichment and exercise on vulnerability to stimulant drug use among experimental rats. He first compared the drug-taking behavior of rats raised in isolation with that of rats raised with toys and other sources of stimulation. The two groups of rats were able to access low doses of amphetamines on demand. While both groups initially used the drugs, the rats from the enriched environment demonstrated less drug-seeking behavior. They also were less likely to reinstate drug use when provided with the opportunity. In further study, Dr. Bardo found that the rats raised in isolated conditions exhibited dysfunctions in: (1) inhibitory control involving the frontal cortex of the brain and (2) the neurological reward system.

Dr. Bardo conducted a similar experiment using rats who exercised at will and those who were not allowed to exercise. He concluded that exercise, enrichment, and amphetamine use activate a common neurobiological reward substrate. Thus, any of these three options may be used to generate a positive mood.

In further remarks, Dr. Bardo observed that exercise, enrichment, and amphetamine use activate a common reward substrate and that this finding applies to both animals and humans. He suggested that additional research be conducted to continue translating findings from the laboratory to the field. He also stressed the importance of studying the effects of exercise and/or enrichment before, during, and after drugs are added to a regimen.

Exercise Reduces Initiation, Maintenance, and Relapse of Drug-Seeking Behavior: Animal Models; Marilyn Carroll, Ph.D., Professor of Psychiatry, University of Minnesota, Minneapolis, MN

Dr. Carroll provided an overview of her research on drug-related behaviors among animals and humans. She also discussed the implications for future research related to the use of exercise as an intervention for SUD treatment and prevention.

Dr. Carroll conducted experiments providing animals with cocaine and nondrug rewards such as physical activity, preferred foods, or enriched environments. She identified two groups of rats—those who spent more or less time running in a wheel. The high runners had symptoms of running addiction, exhibited more drug-seeking behavior, and were more likely to reinstate this behavior after a drug-free period. In a separate study, monkeys were divided into two groups based on how frequently they accessed saccharine. The group that became faster at acquiring the saccharine also was faster to acquire cocaine. This group also had more rapid rates of reinstatement of drug use. In both studies; the effects of the nondrug incentives were more marked among the female than the male rats.

Dr. Carroll also studied the use of exercise in preventing drug cravings among humans. She found that, especially among females, exercise and sweets reduced cravings for nicotine. She also studied the impact of sports on illicit drug use among teens and concluded that more active adolescents were less likely to drink, smoke cigarettes, or use marijuana or hashish. In addition, Dr. Carroll reviewed the variety of exercise and activity videos and games available.

Based on her results, Dr. Carroll recommended that more research be conducted on the impact of exercise intensity on drug cravings. She also suggested that additional investigations be conducted to: (1) further translate findings from animal studies into clinical interventions, (2) better understand the neurobiological underpinnings of SUDs, and (3) explore uses of technology for promoting physical activity adherence.

Neuro-Chemical Correlates of Exercise-Induced Mood Changes in Humans; Henning Boecker, M.D., Professor of Experimental Radiology, University Hospital, Bonn, Germany

Dr. Boecker reported on his studies using functional magnetic resonance imaging and positron emission tomography (PET) to investigate the relationships between physical exercise and brain function. His data provided the first direct evidence of opiodergic release in fronto-limbic brain regions after sustained physical exercise. The close correlation between this release and perceived euphoria in runners suggests a specific role of the opioid system in the generation of the “runner’s high” sensation.

Dr. Boecker also summarized research findings about the associations of specific brain regions with drug-related euphoria and explained that his research confirms and builds on these studies. It also demonstrates that PET ligand techniques can link neuroscience and sports science and provide new data of benefit to the field. For example, the possibility of monitoring endogenous transmitter trafficking *in vivo* should lead to the identification of the central mechanisms of exercise-induced psychophysiological effects. In addition, understanding the neurochemistry of physical exercise may aid in clinical applications of endurance training as preventative or therapeutic SUD interventions.

To move this work forward, research is needed on larger populations. In addition, PET studies need to be undertaken to identify potential biomarkers; however, safety issues must be resolved before this research is conducted.

Circumstances, Motivation, and Readiness to Change in Wilderness Treatment, Keith C. Russell, Ph.D., Associate Professor of Kinesiology, University of Minnesota, Minneapolis, MN

Dr. Russell's research on wilderness treatment focused on coercion because most adolescents in these programs are forced to participate. Dr. Russell investigated the relationship between coercion and motivation during the early stages of treatment and how coercion and motivation affected substance use frequency outcomes. He also studied levels of stress, depression, and anxiety evident at admission and over time in the program. Motivation was measured using the University of Rhode Island Change Assessment questionnaire; substance use frequency was measured with the Personal Involvement with Chemicals survey, and mood was gauged using the Depression, Anxiety, and Stress Scales.

Research participants were drawn from a wilderness treatment program that provided individualized and multimodal care in an outdoor environment for teenagers at risk for SUDs. Participants received individual and group therapy from licensed clinicians and collaborated with these professionals to develop aftercare plans. During the program, which lasted an average of 60 days, participants also engaged in high levels of physical activity, ate nutritious meals, and got sufficient sleep.

Dr. Russell found that motivation to change was low at admission and that the relationship with coercion was unclear. However, motivation profiles shifted by the time of discharge. He also found significant reductions in substance use and few differences across motivational levels at the 6-month follow-up. Based on these findings, Dr. Russell suggested that controlled trials be conducted to identify factors unique to wilderness treatment and their effects on substance use outcomes. He also recommended that psychosocial factors related to outcomes be modeled and tested during wilderness treatment.

Discussion

Participants synthesized the panelists' findings to identify further areas for research. Dr. Wigal suggested that studies be conducted on the impact of wilderness treatment on adolescents with ADHD who were at-risk for SUDs. She also recommended conducting further studies to identify the full range of interactions involved in extinction and reinforcement among animals in substance use trials. In addition, she noted that more study might be conducted on gender-related hormones in relation to SUDs, building on some of the work outlined by Dr. Carroll.

Dr. Compton also suggested possible topics for future research. These included animal studies using experimental groups genetically prone to addiction, investigations of the motivational mechanisms linked to "the runner's high," and randomized trials of

wilderness treatment for adolescents at risk for SUDs. In addition, he suggested that studies focus on the associations between long-term motivation and behavioral change, which is the next priority listed in the NIH research road map.

Closing Comments

Reflections on Physical Activity and Substance Use Prevention; Diana H. Fishbein, Ph.D., Senior Fellow and Program Director, Transdisciplinary Behavioral Science Program, RTI International, Baltimore, MD

Dr. Fishbein provided an overview of the entire meeting. Noting the gamut of issues that was covered, she suggested that a key challenge will be shaping the participants' findings and recommendations into a cohesive research framework.

Dr. Fishbein's general impression was that panelists presented intriguing evidence indicating that exercise has a role in maintaining the integrity of brain function and in shaping individual behaviors. Additionally, the new findings about the shared exercise and drug addiction reward and motivation mechanisms support the conclusion that exercise has a place in drug intervention programs, targeting both prevention and treatment. However, more research is needed about the functional, behavioral, neurological, and physiological aspects of the relationship between exercise and drug use.

Next steps for the leaders of the research effort should include building transdisciplinary teams to: (1) conduct basic, translational, and clinical studies; (2) sift through the results and identify best practices; and (3) disseminate these practices across the field. Overarching issues that should be addressed in the transdisciplinary studies include identifying the optimal dose and intensity of exercise interventions for specific populations and defining the factors that promote adherence to the exercise regimen. Absent this data, exercise will remain an enhancement for existing programs rather than an intervention that can stand independently as a relatively low-cost method for treating and preventing SUDs.

Concluding Remarks, Wilson M. Compton, M.D., M.P.E.

On behalf of Dr. Volkow and himself, Dr. Compton thanked the participants for the stimulating discussions and the staff for bringing the meeting together. He observed that more research across an array of areas is needed to explore exercise as a SUD intervention. However, he concluded, the evidence presented at the meeting does demonstrate that this research is warranted.