Modeling the Transition from Adverse to Healthy Sleep Behaviors among School Age Children: A Simulation Approach

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ABSTRACT

This research models and simulates, by way of a System Dynamics approach, sleep behavior in the presence of intervention strategies. The authors draw upon the established compartmental Susceptible, Infection, and Recovery (SIR) model used in epidemiology to characterize the potential for children and adolescents to both develop adverse sleep behaviors and to recover healthy sleep behaviors as they progress through educational levels. The development of healthy sleep during childhood and adolescence is important to the sustainment of healthy behaviors into early adulthood. Interventions designed to alter unhealthy sleep-related behaviors adopted at an early age may have a salubrious impact upon later chronic disease development. Our initial analyses adequately reproduce the drift experienced by children and adolescents who develop adverse sleep behaviors as they mature and transition through school levels. The ability to evaluate the effectiveness of interventions is important to public health officials. Investments in intervention programs shown to have positive health outcomes are attractive to policy makers. Although such programs may not be cost effective in the near-term, the programs may be cost saving in the long-term. The System Dynamics approach simulates behavior over time and allows policymakers insight into both the short- and longer-term cost and benefits.

Keywords: Intervention Evaluation, School Age Children, Simulation, Sleep Behavior

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INTRODUCTION

It is estimated that 40% of the US population suffers from at least one chronic health condition such as heart disease or diabetes (National Center for Health Statistics, 2011). Truncated physical activity (Center for Disease Control and Prevention, 2011) and insufficient sleep (Liu, 2004), both of which are modifiable health behaviors, have been associated with increased risk for chronic diseases (Liu, 2004) and mortality (Kung, Hoyert, Xu, & Murphy, 2008). Insufficient sleep and short sleep duration are associated with obesity (Robert D. Vorona et al., 2005), incident diabetes (Gangwisch et al., 2007), and hypertension and cardiovascular risk (Buxton & Marcelli, 2010; Knutson, 2010).

Few adolescents sleep an optimal nine hours per night (M. Carskadon, Acebo, & Jenni, 2004), and high school students exhibit a high prevalence of sleep health problems (Ming et al., 2011). Insufficient sleep and inconsistent sleep patterns among adolescents are unhealthy sleep behaviors. Unhealthy sleep behaviors are associated with truancy (Pasch, Laska, Lytle, & Moe, 2010), depression, and substance use (McKnight-Eily et al., 2011; Pasch et al., 2010), decreased physical activity (McKnight-Eily et al., 2011), obesity (M. Carskadon, Vieira, & Acebo, 1993; Drescher, Goodwin, Silva, & Quan, 2011), poor grades (Perkinson-Gloor, Lemola, & Grob, 2013), and diminished cognitive function (Ferrie et al., 2011). The development of healthy sleep during childhood and adolescence is important to the sustainment of healthy behaviors into early adulthood (Brener & Collins, 1998; Tobler & Stratton, 1997). Interventions designed to alter unhealthy sleep-related behaviors adopted at an early age may have a salubrious impact upon later chronic disease (e.g., Wilfley et al. (2007)). Thus, studying the progression from behavior to adverse outcomes may have significant public health implications.

An understanding of the risk factors operating during the vulnerable period of transition from childhood to adolescence (Dekovic, 1999; Fischhoff, Nightingale, & Iannotta, 2001) through high school (Diaz, Szklo-Coxe, Behr, & Toba, 2012; Diaz, Szklo-Coxe, & Behr, 2012; Roberts, Roberts, & Xing, 2010) may allow for the identification of interventions that promote healthy sleep and longer-term positive health outcomes ((Contoyannis & Jones, 2004; Lerner & Galambos, 1998), see also (Moseley & Gradisar, 2009)). Developmental sleep changes and phase delays of the circadian system impact sleep-wake timing in adolescents (M. Carskadon et al., 1993; Owens, Belon, & Moss, 2010). Adolescents are at risk for poor or insufficient sleep due to early school start times (Lufi, Tzischinsky, & Hadar, 2011). Early school start times have been related to both sleep deprivation and daytime sleepiness as adolescents go to bed later, yet may still rise early due to school start times (M. A. Carskadon, Wolfson, Acebo, Tzischinsky, & Seifer, 1998). Increased crash rates in adolescents have also been reported in cities with earlier, versus later, high school start times (Robert Daniel Vorona, Szklo-Coxe, Wu, Dubik, & Zhao, 2011).

The delaying of school start times has been associated with beneficial outcomes (Dexter, Bijwadia, Schilling, & Applebaugh, 2003; Wolfson, Spaulding, Dandrow, & Baroni, 2007). For example, Owens et al. (2010) found that a delay in school start times by 30 minutes for adolescents grades 9 through 12 was associated with increased sleep duration, earlier bedtime, and improved motivation. Delaying school start times has been also associated with decreases in self-reported daytime sleepiness, depressive symptoms, and seeking medical attention for fatigue-related concerns. Similarly, Danner and Phillips (2008) found that a delay in school start times by one hour one for grades 6 through 12 was associated with increased sleep, reduction in sleep deprivation, and decrease in motor vehicle crashes. Lufi et al. (2011) also found that a delay in school start times by one hour in eighth grade led to increases in sleep duration and improved attention.

Clearly, sleep behaviors are associated with multiple individual, environmental, socio-cultural factors (Flay, 2002). Effective interventions must target not only children and