Introduction

The high prevalence of overweight and obesity among children in most parts of the world is a well-documented fact. In parallel with this “obesity epidemic”, increasing numbers of children now show features of the metabolic syndrome (MetS) (1). Essentially, the positive energy balance underlying obesity is attributable to excess energy intake and/or insufficient energy expenditure; however, the regulation of the energy balance equation in humans is quite complex, and effective strategies for the prevention and treatment of obesity are still lacking. Although not having an energy value per se, recent results indicate that this imbalanced equation could partly arise from a lack of sufficient sleep, as sleep could potentially affect both sides of the equation (2). Therefore, several movement behaviors involving various aspects of physical activity (PA), sedentary behavior, and lack of sufficient sleep have all been linked to the recent development of obesity (3-9) and cardio-metabolic risk (10-14) among children.

As the validity of estimates of habitual PA (15) and sleep duration (16) is questionable when self-reported using questionnaires, accelerometers have become the preferred method of choice to measure PA and sedentary time, and in recent years, they have become an important method in sleep research (17). Although the use of objective methods has increased, the majority of studies rely on single-point measurements to characterize habitual movement behaviors. Given the considerable day-to-day variation in behavior and furthermore that the weather changes considerably across the year in northern Europe, taking repeated measures throughout the year could give a better measure of habitual movement behaviors and identify relevant periods to intervene to promote a healthy lifestyle.

Sleep duration and PA are typically reported to be lower and sedentary time (such as television viewing, video gaming, and computer use) to be higher than recommended; however, the potential detrimental effects on health of these movement behaviors are difficult to separate, as one might cause a change in one or more of the others. For example, sleeping less can lead to decreased moderate-to-vigorous physical activity (MVPA) and increased sedentary time due to increased fatigue during the day. It could also be that the increased availability and use of electronic entertainment and communication devices during late evening could delay bedtimes and shorten sleep duration (18), possibly also leading to increased snacking on energy-dense, nutrient-poor foods (19). To examine the independent effects of the different movement behaviors it is important to assess all movement behaviors during an entire 24-hour period. However, studies have primarily investigated PA, sedentary behavior, and sleep in isolation, mostly with suboptimal adiposity

indicators (e.g. body mass index [BMI] or skinfold thickness) or single cardio-metabolic risk markers and failed to adjust for important covariates (e.g. diet). Instead, the clustering of cardio-metabolic risk markers, producing a continuous MetS score, is a more sensitive approach to identify cardio-metabolic risk in children (20). Furthermore, the combined associations between MVPA and sedentary time have only recently been investigated (13, 14), but not in combination with sleep duration, despite its combined potential influence on health (8, 10).

Early puberty is a period characterized by rapid changes in body composition and movement behaviors. As movement behaviors (21, 22), obesity (23, 24), and cardio-metabolic risk (25-29) appear to track from childhood to adulthood, this may be a critical time period for the successful prevention of obesity and MetS in adulthood. An in-depth characterization of movement behaviors, including seasonal and weekly variation, together with a better understanding of the relationships between movement behaviors, diet, adiposity, and cardio-metabolic risk in childhood, may therefore aid in developing lifestyle interventions and public health policies to prevent MetS in adulthood.