1. Introduction

1.1. Physical activity and children

Physical activity (PA) is widely accepted as a key component of a healthy lifestyle across all ages, and insufficient PA, leading to non-communicable diseases, was estimated to have caused 1.6 million deaths and loss of 34.6 million disability-adjusted life years in 2015 [1] and to have cost health care systems a conservatively estimated $53.8 billion worldwide in 2013 [2]. In children, higher PA levels have positive dose-response associations with numerous health outcomes leading to greater health benefits [3], and too low levels of PA lead to a clustering of cardiovascular risk factors [4]. PA behavior starts developing in early childhood, tracks into adulthood and remains at least moderately stable during the life course [5, 6]. Additionally, higher PA levels are associated with better cognitive function [7, 8], academic learning [9, 10], and well-being and mental health [11-13] in children.

In several countries, observed associations between PA and health have led to the development of PA recommendations across different age groups. For children aged 5-17 years, these recommendations are generally at least 60 minutes of daily moderate-to-vigorous physical activity (MVPA), including vigorous sessions of PA to strengthen muscle and bones on three days or more per week [14-16]. Unfortunately, a large proportion of children do not engage in the recommended levels of PA [3, 17]. In addition, PA decreases from childhood to adolescence for both girls and boys [18, 19], and two European samples from a longitudinal study using accelerometers reported decreases in PA ranging from 22-34% in children aged 9 and 15 and lower PA for girls at both ages [20, 21].

1.2. School as a setting for physical activity promotion

The importance of and need for effective PA-promoting initiatives to encourage active lifestyles in children are clear and well established. Governments across the world have called for effective PA promotion strategies that can be translated into policy and implemented cost-effectively at the population level [22, 23]. The school setting is highly important in this quest, as nearly all children spend large proportions of their waken time at school [24].

Traditionally, children have accumulated the highest proportions of time spent in PA in the domains recess (including lunch break) and physical education (PE) in the school setting [25, 26]. One unfortunate finding from a health perspective is that, between 2000 and 2014, schools in the US have provided children with less time for recess and PE and more time for curriculum-based activities [27]. This may be explained by the fact that schools worldwide are facing increasing demands regarding children's academic achievement and that schools' main purpose is academic learning, not PA. The effectiveness of school-based PA promotion initiatives is known to be limited when implemented as extra-curricular activities, or as 'add-ons', which are given lower priority than schools' academic aims [28-30]. As a consequence, increasing PA during

school hours may not be realistic unless it is integrated into curriculum-based activities; moreover, it might be easier to effectively engage teachers in PA-promoting activities that support children's learning during curriculum-based activities. School-based PA should therefore preferably come from all domains of a school day and not only the traditional domains PE and recess. For these reasons, there have recently been calls for holistic school-based PA promotion initiatives targeting curriculum-based activities, aiming for integration with the essential procedures existing within education systems and schools [31].

1.2.1. Integrating physical activity into the classroom setting

Initiatives to develop, implement and evaluate PA promotion as an add-in to the existing curriculum-based teaching practices are not new. A variety of school-based PA promotion initiatives integrating movement into curriculum-based teaching have been shown to promote children's PA in the school setting in the short term [32]. A few of these, such as 'TAKE10!' [33], 'Physical Activity Across the Curriculum (PAAC)' [34], Texas I-CAN [35], and Energizers [36], aim to provide one or two daily sessions of 10-15 minutes of PA that are integrated into the curriculum-based teaching and administered by a regular teacher who has completed a short training session (.75-8 hours duration) and is equipped with an instructional/inspirational booklet. What these interventions have in common is that they are designed to be easy to implement into existing practice and that they have made positive impacts on PA [37-40] and academic outcomes [30, 33, 36]. However, evidence of sustainable movement integration (MI) initiatives at the population level is lacking [32], and the short duration of such initiatives limits their potential effect when implemented on their own.

Education outside the classroom (EOtC) [41, 42] is another example of an 'add-in' educational approach that changes the physical setting of the curriculum-based activities on a regular basis, thereby providing children with opportunities to be more active while learning academically [43, 44]. The physical setting could be a green area, a museum, or an urban space typically located in close proximity to the school. This allows for use of different teaching methods and pedagogies for teachers and extra space and opportunities for PA for children [41, 42]. EOtC in Scandinavia started as a grassroots movement of highly driven teachers in the 1990s [45-47], became increasingly practiced in Denmark through educated nature interpreters in the 2000s [48], and became the object of political attention in the 2010s. This is, for instance, expressed through the more than DKK 26 million spent on funding for two major research projects aimed at evaluating the effects of EOtC (the TEACHOUT study) [49] and increasing the provision and quality of EOtC practice (Development of EOtC – *Udvikling af Udeskole* in Danish) [50].

This PhD thesis was written as part of the TEACHOUT study. A combination of widespread and increasing provision and positive effects on a range of outcomes have led to this political interest in EOtC. EOtC provision in Denmark has been surveyed on the national level in 2007 [48] and 2014 [51], reporting an increase from 14% to 18.4% of schools where at least one class regularly practiced EOtC, whereas a number of European case studies have investigated the effects of EOtC. These studies have reported higher PA levels

in children participating in EOtC [52-54], improved academic learning and achievement [55, 56], as well as improved social relations and well-being [57, 58]. However, these findings are based on small samples of children led by teachers who were highly motivated and driven in their EOtC practice, and collected before top-down ministerial implementation began.

1.3. Physical activity measurement

It is crucial to obtain reliable and valid measures of children's free-living PA in order to properly evaluate the effect of a PA intervention, such as EOtC, as a school-based add-in PA promotion initiative. Accelerometers are widely used to quantify the free-living PA of children, as it is generally accepted that they provide objective and relatively accurate measures of a range of PA constructs across multiple days with time-stamped information on PA intensity [59]. However, the reliability of an accelerometer-measured PA construct varies as a function of the bodily placement, attachment method, and wear compliance of the monitor [60].

Measuring daily life PA requires high wear compliance in terms of a sufficient number of valid day and wear time per valid day if PA behavior is to be representative, including reducing the effects of intra-participant day-to-day variation [61, 62]. High compliance rates are therefore of great importance when measuring children's PA, but daily wear time remains below 24h in the current methodology. As a consequence, it is necessary to apply wear time validation criteria to decide whether or not an accelerometer was worn at any given time, and apply inclusion criteria for a valid day. The chosen criteria significantly impact the reliability and validity through differences in compliance rates [63], daily wear time and number of valid days [64], and time spent in different PA intensities [65], as well as the generalizability due to possible exclusion of more participants with certain characteristics [66]. A review also highlighted comparability issues related to the diversity of wear time criteria used to translate accelerometer data into PA outcomes in children [59].

Accelerometers have traditionally been worn in an elastic belt at the waist [17, 67, 68], based on the strong association between accelerometer counts and energy expenditure at this bodily location. A number of recent studies have changed location to the wrist, the aim being to increase compliance rates with success [63, 69], as compliance for waist-mounted accelerometers in children has been relatively low [17]. Whether or not the bodily location of the accelerometer is the reason for higher compliance is not clear. Other studies have reported higher compliance with a waist-mounted accelerometer protocol asking for 24h wear compared to previous studies, wrist-worn protocols included [70], and no difference in compliance was found between accelerometers concurrently worn at the hip and wrist [71].

Data obtained from waist-placed accelerometers are generally more accurate in classifying PA behavior compared to wrist-placed accelerometers [72-79], although some activities are more accurately classified using wrist compared to hip data, i.e. basketball and dancing [72, 77]. Data from thigh-worn

accelerometers can classify behavior into the activity lying, sitting, standing, transitions between sitting and standing [80, 81], and PA types such as walking, running, cycling, and walking up and down stairs [82] with high sensitivity and specificity. In spite of this, compliance with wearing accelerometers on the thigh has not yet been reported for children.

I expect that skin-taping waterproof waist- and thigh-placed accelerometers to participants and requesting no non-wear will eliminate the problems related to non-wear on valid days, while maintaining or improving the reliability and validity of the measurements used to evaluate an intervention's effect on PA.

1.4. Research aims

The overall aim of this PhD thesis is to investigate the effects of an EOtC intervention on school-aged children's PA. The impact of EOtC on PA is investigated as a school-based PA promotion intervention at the class level and through segmenting activities at the participant level. High quality PA measurements are at the core of this, and a novel, objective methodology to measure free-living PA in children without non-wear time over a large number of valid days is therefore developed and evaluated as a means to enable reliable and valid conclusions to be drawn.

This thesis therefore has three specific aims:

1. To develop and evaluate a methodology to assess free-living PA for multiple days without non-wear time
2. To investigate the effects of receiving regular EOtC on children's weekly PA
3. To compare PA levels on days with EOtC with other types of school days and weekend days, and to compare PA levels in the EOtC domain with other domains.

Aim 1 is accomplished by developing and testing the methodology in a pilot study prior to the actual data collection, and subsequently evaluating the performance of the method in Paper 1 to address the method's compliance, predictors of compliance, and reliability.
Aim 2 is addressed in Paper 2 by investigating the effects on time spent in LPA and MVPA of being in an EOtC compared to comparison class. The data were analyzed using an 'intention-to-treat' as well as 'per-protocol' approach.
Aim 3 is addressed in Paper 3 through analyses comparing the proportion of time spent in LPA and MVPA on different day types and domains across data from all participants.