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Schneller MB, Bentsen P, Nielsen G, Brond JC, Ried-Larsen M, Mygind E, Schipperijn J: **Measuring Children's Physical Activity: Compliance Using Skin-taped Accelerometers.** *Med Sci Sports Exerc* 2017. E-published ahead of print 8 February 2017. DOI: 10.1249/MSS.0000000000001222.

Paper 2:

Schneller MB, Duncan S, Bentsen P, Nielsen G, Mygind E, Schipperijn J. **Are children participating in a quasi-experimental education outside the classroom intervention more physically active?** In second review in *BMC Public Health*, submitted 3 March 2017.

Paper 3:

Schneller MB, Schipperijn J, Nielsen G, Bentsen P. **Children's physical activity during a segmented school week: results from a quasi-experimental education outside the classroom intervention.** In review in *International Journal of Behavioral Nutrition and Physical Activity*, submitted 15 February 2017.

English summary

Background: Increased physical activity (PA) is associated with decreased risk of a range of non-communicable diseases and with improved cognitive function, academic achievement, and mental health. Unfortunately, many children are inactive or spend only limited time engaged in PA. Schools have the potential to transform part of children's time from inactive to active. Curriculum-based classroom activities constitute a large proportion of school time, in which more teaching and learning activities involving PA could be implemented. Education outside the classroom (EOtC) is an example of an educational approach that could increase PA, as case studies have shown positive effects of EOtC on PA, academic learning motivation, well-being and social relations. National surveys in Denmark have shown substantial and increasing proportions of schools and teachers regularly practicing EOtC. When evaluating such interventions' effects on PA, it is crucial to obtain reliable and valid objective measurements of PA. PA is commonly measured using accelerometers and affected by the accelerometer attachment method, bodily placement, instructions for wear, and the chosen inclusion criteria. The accelerometer methodology commonly used to measure children's free-living PA would benefit, regarding the validity and reliability of measurements, from increasing wear time per day and number of valid days. This thesis investigates 1) compliance, predictors of compliance, and within-subject reliability of free-living PA measurements using skin-taped accelerometers; 2) effects of an EOtC intervention on children's weekly PA; and 3) differences in PA levels between domains and day types, primarily comparing EOtC time with classroom time.

Methods: Pairs of one EOtC and one comparison parallel class in grades three through six (18 schools, 46 classes and 1,013 pupils) were recruited to the Danish quasi-experimental TEACHOUT study, investigating how EOtC impacts PA, academic learning, motivation, well-being, and social relations. Children wore skin-taped accelerometers on the thigh and lower back. School activities (including EOtC practice) were monitored at the class level, and diaries were collected at the participant level (i.e., absence from school, reasons for accelerometer non-wear, and sleep times). For evaluation of the PA measurements conducted, predictors of accelerometer wear time and reliability of whole-day PA accelerometer data variability were investigated. The effects of EOtC on PA were compared between children in EOtC and comparison classes over a full week, and assessed at the participant level on specific day types and in specific domains.

Results: Of the children with thigh- (n=903) and lower-back-placed (n=856) accelerometers attached, 65.7% (thigh) and 59.5% (lower back) obtained seven days of uninterrupted 24h wear time. PA was negatively associated with wear time and the strongest of the tested predictors. Being a girl, younger (only for lower back), and having a lower BMI percentile were all associated with higher wear time. Also regarding wear time, 4.2 (thigh) and 3.1 (lower back) days of 24h wear time were needed to obtain 80% reliability due to whole-day PA variability. Sixteen class pairs with 663 children were eligible for the EOtC analyses, and 361

had valid PA data. Boys in EOtC classes spent more weekly time in moderate-to-vigorous physical activity (MVPA) compared to their comparison class counterparts, while no difference was found for girls. The accumulated time spent in MVPA on EOtC days was not different from school days without EOtC and physical education (PE), but lower than on PE days. EOtC days were associated with more light physical activity (LPA) than school days without EOtC and PE, and PE days. Boys spent a higher proportion of time in MVPA and girls in LPA in the EOtC domain compared to the classroom domain. Lower proportions of time were spent being inactive for children in general on EOtC days compared to all other day types.

Conclusions: The developed and evaluated methodology using skin-taped Axivity AX3 accelerometers in children to obtain valid and reliable PA data was successful, with high compliance rates for seven days of measurements, without non-wear. This creates a better and more detailed understanding of the PA effects of an intervention and better possibilities to compare PA outcomes across studies. The EOtC intervention's effects on weekly PA were sex-specific, increasing levels for boys, but with no difference observed for girls. Of the day types investigated, days with EOtC had the highest proportion of time spent in PA, and time in PA was higher in the EOtC domain compared to the classroom domain. Future studies should investigate the contexts within different domains in which high levels of PA are accumulated for boys and girls in order to gain a better understanding of the sex differences found and to increase PA for girls. EOtC was implemented over a full school year and practiced weekly by substituting activities in the classroom domain without adding external resources. This indicates that EOtC is a scalable way to increase PA for many boys during a school day without decreasing time for academic learning, although the effects on academic learning remain to be investigated. Teachers who participated in this study had little or no experience practicing EOtC, which indicates a greater potential for accumulating PA and further emphasizes the need to understand what constitutes good EOtC practice, the aim of which is to increase academic learning and PA simultaneously.

Danish summary

Baggrund: Øget fysisk aktivitet (FA) er forbundet med en nedsat risiko for en række kroniske sygdomme og en forbedret kognitiv funktion, akademisk præstation og mental sundhed. Uheldigvis er mange børn inaktive eller tilbringer kun en begrænset mængde tid på at være fysisk aktive. Skoler har potentiale til at ændre en del af børns inaktive tid til aktiv tid. Curriculum-baserede klasserumsaktiviteter udgør en stor del af børns skoletid tid, hvori en højere grad af undervisnings- og læringsaktiviteter indeholdende FA kan implementeres. Udeskole er et eksempel på en pædagogisk tilgang til undervisning, der kan øge børns FA, da casestudier har vist positive effekter af udeskole på FA, motivation for læring, trivsel, og sociale relationer. Nationale kortlægninger i Danmark har vist, at en betydelig og stigende andel af skoler og klasser nu regelmæssigt praktiserer udeskole. Når man evaluerer en interventions effekt på FA, f.eks. en udeskole-intervention, er det af afgørende betydning at indsamle troværdige og valide objektive målinger af FA. FA er oftest målt objektivt ved brug af accelerometre, og de opnåede målinger er påvirket af fastgørelsesmetoden, placeringen på kroppen, instruktionerne for hvornår de skal haves på, samt de valgte inklusionskriterier. I relation til pålidelighed og validitet vil den typiske metode brugt til at måle børns FA i dagligdagen kunne styrkes af, at øge minimumsmåletiden per dag for at opnå en valid dag, samt øge antallet af valide dage for den enkelte person. Denne afhandling undersøger 1) hvordan FA målinger udført ved at tape accelerometre direkte på huden, påvirker raten af børn der lever op til de opstillede kriterier for valide målinger af FA, hvilke faktorer der prædikterer denne rate, samt pålideligheden af målingerne for det enkelte barn; 2) effekter af en udeskole intervention på børns ugentlige FA; og 3) forskelle in FA niveau på tværs af forskellige domæner og dagstyper, og her primært en sammenligning imellem udeskole- og klasserumsundervisning.

Metode: Par bestående af en udeskole- og sammenligningsklasse i 3.-6. klassetrin (18 skoler, 46 klasser og 1013 børn) blev rekrutteret til at deltage i det danske quasi-eksperimentelle studie TEACHOUT, som undersøger betydningen af udeskole på FA, akademisk læring, motivation for læring, velvære, og sociale relationer. Børnene gik med accelerometre tapet direkte på huden af lænd og lår. Skoleaktiviteter (inklusiv udeskole-praksis) blev monitoreret på klasseniveau, og dagbøger blev indsamlet på elevniveau (f.eks. informationer om fravær fra skole, årsager til et accelerometer ikke længere er fastgjort på kroppen, og sovetider). Til evalueringen af FA målingerne blev prædiktorer for, hvor længe accerometre blev båret, samt heldags variabilitet for målingerne undersøgt. Effekterne af udeskole på FA blev vurderet på gruppeniveau mellem børn i udeskole- og sammenligningsklasser over en hel uge og på individniveau imellem specifikke domæner og specifikke dagstyper.

Resultater: Af børnene med lår- (n=903) og lændeplacerede (n=856) accelerometre påsat, opnåede hhv. 65,7 % (lår) og 59,5 % (lænd) syv dages uafbrudte målinger á 24 timer per dag. FA var negativt associeret med varigheden af accelerometer målinger og den mest vægtige af de testede prædiktorer. At være pige,

yngre (kun for lændeplacering), og have en lavere alderskorrigeret vægtstatus var alle associeret med længere varighed af valide FA målinger. For at opnå en pålidelighed på 80 % ift. dag-til-dag variabilitet var det nødvendigt at måle FA i hhv. 4,2 (lår) og 3.1 (lænd) dage á 24 timer. Seksten klassepar med 663 børn kunne inkluderes i udeskole-analyserne og af dem havde 361 valide FA målinger. Drenge i udeskoleklasser tilbragte mere ugentlig tid i moderat-til-høj intensitets fysisk aktivitet (MHFA) end drenge i sammenligningsklasser, men for piger blev der ikke fundet nogen forskel. Den akkumulerede tid tilbragt i MHFA på dage med udeskoleundervisning var ikke forskellig fra skoledage uden udeskole og idræt, men lavere end på dage med idrætsundervisning. Dage med udeskole var associeret med mere lav intensitets fysisk aktivitet (LFA) end skoledage uden udeskole og idrætsundervisning, samt dage med idrætsundervisning. Drenge tilbragte en større del af deres tid i MHFA og piger en større del af deres tid i LFA i udeskole-domænet sammenlignet med klasserums-domænet. Børn tilbragte generelt en mindre andel af deres tid på at være inaktive på dage med udeskole sammenlignet med andre dagstyper.

Konklusioner: Den udviklede og evaluerede metode til måling af FA på børn, der gør brug af Axivity AX3 accelerometre fikseret direkte på huden med tape, var vellykket, idet den resulterede høje rater af børn der opnåede syv dages FA målinger á 24 timer per dag. Dette fører til en bedre og mere detaljeret forståelse af en interventions effekt på FA, og medfører bedre muligheder for at sammenligne resultater studier imellem. Udeskole-interventionens effekter på ugentlig FA var kønsspecifik, da drenges FA niveau blev øget, men ikke pigers. Af de undersøgte dagstyper, havde dage med udeskole den højeste andel af tid tilbragt med FA, og andelen af tid med FA var højere i udeskole-domænet end klasserums-domænet. Fremtidige studier bør undersøge i hvilke kontekster en høj andel af FA akkumuleres indenfor forskellige domæner for både drenge og piger, for at skabe en bedre forståelse af de fundne kønsforskelle og øge FA for piger. Udeskole var implementeret over et helt skoleår i form af ugentlig praksis i stedet for aktiviteter i klasserums-domænet, uden tilføjelse af eksterne midler. Det indikerer, at udeskole er en skalérbar undervisningsmetode, der kan øge FA for mange drenge, uden at gå på kompromis med tid til akademisk undervisning, selvom det stadig mangler at blive undersøgt hvilken effekt interventionen havde på læring. De lærere der deltog i studiet havde lille eller ingen erfaring med at praktisere udeskole, hvilket indikerer at der eksisterer et uopfyldt potentiale for at øge de positive effekter yderligere. Det understreger yderligere at der er behov for at forstå hvad der kendetegner god udeskole-praksis, hvor formålet er at øge både den akademiske læring og FA siddeløbende.

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.

2. Methods

The purpose of this section is threefold: 1) to provide context to the thesis by describing the Danish school setting and the TEACHOUT study, 2) to clarify concepts and steps taken, from planning data collection to final analyses, and 3) to provide a meta-methods section to set the scene before presenting and discussing the research papers and the main results of the thesis. A description of the Danish school setting will provide an overview. Subsequently grades 3 to 6 will be in focus, as they are the target group of the TEACHOUT study.

2.1. The Danish school setting

In Denmark, primary and lower secondary schools are divided into junior (grade 0-3 – grade 0 is a compulsory pre-school class), middle (grade 4-6) and senior (grade 7-10 – where grade 10 is optional). The teachers have 'freedom of methods' to achieve specific targets established for each subject by the Minister of Education; these targets are to be in accordance with the '*Folkeskole* Act' legislated by the Danish Parliament. Public, private and international schools in Denmark are all structured in this way. Public schools included 82% of school-aged children in 2012 [83].

A new public school reform was implemented in August 2014 focusing on three objectives: 1) to "challenge all pupils to reach their fullest potential", 2) to reduce the social gradient for academic performance, and 3) to increase pupil well-being and trust in the public school system through professional knowledge and practice [83]. Various new initiatives were implemented to achieve these objectives, including a longer and more varied school day, inclusion of more PA during school hours, encouragement to work more closely with the local community, development of competencies for teachers and pedagogues, strengthening of classroom management and decreasing disruptions during lessons, as well as increasing pupil participation. In particular, under the new reform, children in grade 3 are to spend 30 instead of 24.5 hours a week at school, and grades 4-6 33 instead of 24.5-25.7 hours. Three of the extra weekly hours for grades 4-6 are planned lessons in existing subjects. Other additional hours at school are to be spent on a combination of supportive teaching, help with homework, classroom time, breaks, and movement; the schools and teachers are to decide how this time is used. Time allocated to PE lessons remains unchanged post-reform (1.5 hours weekly for grade 3 and 2.25 hours for grades 4-6). It is also specified that an average of 45 minutes of daily PA must be provided to children within teaching time, and it is the school principle's responsibility to ensure provision of PA [83].

2.2. The TEACHOUT study

The overall aim of the TEACHOUT study is to investigate and understand the effects of EOtC on the PA, academic learning, social relations, motivation, and well-being of children in grades 3 through 6 (9-14 years of age). The program theory underlying EOtC is shown in Figure 1 and involves the pedagogy, i.e. enabling

inclusion of more experimentation, problem solving, cooperation, movement, play, and use of senses, and the physical setting, i.e. natural and cultural places in the local community [84]. The study design is quasi-experimental, as effects of EOtC are compared between children in classes where the teacher chose to practice EOtC regularly and children in classes where the teacher did not make this choice. The study is cross-disciplinary and uses mixed-methods evaluation given the range of investigated outcomes. In TEACHOUT, we have operationalized EOtC by defining it as curriculum-based teaching occurring outside the school's buildings with a minimum average of five hours per week over one school year. The five-hour weekly EOtC minimum was chosen to distinguish the practice from occasional field trips and for it to be a substantial part of the children's school time.

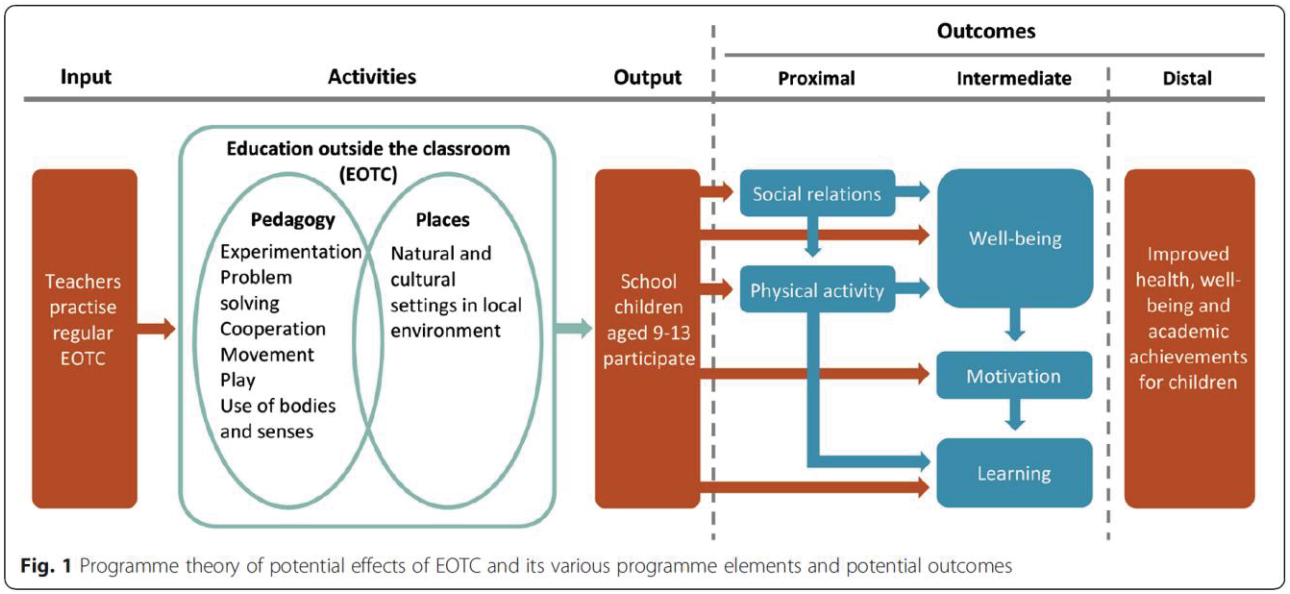

Fig. 1 Programme theory of potential effects of EOTC and its various programme elements and potential outcomes

The figure is copied from the TEACHOUT study protocol [84]

2.2.1. Sampling and participants

The inclusion criteria for classes in TEACHOUT were class pairs consisting of at least one EOtC class agreeing to practice at least 5 hours of weekly EOtC on average for the duration of the school year, and one control parallel class at the same school and grade level that would not practice EOtC regularly. In Danish public schools, children living in a school's enrolment area are randomly assigned to classes when they are formed in grade 0 [85]. As such, the recruitment of parallel classes provides a form of randomization of children between the EOtC and control groups in terms of socioeconomic background, local community and school resources. In addition, measurements were conducted at the same time for all outcomes, ensuring comparability in weather conditions and occurrence of cultural events between groups.

Schools known to practice EOtC were identified via a database based on a national survey [48], by contacting school officials at the municipalities, and by contacting schools and leaders in our networks directly. In total, 549 schools were contacted between February and May 2014 by a member of the

TEACHOUT research group in order to recruit class pairs that were eligible for inclusion and willing to participate. Of the 549 schools, 13 schools with 17 EOtC and 16 control classes, comprising 663 children, met the parallel class inclusion criteria. Participants from these 33 classes were included in analyses conducted for effects of EOtC on PA (Aim 2 and 3). We had intended to include more classes, but the lack of a comparison class and lack of time (many teachers "blaming" implementation of the new reform) made recruitment difficult. We therefore decided to include an additional 13 classes at four schools, comprising an additional 240 children, that did not meet the parallel class criteria, but could meet the inclusion criteria in some analyses in TEACHOUT. Eight of these classes were from three rural schools in which the EOtC and control classes attended school at two different addresses. Another four did not have control classes because the two participating control class teachers decided to practice EOtC regularly. The last of these 13 classes was an EOtC class without a control class, but at a school with an included pair in the grade below. The participating schools were located in northern Zealand (the Capital Region) and Jutland. Participants from all 46 classes were included in the analyses conducted to evaluate the methodology developed to assess free-living PA (Aim 1).

Participating EOtC teachers were invited to a two-day seminar aimed at providing inspiration and networking opportunities for their EOtC practice and in-depth information on their participation in the TEACHOUT study. Inspiration was provided through three 1.5-hour workshops showcasing examples of EOtC practice, a 1.5-hour supervised session to plan own use of EOtC in groups based on subject for EOtC implementation, and a presentation of inspirational materials, such as EOtC-related websites and books. Networking opportunities were provided throughout the seminar, along with a list of the participating EOtC teachers' contact details for networking opportunities afterwards (all teachers gave their consent to be included on the list). Personal information meetings with participating teachers were held at each school prior to the intervention school year to inform participants of the content and obligations of the study. Teachers who provided all necessary information received a gift certificate worth 500 DKK on two occasions: midway and upon completion of the school year.

2.2.2. Data collection

A pilot study of three classes with 57 pupils was conducted in April 2014 to test all intended data collection procedures, and all data in the full study were collected during the school year spanning from August 2014 to June 2015.Table 1 shows an overview of data collected in the TEACHOUT study. Throughout the intervention school year, we monitored the day-to-day EOtC practice of each participating class using an e-based tool. Questions were designed to include any EOtC practice lasting at least 45 minutes in both EOtC and control classes. Children's and teachers' background data were surveyed using electronic questionnaires distributed to the parents and teachers (Appendix 2), respectively. Academic performance, school motivation, social relations, and well-being were assessed by questionnaire or test using repeated measures at

the beginning and end of the school year. Case observations and group interviews were performed during the school year in an attempt to understand how the quantitative effects of EOtC on learning processes, well-being and motivation could be explained.

PA and anthropometric measurements were performed and information about class activities and participant leisure time activities was collected for a 10-day period once per class pair between November 2014 and June 2015. This allowed for overall assessment of children's PA behavior as well as across a range of everyday life contexts. PA was measured using two skin-taped Axivity AX3 accelerometers attached to the lower back and the front of the thigh with instructions not to reattach an accelerometer should it fall off before the end of the 10-day period. We chose not to reattach accelerometers if they stopped being worn prematurely to eliminate issues of wear-time validation of the measurements. Information on everyday life contexts during school hours was obtained through class timetables and a class-level standardized diary (Appendix 2) reporting EOtC activities and changes in school activities compared to those described in the class timetable. The class activities diary was filled in by the class teacher in cooperation with three pupils he/she selected. Leisure time contexts, school absence and sickness were reported through a standardized participant diary (Appendix 3).

Table 1 Data collected in the TEACHOUT study and time of collection

Construct/Measure	**Data collection instrument/method**	**Number of items/tasks**	**Time of collection**
Pupils' physical activity	Axivity AX3 accelerometers		10-day periods from November 2014 to June 2015
Context of PA	Schools' class time tables Activity questionnaires	Questionnaire: 50 items	10-day periods from November 2014 to June 2015
Anthropometrics	Height Measure Body Composition Monitor		At the beginning of the 10-day periods from November 2014 to June 2015
Pupils' background	Electronic Questionnaire to parents	33	March 2015
Teachers' background	Electronic questionnaire	13	March 2015
Degree of implementation of EOTC	Online platform	16	Throughout the school year
Pupils' academic performance in Reading and Mathematics	Sentence reading test Mathematical basic skills test	Reading: 15-24 tasks Math: 50-87 tasks	August 2014 and May 2015
Pupils' social relations	Social Network Analysis Social Cognitive Mapping	21	August 2014 and May 2015

Pupils' well-being	Strength and Difficulty Questionnaire	25	August 2014 and May 2015
Pupils' motivation for school	Academic Self-Regulation Questionnaire	17	August 2014 and May 2015
Processes and interactions of importance to social relations, well-being and motivation	Qualitative case observations, focus-group interviews and personal interviews		Throughout the school year
Learning processes	Qualitative case observations, focus-group interviews and personal interviews		Throughout the school year

The table is based on and modified from Nielsen et al. 2016 [84].

2.2.3. Processing and analyzing physical activity data

The following text provides a brief definition of concepts and an overview of the data processing and conducted analyses. More in-depth information is provided in Paper 1-3.

All participants in the entire sample of 46 classes were pooled in the analyses conducted in Paper 1. The reliability of measurements was assessed for the PA constructs LPA, MVPA and vector magnitude of three axes (VM3) for lower back and thigh placement, respectively, using data from participants with seven days of 24h wear time. Mean wear time was compared between lower-back- and thigh-placed monitors for all participants with monitors attached at setup. Associations between wear time and the participant characteristics PA level, sex, age and weight status were analyzed to investigate how well the characteristics predicted wear time.

In Paper 2 and 3, all participants included in the analyses had seven full days of accelerometer data. If a participant was sick or had any absence from school, he or she was excluded from the analysis. In Paper 2, analyses were conducted on participants in the 33 classes adhering to the pairwise parallel class design to compare the average daily minutes of PA of participants with seven days of 24h accelerometer wear time between EOtC and control groups. Data from participants in the 33 paired classes were pooled in Paper 3, and analyses were conducted to compare average proportions of time spent in different PA intensities for participants with seven days of 24h accelerometer wear time between day types and domains.

The analyses conducted to investigate the effects of EOtC on PA were designed to complement each another. In Paper 2, I investigated the effects of participating in regular EOtC on children's weekly PA. Through the recruitment of parallel classes, I could investigate how EOtC can be expected to influence daily life PA in a case-control design. This provided evidence of the combined effects of degree of implementation and effect of EOtC on PA in an everyday school setting. This was done using an 'intention-to-treat' approach that monitored EOtC implementation, but still included all participating classes, regardless of whether or not they adhered to the definition of EOtC. Additionally, I performed a 'per-protocol' approach to maximize the

difference in the amount of EOtC practiced between EOtC and comparison classes and, thereby, to maximize the potential of the intervention if implemented fully. Inclusion of a class pair in the per-protocol sample required more than 150 minutes of EOtC practice in the EOtC class and less than 150 minutes in the control class during the measured week.

What these analyses lacked, however, was evidence that EOtC is in fact responsible for the differences in PA measured between groups. Investigating Aim 3, which was to compare accumulated PA in different day types and domains at the individual level, provided this evidence by segmenting weekly PA during time in EOtC and other domains for comparison. Six domains were included in this thesis: EOtC, curriculum-based classroom activities, PE, recess, leisure time on school days, and leisure time on weekend days. Sleep was excluded from the domain analysis. However, in this case, the link between EOtC and impact on children's PA and whether or not the intervention is effective at increasing PA is lacking. Analyzing data pooled by day types provides information that is closer to existing practice and explores differences in PA that are more strongly associated with health. For this analysis, I included four distinct day types, with an included day always representing 24h of accelerometer data from midnight to midnight. The four day types were: days with EOtC, school days without EOtC and PE, school days with PE, and weekend days. To qualify, an EOtC day required at least 150 minutes of EOtC and a PE day at least 45 minutes of PE. The connection to existing practice relates to EOtC typically being practiced at least half a school day, one or two days a week [51]. Implementing EOtC in a class for approximately five hours per week is a representative method of implementation, and the difference in PA between a school day with EOtC and a school day without EOtC or PE is therefore a realistic indicator of EOtC's effects on children's PA in a real-life setting. This approach also captures potential compensating mechanisms that could be hypothesized if PA were to increase or decrease during the first half of the day. The combination of analyses therefore provides a package that documents differences in effects on PA among children in the EOtC group compared to the control group, suggesting that any such differences can, at least partly, be ascribed to EOtC.