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Promoting Physical Activity in Girls by a Theory-Based Intervention in Physical Education: Evaluation of the CReActivity Study

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„Das habe ich noch nie vorher versucht, also bin ich völlig sicher, dass ich es schaffe.“

Pippi Langstrumpf

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List of Abbreviations

RCT	Randomized Controlled Trial
cpm	Counts per Minute
e.g.	exempli gratia: “for example”
et al.	et alii: “and others”
HBSC	Health Behavior in School-Aged Children
i.e.	id est: “that is”
KiGGS	Kinder- und Jugendgesundheitssurvey
PE	Physical Education
(M)CFA	(Multilevel) Confirmatory Factor Analysis
p.	Page
MET	Metabolic Equivalent of Task
MVPA	Moderate-to-Vigorous Physical Activity
SOFIT	System of Observing Fitness Instruction Time
WHO	World Health Organization
YPAPM	Youth Physical Activity Promotion Model

Summary

Already in adolescence, physical inactivity is associated with the risk factors of non-communicable diseases and mental health issues. Girls, especially those with low socioeconomic status, represent a high-risk group for inactivity. How the rapidly changing environment and intrapersonal factors contribute to the low and further decreasing physical activity levels is of critical interest. Understanding the behavioral changes in physical activity allows researchers to develop effective strategies promoting physical activity in health-related risk groups. Literature indicates that theory-based school interventions increase students' motivation to engage in physical activity. A self-determination theory-based teaching style in physical education might be fruitful to motivate those who not already adhere to an active lifestyle in their leisure time to engage in sports and exercises.

The CReActivity study aimed to promote the girls' physical activity behavior through a tailored PE intervention in Bavarian secondary schools (Realschulen). This doctoral thesis comprises three peer-reviewed publications that describe the sample's physical activity levels, validate methodologies, as well as evaluate the CReActivity intervention. The description of the girls' physical activity levels, which were assessed using accelerometry, contributes to fill the fragmentary physical activity observations in Germany. By using an innovative multilevel confirmatory factor analysis, the study validated a measurement tool which helps to identify students' perceptions of their basic psychological needs in physical education. Finally, the mixed method evaluation of the cluster randomized control trial represents the core element of this dissertation thesis.

This work provides an insight in an intervention that is among the first studies, which addresses the girls' needs through a tailored and theory-based physical education program. Based on the integration of results from qualitative and quantitative methodologies, girls attribute a certain relevance for need-supportive teaching in physical education, although the

main intervention effect was not significant. It investigates not only intrapersonal factors of the girls' physical activity behavior, but also sheds light on methodological issues throughout the implementation. The innovative methodologies embedded within the CReActivity study help researchers to evaluate physical activity programs, and the evaluated teaching strategies assist teachers that aim to create a need-supportive climate in physical education. Educators and researchers are encouraged to establish collaborations in order to reduce the existent theory-practice gap. This lays the foundation for large-scale interventions as well as adaptions in the policy of the teacher education that could be highly beneficial for our adolescent society.

1 Introduction

Although the health benefits of physical activity are well-known, the majority of children and adolescents do not pursue an active lifestyle (Guthold et al., 2020). So how can we motivate children and adolescents to be more physically active? This question drives researchers, politicians, principals and teachers. In recent years, students and their needs became the focus of attention (Vasconcellos et al., 2020). Yet, it still remains unclear how and to which extent interventions in physical education (PE) influence the physical activity behavior of students in the German school setting (Messing et al., 2019).

This dissertation thesis evaluates the efficacy of the *CReActivity* intervention, which aimed to promote the physical activity in sixth-grade girls through a theory-based intervention in PE (Demetriou & Bachner, 2019). Initially, considering the health benefits of an active lifestyle, the prevalence of the students' physical activity levels is introduced. Subsequently, a focus on the significant role of PE for the physical activity promotion and its educational objectives is leading to the theoretical framework of the study. Then, the critique of current research and aims of the studies are explicated.

Three publications present results of innovative and validated methods for public health researchers that seek to investigate the mechanisms of behavioral changes in physical activity. The core aspect for this dissertation is the mixed method approach utilized to evaluate the efficacy of a need-supportive teaching style in PE to promote girls' moderate-to-vigorous physical activity (MVPA) in Publication 3. In addition, Publications 1 and 2 exemplify the importance of valid measurements to gain meaningful insights into the physical activity levels and sedentary time as well as the motivational resources of girls. Finally, this dissertation relates to these empirical findings by discussing the added pedagogical value of need-supportive teaching in PE, and providing a future perspective for practitioners and researchers who aim to change adolescents' physical activity behavior.

1.1 Physical Activity as Part of a Healthy Lifestyle

In 1946, the World Health Organization (WHO; 1946, p.1) defined *health* as "a state of complete physical, mental and social wellbeing and not merely the absence of disease or infirmity." Besides, health is understood as a biopsychosocial process, which is influenced by a variety of internal (e.g., attitudes, knowledge, motivation, behavior) and external (e.g., access to treatment, social assistance) resources. Individuals' social, physical, and mental dimensions interact on a continuum that ranges between the extremes of *health-ease* and *disease* (Bouchard et al., 1994). Based on this salutogenetic perspective, preventive and health-promoting measures support the individuals' balance within this dynamic health-disease-continuum.

Experts share the sense that physical activity "promotes wellbeing, physical and mental health, prevents disease, improves social connectedness and quality of life, provides economic benefits and contributes to environmental sustainability" (Global Advocacy Council for Physical Activity, International Society for Physical Activity and Health, 2010, p. 1). Bouchard's health model describes an interactive reciprocity between health and physical activity which is influenced by health-related fitness, genetics, and environmental factors (Bouchard et al., 2012). In this light, the mediating role of physical activity for certain health outcomes is widely recognized (Granger et al., 2017). Convincing evidence illustrates the holistic influence of physical activity on body (Janssen & LeBlanc, 2010) and mind (Biddle et al., 2019; Rodriguez-Ayllon et al., 2019). In addition, several studies underpin that physical activity promotes cognitive and affective processes as well as encourages experiencing and controlling of physiological and psychological changes, such as emotions and motives (Hogan et al., 2015). Especially, relations with school engagement (Owen et al., 2016), academic performance (Greeff et al., 2018), and cognitive functioning are evident (Biddle et al., 2019).

Moreover, it is recognized that complex socio-ecological as well as psychological factors influence adolescents' activity behavior (Sallis et al., 2008). Put simply, girls' activity behaviors decrease because social media receives more attention (Burnette et al., 2017) and doing sports in the peer group is "uncool" (Slater & Tiggemann, 2010, p. 620). The lifestyles of adolescents are characterized by fluctuating high levels of alcohol and tobacco consumption; unhealthy diet, excessive media consumption and sedentary behaviors (Marques et al., 2019), which sooner or later lead to health complaints and non-communicable diseases (Lee et al., 2012; Uddin et al., 2020). To date, improved health care systems are able to avert the consequences and–due to medical advance–to even increase life expectancies (Ranabhat et al., 2018). However, governments and health insurance companies foresee increasing costs if the society retains current prevalence levels (Candari et al., 2017). Due to the rapidly changing urbanization and increased use of technologies the WHO (2018) predicts a generation of people suffering from obesity, type 2 diabetes, hypertension, cardiovascular diseases, and cancers, all of which are often exacerbated by unhealthy behaviors, including physical inactivity and sedentary behavior (Anderson & Durstine, 2019).

Maintaining a certain physical activity level in adolescence also affects the physical activity behavior in adulthood (Corder et al., 2019; Miller et al., 2018; Rovio et al., 2018) and thereby constitutes an important feature for societies' costly health maintenance fighting against morbidity and mortality (van Sluijs et al., 2007). Yet, health motives do not seem to be reason enough for adolescents to be physically active (Iannotti et al., 2013). For them social and achievement related motives, for example their outer appearance or having fun, are more important (Iannotti et al., 2013). Especially for girls aged 11 to 15 years from Western European countries the social aspect plays a major role for engagement in physical activity, while health is just a side-effect (Marques et al., 2019).

1.2 Measurement of Physical Activity

Physical activity is defined as "any bodily movement produced by skeletal muscles that increases energy expenditure" (Caspersen et al., 1985, p. 129). Physical activities are often classified by their intensity, referenced by metabolic equivalent of tasks (MET). One MET is the rate of energy expenditure while sitting at rest, which by convention corresponds to an oxygen uptake of 3.5 milliliters per kilogram of body weight per minute (Byrne et al., 2005). The higher the energy expenditure during physical activity, the higher the measured MET will be. Defined as "any waking behaviors characterized by an energy expenditure ≤ 1.5 METs, while in a sitting, reclining, or lying posture" (Tremblay et al., 2017, p. 9), *sedentary behaviors*[1] characterize occupational and domestic activities, such as TV viewing, video game playing, computer use, driving automobiles, and reading, of which the first three are summarized as screen-based behaviors. Passive standing corresponds to around 2 METs (Thivel et al., 2018). Generally, intensities from 3 to 6 METs are called moderate activities which comprise among others brisk walking or stair climbing; activities higher than 6 METs are called vigorous activities including for example jogging, fast swimming or intense playing with children (Ainsworth et al., 2011).

When using accelerometers to measure physical activity, this differentiation is based on so called counts. Put simply, an acceleration sensor counts the movement in one or three axes. Then, results can be converted to rate frequency and intensity within a certain epoch of time. Specific cut-off criteria were validated for different populations because the magnitude of counts has different physiological consequences across age groups and sexes. These so called intensity cut-points, which are usually referenced in counts per minute

[1] Experts of the Sedentary Behaviour Research Network (2012) note that the concept of sedentary behavior should not be equated with *physical inactivity*, which is in their eyes the non-compliance with specified physical activity guidelines.

(cpm), allow researchers to estimate the physical activity levels, usually ranging from sedentary time, simply understood as the measured time spent in sedentary behaviors, over light and moderate, to vigorous activities (Burchartz et al., 2020).

Important to realize is that a measurement tool that comprehensively measures the construct of physical activity is nonexistent. The existing measures differ in terms of objectivity, applicability and validity (Beneke & Leithäuser, 2008). Large-scale physical activity surveillance studies are limited to self-report methods, which provide only a rough approximation of the individual physical activity behavior. Self-report measures such as questionnaires, self-reports, and observations clearly depend on subjects' perceptions and are not free of biases, such as social desirability and recall bias (Eckert et al., 2014). "Accelerometers have become the preferred method in studies involving children and adolescents" (Trost, 2020, p. 1). These devices allow researchers to identify physical activity patterns and provide reliable information about the intensity, duration and frequency of physical activity (Pedišić & Bauman, 2015). However, the derived results are also not free of systematic measurement errors.

The device-based results allow higher objectivity and reliability than self-reports but they still depend on the researcher's analytical decisions (Pedišić & Bauman, 2015). The issues in physical activity surveillance and especially the limited comparability of accelerometry data are subject to ongoing debates in the research community (Pedišić & Bauman, 2015; Trost, 2020). In other words, the reported physical activity levels should not be interpreted without taking the used methods and its implications into consideration.

1.3 Recommendations and Physical Activity Levels

Although the dose-response relationship is not necessarily a linear and inverse relationship (indicating less health problems for higher levels of physical activity), the "complete absence of physical activity is still the best indicator for the development of health

problems" (Kretschmann, 2014, p. 27). It is noteworthy that once an optimal physical activity level has been transcended, physical activity beyond that level has no further risk reducing effects. This inverse and curvilinear relationship of physical activity and risk reduction of diseases indicates a relative maximum of physical activity (Mutz et al., 2020; Schlicht & Brand, 2007). Nevertheless, all types and levels of physical activity provide a certain physical and/or mental health benefit (Poitras et al., 2016).

A consensus of physical activity recommendation for children and adolescents aged 5 to 17 comes from the WHO (Parrish, 2020). On average at least one hour MVPA per day, incorporating vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone, at least three days a week, are recommended to adhere an active lifestyle and prevent health issues (WHO, 2020). Experts all around the world usually refer to these 60 min of MVPA as a minimum guideline. Germany recommends activities of moderate-to-vigorous intensity of even 90 min per day, of which 60 min may be accumulated by daily routines, such as walking 12.000 steps or more per day (Pfeifer & Rütten, 2016). Unlike Germany, both the United States of America and the United Kingdom created a recommendation specifically for school days of at least 30 min of MVPA during school hours (Department of Health, 2016; Institute of Medicine, 2013). In addition, researchers of the Institute of Medicine recommend that students should spend on average 30 to 45 min per day in PE class, with half of the lesson time spent in MVPA.

But how many adolescents actually meet these physical activity guidelines? An expert panel summarized the existing, mostly self-reported evidence from Germany and rated children's and adolescents' overall physical activity as poor, since about 80% of girls and boys failed to meet the WHO guideline (Demetriou et al., 2018). An introduction of questionnaire-based results from two included studies illustrates that girls are at high risk for physical inactivity in Germany.

According to the *Kinder- und Jugendgesundheitssurvey* (KiGGS) only 16.5 % (95% CI = [14.1, 19.1]) of the girls aged 11 to 13 years are physically active for at least 60 min per day, while 21.4 % (95% CI = [18.7, 24.3]) of boys achieve the WHO recommendation (Finger et al., 2018). In contrast, more than three-fourth of adolescents are primarily inactive. Specifically for girls aged 3 to 17 years, inactive behaviors during leisure time and overweight are more prevalent in lower socioeconomic classes (Kuntz et al., 2018). The comparison of KiGGS Wave 1 (2009-2012) and KiGGS Wave 2 (2014-2017) confirmed the aforementioned associations between the adherence to physical activity guidelines and age, sex and socioeconomic status. In addition, girls' physical activity tended to decrease even further with increasing age (Finger et al., 2018).

In line with these findings are results by the *Health Behavior in School-aged Children* (HBSC) study from 2017/18: Only 10.1 % of girls aged 11 to 15 years and 16.9 % of boys fulfill the WHO recommendation. Moreover, the students of higher family status were more active and the girls with migration background were likely more physically inactive than the girls without migration background (Bucksch & Sudeck, 2020).

A meta-analysis of 36 studies using accelerometer-measured data from school-aged children (4-18 years) evidenced an average of 82.3 min (*SD* = 44.0) in MVPA on weekdays (Brooke et al., 2014). But from this result we cannot conclude that the surveyed population meets the WHO guideline because the authors did not account for the methodological differences, which illustrates the comparability issues across accelerometer studies. One solution to this problem is the harmonized analysis of accelerometry data. Steene-Johannessen et al. (2020) analyzed data from 47,497 adolescents and Cooper et al. (2015) analyzed 27,637 subjects from the *International children's accelerometry database.* Both studies underline the prevalence of physical inactivity. In Europe, two-thirds of children and adolescents are not sufficiently active (Steene-Johannessen et al., 2020) and girls show less

physical activity and higher sedentary behavior than boys (Cooper et al., 2015). In addition, the analysis of self-report data from 1.6 million students aged 11 to 17 years from 146 countries, derived from 298 school-based surveys, showed that the prevalence of physical inactivity decreased for boys from 2001 to 2016, however, girls' prevalence did not significantly change, meaning that girls are still at higher risk for being physically inactive (Guthold et al., 2020).

Literature further supports the evidence that girls with a lower socioeconomic status and higher body mass index represent a major risk group for physical inactivity (Kuntz et al., 2018; Schwarzfischer et al., 2017). Considering that the physical activity levels further decrease with increasing age (Corder et al., 2019), public health researchers warn of the long-term consequences of being physically inactive (Cunningham et al., 2020) and call on the role models, parents and teachers, to set an example of an active lifestyle (McDavid et al., 2012).

1.4 The School Environment as an Activity Setting

Promoting a healthy, active lifestyle is an educational duty of the schools in Germany (ISB, 2020). A close look reveals that during school hours and especially in the classroom the students' activity behavior is characterized by large amounts of sedentary time (Calvert & Turner, 2019). Indeed, school-related activities, i.e. active transportation, contribute significantly to the students' daily physical activity levels (Bachner et al., 2021; Brooke et al., 2014; Kallio et al., 2020). But, results from the German *Motorik-Modul* study showed the trend of decreasing rates of active commuters to school (Reimers et al., 2020). During recess, girls are less active than boys (Ridgers et al., 2012), and girls show relatively low physical activity levels, which was confirmed in secondary school students from the UK and Spain (Bailey et al., 2012; Viciana et al., 2016), and German elementary school students (Kobel et al., 2017).

In contrast to the sedentary routine throughout the school day, PE triggers students to fulfill the natural need to move (Kretschmann et al., 2016). The question arises how demanding PE actually is. A systematic review by Hollis et al. (2017) provides an overview of 25 studies from seven countries, which assessed the secondary school students' physical activity levels in PE using device-based measures. On average the students spent 40.5 % of PE duration in MVPA. A study from the United States recently confirmed the sex-related physical activity pattern in PE that girls were less active than boys (McLoughlin & Graber, 2020). Moreover a study from Scotland showed that "girls spent significantly more time in MVPA in the single-sex session compared to the mixed-sex session" (Wallace et al., 2020, p. 235).

A survey in Germany showed that a regular PE lesson lasts for 70 min on average (Wydra, 2009). Deducting time for changing clothes and organizational arrangements, only 44 min remain for the engagement in physical activities (Wydra, 2009). From the scheduled 90 or 45 min of PE lesson time on average only 50 % remain as effective time for physical activities (Hoffmann, 2011). A cross-sectional study provides device-based results of the physical activity levels during PE from 284 (58.1 % female) students aged 9 to 21 years from grade 5 to 12 from a secondary school in Bavaria (Kretschmann et al., 2016). Time spent in MVPA during PE lessons was on average 42.13 min (SD = 13.66); which accounted for 70.23 % of the recommended daily activity. Kretschmann et al. (2016) also surveyed participants aged 15 to 16 years of one class (n = 26, 80.8 % female) and could show that the physical activity levels were higher on days with PE compared to days without PE. Studies from Spain evidenced that "PE contributes significantly to reducing adolescents' daily physical inactivity and sedentary behavior" (Mayorga-Vega et al., 2018, p. 1920). Hence, the significance of PE as a major contributor to the students' daily MVPA is undisputed (Álvarez-Bueno et al., 2017).

Unfortunately, often boundary conditions make it difficult for teachers to create intensive activities within the scheduled lesson time or to conduct a perfectly structured and motivating PE lesson (Wydra, 2009). Those conditions comprise, for instance, school-intern policies, personnel capacities, physical conditions, quantitative factors, e.g., scheduled lesson times and class sizes (Herrmann et al., in press). The quality of PE is determined by contextual factors as well as structural and process-related factors. How teachers *can* work and how this in turn affects the students' motivation for physical activity, illustrates that school-, class-, or teacher-related factors may influence not only instruction quality in PE but also the daily physical activity behavior of students (Nathan et al., 2018; Herrmann et al., in press).

1.5 The Pedagogical Role of Physical Education

Good teaching is important because it motivates students for physical activity and improves social and emotional skills which enable adolescents to become a responsible member of the society (Shimon, 2019). According to the UNESCO report on Physical Education, the aims of PE "are those which embrace cognitive (knowledge/knowing), psycho-motor (skills/doing) and affective (attitudes/values) outcomes associated with a healthy, active life-style philosophy and connected with physical literacy and the notion of the physically educated person" (North Western Counties Physical Education Association [UK], 2014, p. 8). In order to fulfill these high demands, Bavarian PE teachers run through an intensive academic education, in which they receive comprehensive pedagogical assistance and a health-oriented education.

Within this education, the two missions of PE are emphasized. The aspect of *education to sport* entails the conveying of movement as life principle and the motivation for life-long engaging in sport activities, and the aspect of *education through sport* includes an age-appropriate promotion of health awareness and physical fitness (Kurz, 2008). Hereby,

fundamental competencies and skills are supposed to be facilitated to enhance individual success and confidence in the own capabilities in an environment that offers less and less opportunities for physical activity (Balz & Kuhlmann, 2015).

These two aspects are also applied in the Bavarian curriculum, in particular the domain *health and fitness* encourages teachers to impart age-appropriate health competence and physical fitness (ISB, 2020). In this context, the acquisition of comprehensive competencies and an individual purpose for the engagement in physical activities is ensured by the six pedagogical perspectives for PE (see Table 1; Prohl, 2010).

Table 1

Description of the six Pedagogical Perspectives of Physical Education

Perspective	Description
Impression	Students should experience their body in movements and increase their perceptiveness.
Expression	Students should receive opportunities to express and create movements.
Venture	Risk and account for one's action in situations with unknown ending.
Performance	Students should fulfill sport challenges and develop an attitude in respect of performance.
Cooperation	Students should engage in physical activity through cooperation and communication.
Health	Promoting and developing health awareness.

It is assumed that the quality criteria of good instruction help teachers to create high-quality PE that impacts students' physical activity behavior and active lifestyle (Slingerland & Borghouts, 2011). Prominent in the German academic and practical discourse of PE teacher education are Gebken's (2005) criteria (see Table 2), which are almost identical to Helmke's (2017) considerations.

1. Clear structure of the teach-learn process
2. Ideal use of given time
3. Long involvement of students in motor activities (= extension of the amount of real movement time)
4. Pluralism of methods
5. Coherence of goals, contents, and methods
6. Class climate (= creation of a learning-beneficial, positive work-climate)
7. Meaningful class-conversations (= mediation between the curriculum and the students' interests)
8. Fostering approach (= orientation at the individual learning state, encouragement to learn, communication of learning strategies)
9. Student-feedback
10. Achievement expectation and control

On a theoretical basis these proposed activities are extended within the three basic dimensions for quality in PE: Classroom management, student orientation, and cognitive activation (Herrmann et al., 2016). Examples of good classroom management are a structured, transparent organization of the PE lesson, in which behavior rules are clearly communicated to avoid disciplinary problems. The teacher focusses on efficient use of time, and is able to adapt content, learning tempo and challenges to the students' level, also under consideration of the subject-specific characteristics, such as materials and equipment; room and location. In particular, the competitive orientation of sports should be incorporated within this dimension. Student orientation comprises, for example, a caring teacher behavior which aims to create a positive teacher-student relationship. The consideration of an individual rather than social reference norm orientation, and the provision co-determination for students as well as differentiating tasks and challenges to account for the heterogeneity of students. Finally, cognitive activation is described as the supportive presentation of adequate learning opportunities which encourages the cognitive learning activity of students. With regard to PE, the cognitive activities of students are compiled by cognitive and motor

skills that influence their activity behavior. Examples for cognitive activation are teachers' support, focus on learning objectives, adequate challenges and clear communication and explanation of tasks (Herrmann et al., 2016).

Critics might argue that some established quality criteria of teaching in PE (Gebken, 2005; Helmke, 2017), such as a sound lesson structure, efficient use of lesson time, long involvement in motor activities already enhance the MVPA levels in PE. Moreover, incorporating the students' feedback and creating a positive atmosphere likely support the students' needs. On closer inspection, however, the "we are already doing that"-mentality reveals that there is still room for improvement (Ntoumanis et al., 2018, p. 16). Stating that the concept of self-determined learning is embedded in the framework of the (Bavarian) curriculum neither means that all teachers know how to implement need-supportive teaching styles nor that controlling teaching behaviors are absent in the gyms. In this context, it requires combined forces of practitioners and researchers to prove the efficacy and practical utility of the pedagogical and theoretical considerations and to identify overlaps between and across certain behavior change techniques, in order to subsequently examine the impact of PE teachers' need-supportive behavior on students' daily physical activity behavior.

1.6 Theoretical Framework of the CReActivity Study

The CReActivity project is based on a socio-ecological approach. Most notably, the Youth Physical Activity Promotion Model (YPAPM; Welk, 1999) describes the influences of personal and socio-ecological factors for adolescents' physical activity behavior, which were taken into account in the intervention development. The YPAPM reflects main parts of the ecological model by Sallis et al. (2008) and Deci and Ryan's (2000) self-determination theory. In the following, these theories are introduced in order to explain why the motivation and the actual physical activity levels differ and change to a variable extent amongst students.

1.6.1 *Ecological Model of Health Behavior*

The tradition of ecological models started with the *ecological psychology* by Lewin and Cartwright (1951) who were the first to study the influences of the environment on a person. Several years later, Bronfenbrenner (1979) formulated the ecological systems theory. McLeroy et al. (1988) firstly introduced an ecological model of health behavior, in which correlates of physical activity were categorized as one of five types. With regard to Stokols' (1992, 1996) core principles, Sallis and Owen (1997) have broadened the considerations by McLeroy et al. (1988) and developed the *ecological model of four domains of active living*. This hierarchical model describes the socio-ecological perspective that several factors influence individuals' health behaviors and claims that those influences interact across levels within certain living domains.

Taking the school as an example for a behavior setting, the students' physical activity depends on intrapersonal, interpersonal, institutional, community, and policy factors (Zhang & Solmon, 2013). Public laws and policies shape and regulate the living environment, which generally refers to factors "outside" of the person. At the community level, especially the built environment conduces whether a student commutes by bike on a safe bike lane to school or meets his friends to play in the nearby park after school. In the specific behavior setting of schools, the availability and convenience of playgrounds and gyms are factors that determine whether the student performs physical activity in recess and PE. Interpersonally, the social support provided by teachers and classmates dynamically influences the physical activity behavior, which is at the intrapersonal level affected by biological factors, demographics, family situation, and psychological processes, such as motivation.

In summary, Sallis et al. (2008) provide not only a theoretical framework which can be used to systematically identify and discourage barriers of physical activity in the school setting but can also be used as a suitable framework in the design of physical activity

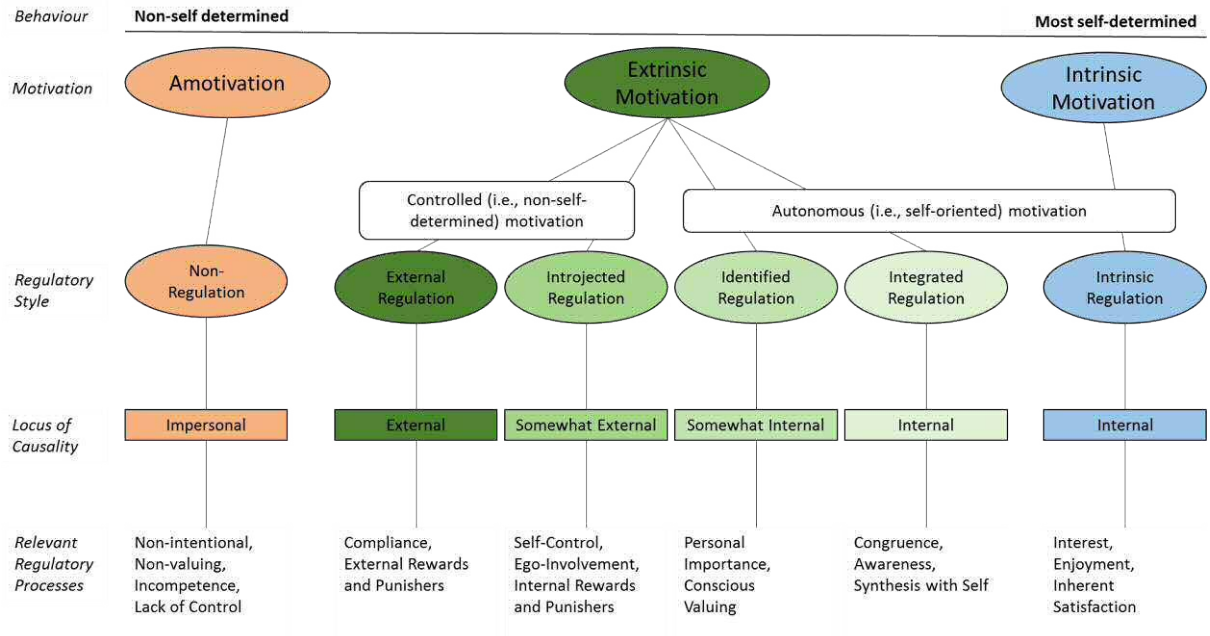
promotion programs. The conclusion is that the environment should supply opportunities and (social) support, before motivational processes should be activated so that individuals engage in physical activity. At the intra- and interpersonal level, the self-determination theory as one of the most commonly used theories within the educational setting, contributed substantially to exploring the motivational mechanism of changes in physical activity behavior (Zhang & Solmon, 2013).

1.6.2 *Self-Determination Theory*

Referring to the originators of the self-determination theory, a person naturally tends to interact within their social environment in order to perceive themselves as effective, proactive and autonomous (Deci & Ryan, 2000). This assumption demonstrates an organismic approach describing human behavior as something that relies on the inherent propensity to grow and learn.

Figure 1

The Internalization Continuum: Types of Motivation According to Self-Determination Theory (Illustration from Legault, 2017).



The underlying motivational processes are differentiated on a self-determination continuum (see Figure 1; Ryan & Deci, 2000). The internalization describes a process, in which the behavioral regulations change from external to internal loci. The individual perceives external regulations, such as reward and punishment, as controlling and therefore shows extrinsically motivated behaviors, which are completely heteronomous at this level. When the individual is able to involve itself in the regulatory process, for example through internal rewards or punishments, the external process is more self-determined and called introjected regulation since the individual feels a sort of self-control. Identified regulation, however, is characterized by the perception of personal importance and conscious value, which already represents an autonomous form of motivation. When the individual synthesizes or attributes the cause of the desired behavior with itself, the regulatory style is called integrated regulation. Finally, the most self-determined form is intrinsic motivation, which is characterized by autonomous behavior activated by individual volition, personal interest, or enjoyment (Ryan & Deci, 2000).

These proactive behaviors require supportive conditions, particularly the three basic psychological needs autonomy, competence and relatedness should be satisfied in order to develop a healthy lifestyle (Ryan & Deci, 2020). Research grounded in the self-determination theory contributed substantially to educational research (Ryan & Deci, 2020), and states that motivational attitudes with regard to adaptive outcomes may be influenced by the support and satisfaction of the basic psychological needs. In line with this assumption is Vallerand's hypothesized motivational sequence (1997), which describes the mechanism of behavioral change from support over satisfaction to autonomous forms of motivation leading to the desired behavior.

The preferred definition of *autonomy* is "being the perceived origin or source of one's own behavior" (Ryan & Deci, 2002, p. 8). The need for *autonomy* is fulfilled when the

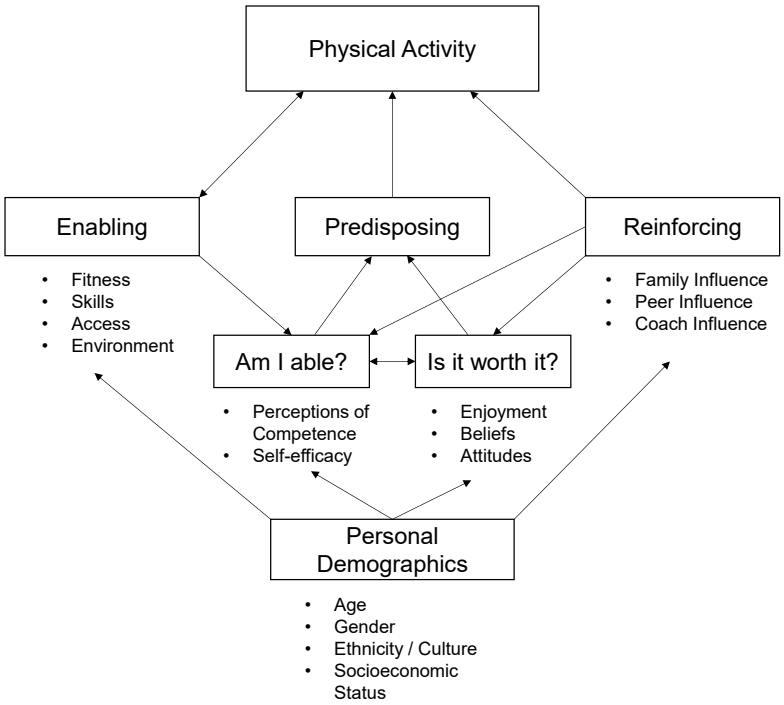
individual acts from interest and experiences self-determined behavior in an environment where external factors do not interfere but concur with one's own values. The respective need-supportive teaching styles in PE include but are not limited to offering freedom of choice, transparency of content, and space for independent action for students (Reeve, 2016). *Relatedness* describes the desire to feel connected with, care for, and being cared for by significant others, such as parents, friends. In the sense of belongingness it reflects the need of being an integrated and accepted part of the community (Ryan & Deci, 2002). The PE teacher supports relatedness through creating a trust-based learning environment that inspires confidence, which is sustained by social rituals and embedded in games and projects. The need for *competence* refers to experience effective interactions within the social environment. When feeling competent, the individual meets challenges that are, from subjective certainty, optimal for their capacities and skills even when persistent attempts were necessary to enhance the success. The PE teachers are supposed to provide a sense of achievement through respecting the students' interests and offering individual feedback. An optimal level of challenge is a condition for this. Thus, the task should neither be too hard nor too easy (Deci & Ryan, 2000).

1.6.3 *Synthesis to Youth Physical Activity Promotion Model*

The YPAPM describes the interplay of environmental (enabling), psychological (predisposing), and social (reinforcing) attributes, which are identified as modifiable correlates of physical activity. The conceptual model incorporates several constructs from competing theories and thereby tries to bridge theory and practice. For example, *perceptions of competence* and *influence by peers and teachers* reflect the aforementioned constructs of *competence* and *relatedness* grounded in self-determination theory (Deci & Ryan, 2000).

Figure 2

Youth Physical Activity Promotion Model (Welk, 1999).



Two fundamental questions form the predisposing basis of the decision-making process, *Is it worth it?* and *Am I able?* (Bandura, 1986). A similar term to the self-evaluative construct of competence derived from Bandura's social cognitive theory (1997). With regard to physical activity of adolescents, the construct of *self-efficacy* is defined "as a youth's belief in his/her capability to participate in physical activity and to choose physical activity despite existing barriers" (Voskuil & Robbins, 2015, p. 2014). Within the decision-balance relationship, affective and cognitive factors are likewise important for participation in physical activity. Enjoyment and/or attraction of physical activity are worthwhile (affective) outcome expectations, while the construct of attitudes, construed from theory of planned behavior (Ajzen, 1991) or health belief model (Rosenstock, 1974), is with regard to physical activity defined as individual, positive or negative, value disposition to engage in physical activity (Erdmann, 1982). The encouraging or discouraging influence of reinforcing and enabling factors are thought to directly or indirectly (through the predisposing factor) affect adolescents' physical activity behavior. Examples of reinforcing factors are family, peers,

teachers influence (e.g., teachers' focus on high-intensity PE). As the label suggests, enabling factors enable or hinder adolescents to be physically active. Those factors include but are not limited to access and availability of playgrounds or sports equipment as well as policy-related factors, such as the opportunity to engage in PE. The social-ecological foundation of the YPAPM is reflected by the inclusion of socio-demographic, ergo intrapersonal, factors, such as age, gender, ethnicity and socioeconomic status (S. Chen et al., 2014; Welk, 1999).

These and further social and educational theories, such as the health promotion model (Pender, 1996), protection motivation theory (Rodgers, 1983), and transtheoretical model (Prochaska et al., 2009), describe influences on individuals' behavior and claim that changes in physical activity behavior are basically possible. By the syntheses of diverse theoretical approaches the YPAPM aims to enhance the promotion of physical activity among children and adolescents, but the author states that "some theoretical approaches may offer intervention targets that are more effective than others" (Welk, 1999, p. 7). The measurement model of the YPAPM was supported using structural equation modeling and the relationships between those constructs and participation in physical activity has been shown by cross-sectional studies (e.g., S. Chen et al., 2014; Heitzler et al., 2010; Seabra et al., 2013). However, a deeper understanding of the underlying mechanisms of changes in physical activity behavior is still required. Zhang and Solmon (2013), for example, provide an additional theoretical model that focusses on how the social (including reinforcing factors) and physical (including enabling factors) environment affect the hypothesized psychological mechanism of the self-determination theory in terms of adolescents physical activity by integrating the self-determination theory in the socio-ecological model of health behavior. In particular, the presented examination of individual (intrapersonal) and social (PE teachers need support) factors that influence female adolescents' physical activity, may help to create

a detailed understanding of the students' physical activity behavior and subsequently to inform the development, design and implementation of future interventions promoting children' and adolescents' physical activity.

1.7 Efficacy of Physical Education Interventions

Facing the pedagogical background of this project, it is of particular interest if PE interventions are able to provoke a change in adolescents' daily physical activity behavior. The strategy of qualitatively enhanced PE lessons is often accompanied by the expansion or extension[2] of existing opportunities in schools to engage in physical activity (Slingerland & Borghouts, 2011). Such interventions are understood as *multi-component* interventions because they combine or include strategies addressing different levels, i.e., policy, physical environment, classroom; by incorporating several stakeholders, i.e., principals, teachers, parents; and/or using innovative technologies, e.g., smartphones (Mikkelsen et al., 2016). The analysis of these multi-arm study designs is a sophisticated task and makes it difficult to identify the factors or components that triggered the intervention effect (Komro et al., 2016).

Another issue that limits the consistency of empirical evidence for PE interventions and its effects on adolescents' daily physical activity (Jones et al., 2020; Slingerland & Borghouts, 2011) is the limited number of studies which set (accelerometer-measured) physical activity as their primary outcome (see Demetriou and Sturm, 2020, for an overview in Germany and the systematic review of 33 international studies by Vaquero-Solís et al., 2020). Subsequently an identification of effective measures was not possible due to lacking process evaluations or inadequate statistical analysis (Dobbins et al., 2013; Jones et al., 2020; Klos et al., 2020).

[2] The theory of expanded, extended and enhanced opportunities for youth physical activity promotion by Beets et al. (2016) provides a taxonomy of approaches to promote physical activity among adolescents.

Although the authors note the partially limited or inconclusive evidence caused by the high heterogeneity of studies, the conclusion that can be drawn from these systematic reviews is the indication for the effectiveness of theory-based, multi-component interventions. Those provide in varying sizes and qualities promising effects on activity-related or activity outcomes (Dobbins et al., 2013; Klos et al., 2020; Kriemler et al., 2011). In a more general sense, school-based interventions have an impact on health-related and wellbeing outcomes (Singh et al., 2019; van de Kop et al., 2019; Vaquero-Solís et al., 2020; Yuksel et al., 2020).

Two recent meta-analyses exemplify the inconclusive empirical findings. Based on included 17 randomized-controlled trials (RCT), Love et al. (2019) could not evidence a significant effect of school-based physical activity interventions on accelerometer-assessed daily MVPA of adolescents. But the mixed-studies review of 38 studies by Jones et al. (2020) indicated a significant but moderate effect on accelerometer-assessed daily MVPA. Moreover, Voskuil et al. (2017) identified the low number of studies using accelerometry for physical activity assessment. Their systematic review of effects of physical activity interventions for girls on objectively measured outcomes presents only one RCT which showed a positive intervention effect on physical activity. The respective multi-component intervention by Webber et al. (2008) provoked a significant difference of 10.9 min in MET-weighted MVPA between the intervention and the control group in sixth grade girls, but group differences in total physical activity were not significant. Specifically focusing on interventions promoting physical activity of girls, the systematic review of 21 interventions by Camacho-Miñano et al. (2011) concluded that multi-component interventions were effective, if they offered a PE that was tailored for girls' needs.

This leads to the question if PE teachers or their teaching strategies impact students' physical activity levels. In fact a systematic review on PE interventions showed that PE

interventions are efficient to increase MVPA levels during PE but the impact on leisure-time PA is limited (Errisuriz et al., 2018). Based on 14 reviewed studies, the meta-analysis by Lonsdale et al. (2013) provided evidence for a positive, direct effect of certain teaching strategies on children and adolescents' MVPA level during PE. However, the strategies differ in terms of implementation (e.g., fitness infusion or various theory-based teaching strategies) and theoretical foundation (e.g., social-cognitive theory, theory of planned behavior, and self-determination theory). Hence these results are highly heterogeneous and specifically, findings from theory-based interventions are quite inconsistent (Gourlan, 2014).

In their systematic review on PE and school interventions, Dudley et al. (2011) provided evidence for direct instruction teaching methods that have an impact on children's physical activity levels and improve movement skills in PE. However, the authors criticized missing process evaluations and lack of statistical power of reviewed studies to draw strong conclusions concerning the effectiveness of interventions conducted in PE and school sport (Dudley et al., 2011), which were mostly implemented in primary schools.

Two meta-analyses of school-based programs using the self-determination theory suggest that programs might be effective in increasing motivational outcomes with regard to physical activity (Kelso et al., 2020; Vasconcellos et al., 2020). In addition, the meta-analysis by Sheeran et al. (2020) provided evidence for a small, positive effect size of self-determination theory-based interventions on physical activity. It also suggested that autonomous motivation and perceived competence mediated the effects on health behaviors. The systematic review on self-determination theory in PE by Saugy et al. (2020, p. 1) highlights "the fact that a combination of psychological and physiological assessments is needed to reach the most global understanding of physical activity engagement during PE classes and that this engagement mostly depends on the students' motivations." Students who attribute personal importance, interest, or even enjoyment regarding physical activity

are likely to engage more in physical activity since their motivation derives from an internal (i.e., autonomous) source. Two previous systematic reviews confirmed that the students who predominantly perceive external regulations, such as reward and punishment, engage less in physical activity than the autonomously motivated students (Cortis et al., 2017; Owen et al., 2014). Moreover, need-supportive programs with the aim of increasing engagement (Gairns et al., 2015), enjoyment (Huhtiniemi et al., 2019; Leptokaridou et al., 2015), motivation, and intentions showed promising results in regard to physical activity (Sánchez-Oliva et al., 2020).

1.8 Critique of Current Research

The direct effect of a need-supportive teaching style in PE on adolescent girls' physical activity behavior has not been examined in Germany. This might be due to the small number of implemented RCTs in this research field and the lacking empirical investigations of theoretical teaching behaviors (Herrmann et al., 2016; Love et al., 2019). Especially in Germany, intervention studies focusing on the physical activity promotion of secondary school students through a modification of PE teacher behavior are nonexistent (Demetriou & Sturm, 2020; Jordan et al., 2012; Messing et al., 2019). From a global perspective, the existing evidence stems mostly from studies conducted in primary schools and a lack of process evaluations hinder the identification of effective behavior change techniques (Dudley et al., 2011; Errisuriz et al., 2018). Moreover, sex-related discrepancies in terms of physical activity are evident, but most disseminated physical activity interventions are not sex-specific (Schulze et al., 2020).

Another reason for the limited evidence is that the majority of intervention studies often neglect to implement process evaluative measures (Lewis et al., 2017), although a comprehensive evaluation is key to illuminate the "black box" mechanisms that could affect the program or outcomes (Saunders et al., 2005). In this context, a clarification of the

theoretical framework is important to identify overlaps of the intervention components (Teixeira et al., 2020). In addition, RCTs require a maximum of implementation fidelity, but the structural barriers in the educational settings are going to lead to unintended variations. This issue urges researchers to implement evaluative measures in order to monitor the quality of implementation (Hilitzer et al., 2015; Love et al., 2019).

2 Aims of the Studies

As one of the first implemented cluster RCTs focusing on girls at Bavarian secondary schools, the CReActivity study aimed to explain the mechanisms of girls' behavioral changes in physical activity. The purposes of this thesis were to examine the intervention effects on adolescent girls' MVPA as well as to evaluate the quality of implementation based on a mixed method evaluation. By integrating both quantitative as well as qualitative methods, Publication 3 presents an innovative strategy to create a comprehensive overview of the influence of need-supportive teaching as well as intrapersonal factors such as age, body mass index, and socioeconomic status on the girls' MVPA.

Thereby, Publication 1 plays a supportive role since it enlarges the insights into the baseline activity behavior of girls from the CReActivity sample during segments of a regular school day. By disclosing the processing criteria and methodological decisions, this publication helps to align the scientific quality criteria of the physical activity assessments and summarizes the added value of the accelerometer-measured physical activity data.

In Publication 2 psychometric properties of a newly developed scale assessing girls' satisfaction of basic psychological needs in PE were investigated. A procedure for a multilevel confirmatory factor analysis (MCFA) was performed which accounted for the clustered data structure and thereby addressed limitations of previous validation studies that ignored intraclass correlations in their analysis. This procedure identified the scale as a valid measurement tool and thus supports the validity of results from Publication 3. Overall, publication 2 exemplifies the applied validation procedure of questionnaire scales and the consistently high methodological rigor applied in all studies, which is the core aspect of good scientific practice.

3 Methodology

This chapter summarizes the methods section of each publication. Initially, in chapter 3.1, the procedures of the physical activity assessment are described, which are particularly relevant for publication 1 and 3. In chapter 3.2, the analytical approach from publication 2 to test the psychometric properties of a newly developed questionnaire scale is presented. In chapter 3.3, the mixed method design of publication 3 is explained. The chapter concludes with a description of the intervention components.

3.1 Accelerometry

The physical activity levels and sedentary time of adolescent girls were measured using the three-axial GT3X-BT, GT9X, and GT3X ActiGraph models. For technical specifications refer to the manual by ActiGraph (2013). Data were collected for seven consecutive days. For initialization and processing of accelerometer data, we considered the systematic review by Migueles et al. (2017). Participants were instructed to wear an accelerometer attached to an elastic belt on their right hip from awaking and latest to 9 pm, except during water activities (e.g., swimming, bathing, showering) or in case of concerns related to any safety issues (e.g., combat sports, rock climbing). Accelerometers were initialized to record activity at a sampling rate of 30 Hz, 1 s epoch length (10 s epochs were used for GT3X models (N = 42) due to lower battery and memory capacity), and were downloaded using the ActiLife software v6.13.4 (ActiGraph, 2019). A low frequency extension filter was not applied. The wear-time algorithm by Choi et al. (2011) was used to check compliance (see Bachner et al., 2021, for detailed specifications) and cut-points by Hänggi et al. (2013) were used to determine sedentary time (< 180 cpm), light physical activity (180-3360 cpm) and MVPA (≥ 3361 cpm). Due to the focus on schooldays in Publication 1, data were considered valid if at least three schooldays with at least 8 hr of

wear time were recorded (Migueles et al., 2017). Publication 3 focused on the daily MVPA levels throughout the week, thus data were considered as valid if the accelerometer recorded at least three weekdays and one weekend day with at least 8 hr of wear time. The chosen criteria compromised good reliability and measurement accuracy with acceptable loss of sample size. Thereby, the devices provided detailed information of intensity, frequency, and duration of physical activity.

3.2 Multilevel Validation

In Publication 2, the German Basic Psychological Need Satisfaction Scale for Physical Education was validated using the MCFA procedure by Huang (2017). This procedure was chosen as it accounted for clustered data in contrary to regular confirmatory factor analysis. Two researchers translated the twelve satisfaction items of the Basic Psychological Need Satisfaction and Frustration Scale by B. Chen et al. (2015) from English to German and adapted the scale in terms of age-appropriate style and language. Participants rated the degree of perceived satisfaction in PE on a 5-point Likert scale by a paper-pencil questionnaire under supervised conditions. Baseline data of 481 adolescent girls participating in the CReActivity study were analyzed to examine factor structure, scale dimensionality, reliability, and criterion validity in terms of accelerometer-assessed MVPA. The MCFA procedure estimates factor loadings at both levels and thus provides detailed insights into the scale's psychometric properties. The defined but adaptable R code of the MCFA procedure allows us to test several factor structures through comparing the model fits to a defined set of cut-off criteria. Internal consistencies were also computed at class level as well as student level. Moreover, multilevel correlations including MVPA were computed. A detailed description of the MCFA procedure can be found in Huang (2017).

3.3 Mixed Method Evaluation

Pioneers in the mixed-methods research field share the notion that mixed-methods study designs (see Creswell and Piano Clark, 2018, for an overview) provide beneficial insights into several topics in health sciences (Creswell et al., 2011). Their disseminations inform in detail of the process and the efficacy of interventions or explain phenomena which are often overlooked or misunderstood using frequentist statistics (e.g., Christian et al., 2020; Innerd et al., 2019; Jong et al., 2019). The integration of quantitative as well as qualitative strands in the analysis and/or interpretation provides an in-depth description of the process, such as the quality and fidelity of implementation (Durlak, 2016), as well as the outcome measures, in this case the efficacy of the intervention (McCrudden et al., 2019). Yet, from an epistemological perspective, this methodological variety should be justified (Hathcoat & Meixner, 2017). A critical realist perspective on the underlying pragmatic research philosophy for sport and exercise psychology is taken in order to reflect and ensure the utility and value of the methods and its empirical contributions (Giacobbi et al., 2005; Ryba et al., 2020).

A convergent mixed method design was applied to evaluate the intervention effects of a 16-weeks cluster RCT and its quality of implementation. Computer-based randomization took place at school level, meaning that all classes from one school were assigned to either the intervention or control condition. All intervention teachers conducted the training session, whereas control teachers continued with their usual teaching approach (Demetriou & Bachner, 2019). The two assessment waves were administered in the school years 2017/2018 and 2018/2019 and consisted of (a) baseline assessments between October and December (b) posttests between March and May and (c) follow-up tests between June and July within the respective school year. Adolescent girls completed a paper-pencil questionnaire on their perceived need support, need satisfaction, and socioeconomic status

supervised by researchers during one PE lesson. The daily MVPA level was assessed using accelerometry. Body mass index was assessed using a weight scale and stadiometer. During the intervention period of the Wave 2 assessment, two PE lessons of each class were systematically observed. With respect to a modified System of Observing Fitness Instruction Time (SOFIT) protocol (McKenzie, 2015), MVPA in PE and need-supportive teaching behavior were coded by two independent, trained observers. After the intervention period, semi-structured focus group interviews were conducted with four to five adolescent girls of each class.

Initially, descriptive statistics, correlation structure, and baseline differences were analyzed using R (R Core Team, 2018). Beforehand, the newly developed need support scale was validated. Linear mixed models were used to determine the intervention effect of perceived teachers' need support in PE on the girls' daily MVPA. Due to unbalanced distribution of classes in schools and partially sparse students' observations within classes, random intercept-only models were tested. Since the issue of multicollinearity occurred, collinear constructs were grand mean centered, which increased the model precision and explanatory power (Finch et al., 2019). Multilevel repeated measures analysis with follow-up post-hoc pairwise mean comparisons was conducted to test mean differences between measurements and groups. The interobserver-agreement of systematic observations was computed and bootstrapped confidence intervals of group differences in need support were contextualized. Focus group interviews were interpreted based on the results of a structured content analysis (Mayring, 2015). Finally, the different methodological strands were integrated to rate the convergence of results in terms of the quality of implementation and the intervention's efficacy.

3.4 Intervention Components

A teacher training was designed and pilot-tested prior to the intervention's start. Each intervention teacher (N = 13) participated in a face-to-face training session of approximately two-hours in the same week the baseline assessments were conducted. In this training session, a researcher introduced the theoretical framework and intervention components and explained the implementation of the intervention. The teachers received a training manual and 48 lesson plans[3] in the domains of football, basketball, gymnastics, health and fitness, swimming, and dancing. Each lesson plan included specific instructions for need-supportive teaching and was created in accordance with the curriculum. Where necessary, supportive material for up to 30 students was provided. With regard to the implementation protocol, teachers were instructed to conduct at least 16 lessons, each lasting 90 min, which could be freely selected from the 48 elaborated lesson plans. Reminder e-mails to provide documentation of all conducted lessons and elements were sent to the teachers every four weeks after the start of the intervention. The researcher acted as contact person throughout the entire intervention period.

A set of teaching modules that can be used to promote the three basic psychological needs are described in order to explain how the YPAPM and the SDT have been incorporated in this intervention. According to the aforementioned dual mission of PE, our lesson plans had the intention to enable students to exercise their fitness and/or to play basketball, football, etc. Through the underlying didactical principles, the students should learn the fundamental movement skills, techniques, and knowledge necessary to enjoy physical activities in their leisure time.

[3] The author will provide access to the training manual and lesson plans upon request.

In terms of the predisposing factors we focused on the strategy to nurture inner motivational processes (Reeve, 2016), namely the support of the basic psychological needs. By providing a meaningful rationale for exercises, critical reasoning of the content and course of the lesson, the teacher might support the students' need for autonomy. It is clear that students can only express themselves freely within the permitted framework of PE lessons. The provision of choice and co-determination might help students to perceive their actions as more autonomous. This means that the teacher allows a certain degree of co-creation, for example in terms of the rules, games, task level, or the social and organizational form of exercises. Moreover, the teacher should encourage students to give (critical) feedback through reflective rituals (e.g. mood-o-meter) and more importantly, the teacher must acknowledge and respect the negative and/or constructive feedback through non-controlling language.

Every student has strength. It is the teachers' task to promote these to provide each student with a feeling of success. This didactical aspect of natural differentiation (Helmke, 2017), namely to provide an adequate task level in exercises for every student, may be fulfilled by several ways or opportunities to score a goal, exercises with or without time- and opponent pressure, group-tasks so that other students can help "weaker" students to achieve a common goal, or tasks without a specific goal or a certain number of repetitions. In this sense it is also important to give positive feedback, which might promote students' perceived self-efficacy. Providing feedback is a behavior change technique itself and teachers should focus on students' strengths instead of weaknesses. The intraindividual process and improvement is more important than the comparison with others. Besides students' performance teachers should also appraise the cooperativeness, engagement or participation in PE. Teachers should also encourage students to give each other valuable and friendly feedback.

In this way the predisposing question of “Am I able?” might be answered with yes. Moreover, the involvement of students expertise’ considers aspects of the social learning theory (Bandura, 1986). A student role model might serve as a better demonstrator of techniques for their peers than the teacher and thereby, the need for competence might be further supported. However, the teacher has to vary the student experts and the teacher must acknowledge that not every student may want to present or demonstrate exercises.

To get “in synch” with the students (Reeve, 2016, p. 133) helps to foster a positive teacher-student relationship “in which the actions of one influence the actions of the other, and vice versa” (Reeve, 2016, p. 133). In general, it is important to create a respectful and fair community. A certain degree of team spirit can enliven the lesson. A ritual in in the beginning and the end of the class might promote relatedness, Ideally, the students create their own rituals, but the teacher can also implement a ritual in which students can express their moods, motivation, and attitudes so that the teacher gets feedback from the students. Lastly, the social environment can be addressed through physical activity-related homework that the students should accomplish with their family members or friends. This aspect concludes the reinforcing aspect of social support, which can increase the physical activity of students.

4 Publications

4.1 Publication 1

Authors: David J. Sturm, Anne Kelso, Susanne Kobel, & Yolanda Demetriou

Title: Physical Activity Levels and Sedentary Time during School Hours of 6th-grade Girls in Germany

Journal: Journal of Public Health

Doi: doi.org/10.1007/s10389-019-01190-1

Summary: The school provides several opportunities for students to be physically active. However, device-based data describing the physical activity levels and sedentary time of students in secondary schools in Germany are rare. The aim of this article was to investigate the physical activity levels and sedentary time of adolescent girls during a regular school day with a particular emphasis on recess activities. Cross-sectional accelerometer data from 308 sixth graders were analyzed. Results showed that the majority of girls accumulated sufficient levels of daily MVPA. However, sedentary time was high throughout the segments of the school day. Thus, the study demonstrated the need to promote school-related physical activity and to reduce sedentary time during school hours.

The manuscript was submitted in the *Journal of Public Health,* which is an interdisciplinary, peer-reviewed, open access journal, in September 2019, accepted in December 2019, and published in January 2020.

Contribution: David Sturm was the leading author of this article. He collected data and chose the methods for the analysis in consultation of the expertise by Susanne Kobel. Yolanda Demetriou engaged in acquisition of funding. David Sturm wrote the published article with substantial support by Anne Kelso and under consideration of feedback by all co-authors.

Journal of Public Health: From Theory to Practice
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ORIGINAL ARTICLE

Physical activity levels and sedentary time during school hours of 6th-grade girls in Germany

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Abstract

Aim Regular physical activity and low levels of sedentary time have positive health effects on youth, and data are needed to base public health recommendations on. Here, findings of device-based physical activity and sedentary time in sixth graders are presented. Data below are presented as mean (SD).

Subject and methods Three hundred and eight sixth-grade girls [11.6 (0.6) years] from the CReActivity study in Germany wore accelerometers (ActiGraph GT3X) for 7 consecutive days. Moderate to vigorous physical activity (MVPA), light physical activity (LPA), and sedentary time (ST) was obtained during school days with a focus on recess times.

Results Girls spent 79.9 (23.2) minutes in MVPA and 9.4 (1.2) hours in ST during schooldays, of which 20.5 (8.2) minutes and 3.8 (0.4) hours respectively were accumulated during school hours. On average, students had 35.4 (4.5) minutes break, of which 6.3 (3.2) minutes (17.8%) were spent in MVPA activity and 16.5 (6.2) minutes (46.6%) in ST.

Conclusion School setting is an important factor for physical activity and sedentary time. Therefore policy, curriculums, and school environment should promote physical activity und reduce sedentary time during school hours.

Keywords Accelerometer · Adolescent · Moderate to vigorous activity (MVPA) · Secondary school · Break time

Background

Physical activity (PA) contributes to the development of the muscoskeletal and cardiovascular system, to neuromuscular control, and to the maintenance of healthy body weight and body composition (Poitras et al. 2016; WHO 2011). Additionally, PA is positively associated with psychological health and cognitive performance (Poitras et al. 2016). The World Health Organization (WHO) therefore recommends at least 60 min of daily moderate to vigorous physical activity (MVPA) for children and adolescents aged 5 to 17 years (WHO 2011). Since sedentary behaviours (SB) have been found to lead to adverse health outcomes in children and adolescents such as measures of obesity, lower cardiorespiratory fitness, and lower insulin sensitivity (Mitchell and Byun 2014; Tremblay et al. 2011b), the German activity guidelines recommend a minimum of 90 min MVPA per day. In addition, Pfeifer and Rütten (2017) incorporate a recommendation of maximum of 2 hours SB for children and adolescents between 6 and 18 years of age (Pfeifer and Rütten 2017). Nevertheless, PA levels of children and adolescents around the globe are low; the majority of adolescents do not meet the WHO activity guidelines, and girls are generally less active than boys (Hallal et al. 2012; Kalman et al. 2015; van Hecke et al. 2016). Based on self-reported PA data, 23.1% of boys and 14% of girls aged 11 to 15 years across Europe and North America engage in 60 min of daily MVPA (Kalman et al. 2015). In Germany, about 20% of girls and boys accumulate at least 60 min of MVPA per day, and the prevalence of SB of children and adolescents cannot be dismissed.

By definition, SB cannot be equated with screen time (Hoffmann et al. 2019), assuming that SB is characterized by a sitting or reclining posture with an energy expenditure of less than 1.5 METs (Metabolic Equivalent of Task) (Sedentary Behaviour Research Network 2012). However, Demetriou et al. (2019) reported that in Germany children and adolescents spend about 70% of their waking time in a sedentary position, of

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which a large share is accumulated by media consumption in front of a screen (Huber and Köppel 2017; Konstabel et al. 2014; Smith et al. 2016; Manz et al. 2014). Recommendations for SB suggest that children and adolescents should reduce unnecessary ST, and accumulate a maximum of two hours screen time during a day (Tremblay et al. 2011a; Pfeifer and Rütten 2017). In particular, limiting sedentary motorized transport, extended sitting time, and time spent indoors is recommended (Tremblay et al. 2011a). Although the school setting contributes to the aforementioned cases of SB (Smith et al. 2016; Bailey et al. 2012), an explicit recommendation for school time regarding SB is not yet available.

Nonetheless, the school setting provides numerous opportunities for students to be physically active (Ridgers et al. 2013). To ensure that children and adolescents meet current activity guidelines and benefit from the diverse health effects of PA, recommendations specifically for the school setting have been made. Both the USA and the UK recommend that students should accumulate a minimum of 30 min of MVPA during the school day (Department of Health 2016; Institute of Medicine 2013). Further, US guidelines recommend that students spend 30 to 45 min per day on average in Physical Education (PE) class, with half of the lesson time spent in MVPA; the remaining minutes of MVPA should be accrued during recess and classroom time devoted to PA (Institute of Medicine 2013). Additionally, at least 40% of recess time should be spent in MVPA (Ridgers et al. 2005).

Systematic reviews have described the correlates of PA behaviour of school-aged children and adolescents during break times (Ridgers et al. 2012), and examined the effectiveness of recess interventions on PA behaviour (Parrish et al. 2013; Ickes et al. 2013), yet there is a lack of information on students' actual activity levels and sedentary time (ST) during break times. Only a few original studies can provide some insight into students' PA levels during school break times. For example, Bailey et al. (2012) examined PA levels and ST in 10- to 14-year-old students during different segments of the school day and found that morning recess and lunch break accounted for 7% and 19.5% of daily MVPA respectively. Girls were less active and more sedentary than boys during both break times, and more boys than girls reached the recommended 40% of MVPA during recess (60% and 28% respectively) and lunch break (64.9% and 10.3% respectively) (Bailey et al. 2012). Ridgers et al. (2013) combined recess and lunchtime PA data of adolescents (14.1 (0.6) years) and found that students spent an average of 7.6% of their break time in MVPA compared to 39.4% in light PA and 52.9% being sedentary. Again, girls were more sedentary during break times than boys (Ridgers et al. 2013). Moreover, a decrease in PA participation during recess across the school grades 4 to 10 has been reported, together with a lower prevalence of girls being active during recess than boys across all school grades (Haug et al. 2010).

To date, only Kobel et al. (2015) have investigated the PA levels of German schoolchildren during recess in a sample of primary school children (7.1 (0.7) years), and found that recess accounted for nearly 7 min (5.8%) of daily MVPA and that boys accumulated significantly more minutes of MVPA during morning recess than girls.

These studies suggest that recess and lunch break can contribute, with varying proportions, to daily MVPA of school-aged children and adolescents. Throughout the studies and investigated age groups, girls had lower PA levels than boys (Bailey et al. 2012; Haug et al. 2010; Kobel et al. 2015; Ridgers et al. 2013). However, differences in the methods used to determine PA as well as differences in the education systems (and allocated break times) between the studies limit their comparability.

Therefore, more studies are needed to develop a detailed understanding of children's and adolescents' PA behaviour during the school day and to develop effective interventions promoting PA levels and reducing ST during the school hours. The purpose of this study is to provide a further insight into PA levels and ST during school hours, with a special focus on activity levels during break times in a sample of sixth-grade girls located in the area of Munich, Germany.

Methods

Participants

Cross-sectional data of 308 sixth-grade female students participating in assessment wave 2 of the CReActivity project, a school-based intervention study aiming to promote girls' PA by supporting autonomy, relatedness, and competence in physical education (Demetriou and Bachner 2019a), were analysed. Girls aged 9 to 14 years [11.6 (0.6) years], from 11 secondary schools (Realschule) located in the Munich area of Germany formed this sub-sample. The sample size reduced due to failure or loss of PA assessment devices or insufficient wear time (WT) of the devices, resulting in invalid PA measurements. Two full-time classes with 28 students were excluded from the analysis because of deviations in school hours and school routines in comparison to the usual half-day school system in Bavaria, which determines school lessons from 8:00 a.m. to 1:00 pm with slight deviations in the starting time of school between 7:50 a.m. and 8:10 a.m. and in the finishing time of school between 12:55 a.m. and 1:15 p.m. In total, 254 sixth-grade students provided valid data for this analysis (see Fig. 1).

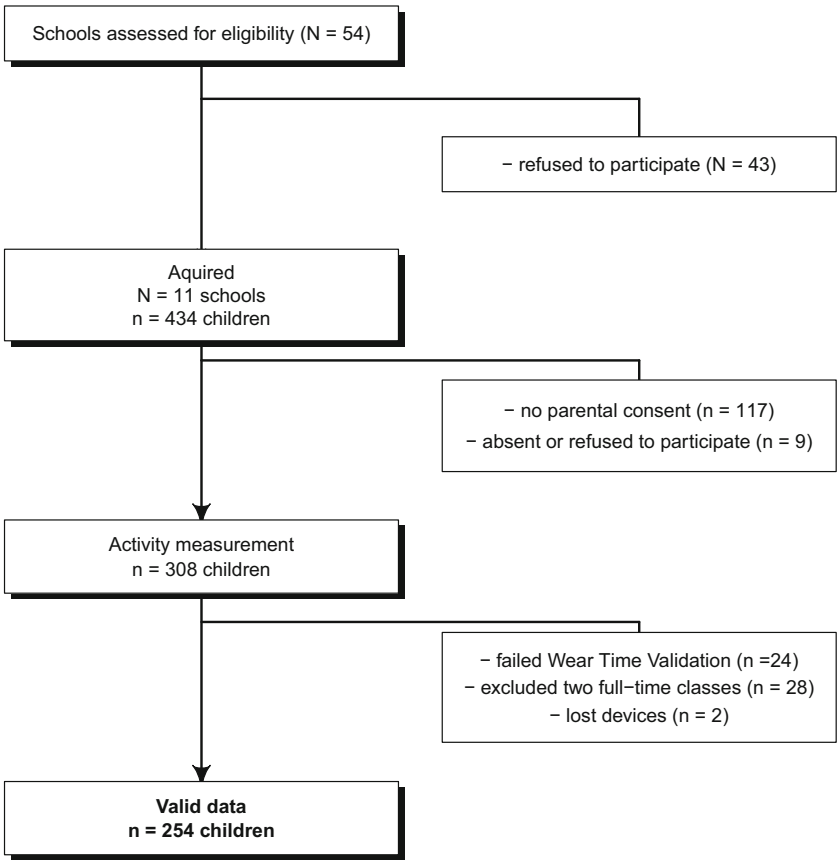

Fig. 1 Flowchart of activity measurement procedure for the CReActivity study wave 2

Measurements

Physical activity and sedentary time measurement

PA and ST were assessed using accelerometers (ActiGraph models GT3X – wGT3X-BT; Pensacola, FL, USA), which were attached on the right hip with an elastic belt. The participants were asked to wear the accelerometers for 7 consecutive days. On schooldays, students were advised to put on the devices in the morning after getting out of bed and wear them, except during water-based activities, until 9 p.m. or just before bedtime. Sampling rate was set to 30 Hz and has been described in detail previously (Demetriou and Bachner 2019b).

Commuting to school

Commute to school was assessed with two items, based on the validated MoMo-Physical Activity questionnaire (Schmidt et al. 2016). Two hundred and six of 278 participants answered the question "How do you usually get to school?" by marking one of the four possible answers: by foot, by bike, by public transport, by car. For the first two response options, the students were also requested to note down the number of minutes it took to get to school one-way, while for the third option only, the active walking time from home to station and from station to school was requested.

Procedure

The study was approved by the ethics commission of the Technical University of Munich, registered as 155/16S, and by the Ministry of Culture and Education of the state of Bavaria, Germany. Additionally, the school principals, parent's council, and the parents gave written informed consent to student's participation. A member of the research team explained how to put on the accelerometers and distributed the devices to all eligible students ($n = 308$) at the beginning of a school lesson. Afterwards, students completed the paper pencil questionnaire. After one week, the accelerometers were collected from the students (Demetriou and Bachner 2019b). The teachers reported morning breaks and school times of their classes. Data were collected in staggered time slots from October to December 2018.

Data analysis

After downloading the data from the device, vector magnitude counts from all three movement axes were calculated and pooled in 1-second epochs to describe the volatile activity behaviour of

children (Baquet et al. 2007). Participants' accelerometer-based data were considered as valid if recorded data on at least 3 schooldays with at least 8 hours of WT were available. The algorithm of Choi et al. (2011) was used for the compliance check, since it effects a reasonable compromise with regard to remaining sample size and loss of information (Demetriou and Bachner 2019b). The first and the last day of assessment were excluded from the analysis to counteract novelty, and the last day had never more than 8 hours WT (Kobel et al. 2017). Moreover, school holidays were extracted from analysis. Activity levels were analysed using the cut points described by Hänggi et al. (2013) to calculate the average duration of ST [< 180 counts per minute (cpm)], LPA (180–3360 cpm) and MVPA (≥ 3361 cpm). ActiLife v6.13.4 (ActiGraph 2019) was used for initialisation of accelerometers and the processing of the assessed data. In accordance with the aforementioned wearing guidelines, a school day was considered to be from 5 a.m. to 9 p.m., regular school time from 8 a.m. to 1 p.m. with respect to slight deviations, travel time 30 min before and after school time, and recess time as per the reported schedules of each class. PA analysis was considered for each individual separately for each time period. Descriptive statistics and illustrating graphs were performed using R (R Development Core Team 2008). The proportion of girls fulfilling the PA recommendations was determined (WHO 2011; Department of Health 2016; Institute of Medicine 2013).

Results

Applying the above-mentioned criteria, 91.3% of the sample provided valid PA and ST data ($n = 254$ of 278). Table 1 shows PA levels and ST of girls throughout different segments of the school day; 83.9% of girls fulfilled the global WHO guideline of 60 min MVPA per day. On a weekly average, the girls spent almost 80 (23.2) minutes per day in MVPA and 9.4 (1.2) hours in ST. During regular school time, those amounts decreased to 20.5 (8.2) minutes for MVPA and 3.8 (0.4) hours for ST daily. Mean duration of active travel time was 16.1 (12.0) minutes; therefore, 30 min before and after regular school time were assumed as travel time for students to and from school respectively. Including those time slots in the analysis, LPA level increased from 52.5 (15.0) to 68.0 (18.3) minutes and MVPA level from 20.5 (8.2) to 32.2 (10.6) minutes.

Figure 2 shows average activity behaviour during school time. ST is high during lesson times, while higher amounts of MVPA and LPA before and after school time as well as in recess are recognisable. A detailed evaluation of break times showed that the morning breaks took place in two time slots from 09:20–10:00 a.m. and 11:10–11:45 a.m., with a duration of 10 to 20 min. While break 1 had a mean of 17.4 (3.7) minutes, break 2 was on average 18.0 (2.5) minutes long. Girls spent 46.6% of their recess time being sedentary (see Fig. 3). Combining both break times [35.4 (4.5) minutes], girls spent 17.8% of their average break in MVPA. Those 6.3 (3.2) minutes in MVPA accounted for an average of 8.0% of daily MVPA. Also shown in Table 2, the majority of participants did not meet the guidelines for MVPA during school times (Department of Health 2016; Institute of Medicine 2013).

Discussion

This study provides an overview of device-based assessed PA levels and ST of sixth-grade girls during different segments of the school day. The results underpin the assumption that school plays an important role in PA engagement on a regular weekday, and in particular that the commute to and from school and morning breaks are key sources for school-related PA. ST was most prevalent during lesson hours, but also accounted for the largest proportion of recess time.

Within a day, 60 min of MVPA are required to fulfill the global recommendation (WHO 2011). The results suggest that the majority of girls in this study sample are being more active than the WHO recommends. Demetriou and Bachner (2019b) analysed the activity of sixth-grade girls in southern Germany ($n = 482$), including the CReActivity sample, and stated that 90% of the girls fulfill the WHO recommendation. As mentioned before, analysis methods were similar to this analysis; both used

Table 1 ST and PA behaviour in minutes [mean (standard deviation)] throughout the school day and during different segments of the school day

	School day (5 a.m.–9 p.m.)	Regular school time + travel time	Regular school time[a] (8 a.m.–1 p.m.)	Recess
ST/day	561.93 (70.56)	255.09 (34.68)	226.95 (25.83)	16.50 (6.16)
LPA/day	152.82 (33.82)	68.04 (18.32)	52.46 (14.95)	11.10 (4.01)
MVPA/day	79.94 (23.23)	32.17 (10.59)	20.49 (8.24)	6.29 (3.21)
VMCPM	767. 05 (215.24)	667.14 (209. 84)	544.36 (216.81)	1400.84 (687.83)
WT/day	794.69 (75.42)	355.41 (38.39)	299.98 (23.68)	33.90 (3.86)

ST sedentary time, *LPA* light physical activity, *MVPA* moderate to vigorous physical activity, *VMCPM* vector magnitude counts per min, *WT* wear time on valid days

[a] including recess

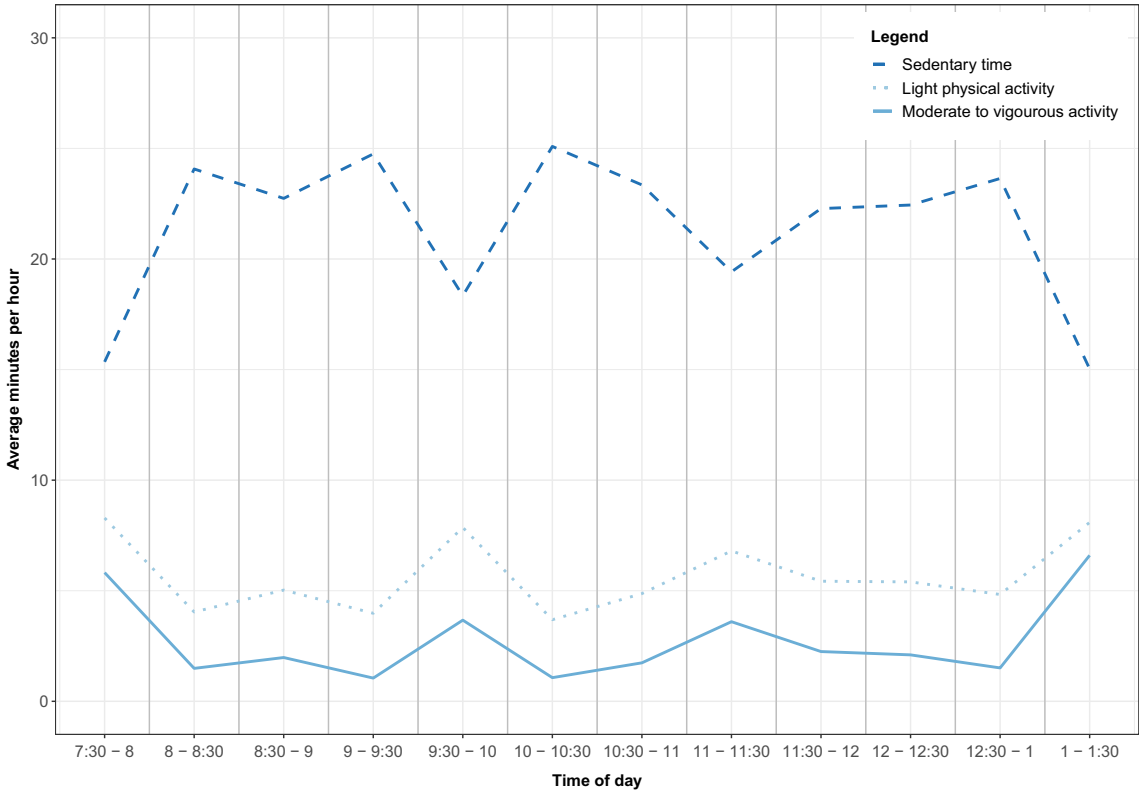

Fig. 2 Activity behaviour during school time

the relatively high cut-off points of Hänggi et al. (2013), and showed that the proportion of students fulfilling the WHO recommendation is large. However, Troiano et al. (2014) stated that the comparison of these guidelines with device-based assessed data has to be interpreted carefully, because the WHO guidelines were developed on the basis of self-reported PA behaviour (Troiano et al. 2014), and both measurement methods could over- or underestimate PA and ST due to varieties in validity. Furthermore, results of accelerometry data depend on the methodological decisions made under consideration of age, gender, and setting (Guinhouya et al. 2013). Although Migueles et al. (2017) provide good indications, a best practice to process and analyse such data is not yet available. However, the comparison of outcomes with other studies is limited, because of the scientific

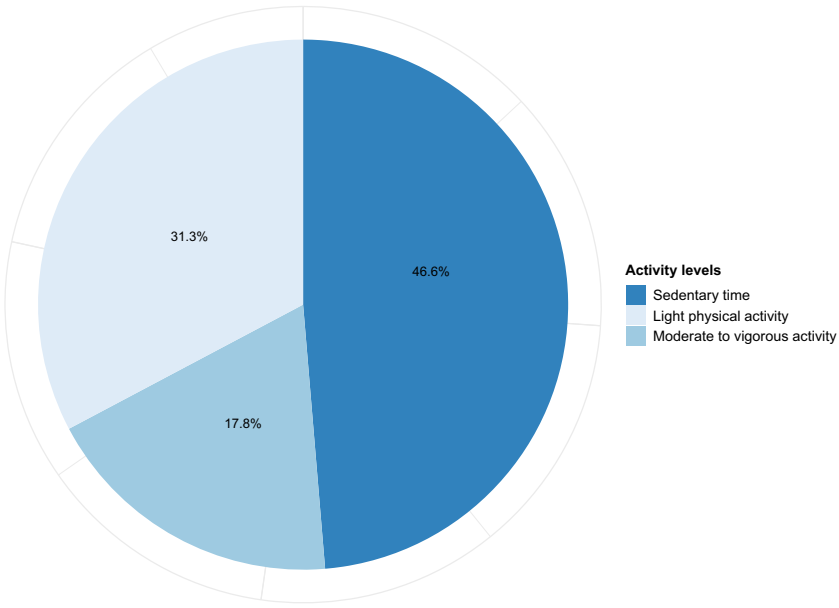

Fig. 3 Activity behaviour during recess

Table 2 Proportion of girls fulfilling global guidelines for MVPA during school hours and recess

Guideline	Time	Proportion	Reference
≥ 30 min MVPA	Regular school time	11.02%	Institute of Medicine (2013), Department of Health (2016)
≥ 60 min MVPA	School day	83.86%	WHO (2011)
≥ 40% of recess in MVPA	Morning break times combined	2.76%	Ridgers et al. (2005)

MVPA moderate to vigorous physical activity, *WHO* World Health Organization

decisions on processing the data (Guinhouya et al. 2013), and are not the subject of this discussion. Instead, we refer to Demetriou and Bachner (2019b) and continue with the results regarding PA during school time and recess.

Further, there is the possibility that the MVPA recommendations of 30 min during school time in the USA and UK (Department of Health 2016; Institute of Medicine 2013), may not be applicable to the half-day school systems in Germany. Since there is no national recommendation available for MVPA during school time, this recommendation was used as a reference point. The obvious difference in MVPA during school time between Bailey's et al. (2012) full-time students and the students in this sample implies discrepancies in their daily activity behaviour. In this study, girls' school time accounted for an average of 20.5 min of MVPA, which is one quarter of their daily MVPA. In comparison to longer school times, the sample of Bailey et al. (2012) accrued 35.3% of their daily MVPA in school. In both studies, the majority of daily MVPA was accumulated outside school hours, of which a considerable share is still school-related. One should consider that travel to school contributes to the daily MVPA level with 10% (Bailey et al. 2012), 14% (Smith et al. 2016), and 15% in this study sample. Hence, school travel is an opportunity for all pupils to be physically active during the school day, but within daily school life PA levels are negatively influenced by another distinct health factor (Thivel et al. 2018; Tremblay et al. 2011b).

Moreover, three-quarters of school time was spent in ST. As other studies have shown, the school setting accounts for high ST (Bailey et al. 2012; Smith et al. 2016; Sprengeler et al. 2017), and girls in this study spent 3 h and 30 min sedentary during lesson hours. Huber and Köppel (2017) reported even 4.9 h of school-related ST across all grades. Evidently, school-related sitting is dominant (Demetriou et al. 2019), but also leisure time accounts for additional ST, with the result that 9.4 h in this sample and 10.6 h in Huber and Köppels' (2017) sample of 4- to 20-year-olds were spent in a sedentary position. Referring to Hoffmann et al. (2017), sample primary students are less sedentary, with 3.7 h ST on schooldays than secondary female students in UK, with 6.2 h ST (Bailey et al. 2012). Self-reported data of numerous studies hold media consumption (e.g., screen time) to be accountable for high SB (Manz et al. 2014; Bucksch and Dreger 2014; Konstabel et al. 2014). This clearly illustrates the indistinctive terminologies with regard to SB in literature (Graf et al. 2014). But in summary, it can be said that school should educate students towards an active healthy lifestyle and a meaningful and responsible handling of media to overcome sedentariness (Strasburger 2010).

The data indicate that this task could be accomplished. Girls spent more than 40 min of lesson hours in LPA. This shows that during regular lessons at least light activities can be performed, e.g., walking to the next classroom in transition times, or by means of active teaching methods. However, ST was high during lesson time and it seems that most of the girls do not compensate for this by an intense activity during break time. Not even 3% of the sample meet the MVPA guideline for break times (Ridgers et al. 2005). Girls of this study accrued more than 6 min in MVPA during break times, which is less than 18% of the average break time. In comparison, primary school girls in Germany spent an average of 20.4% of their break times in MVPA (Kobel et al. 2015). In accordance with previous research, the guideline of 40% of MVPA during break times appears to be a high threshold for girls. In the UK, 28.2% of 10–14-year-old girls (Bailey et al. 2012), and only 4.3% in a sample of younger girls met the guideline.

In order to understand these low MVPA levels future research should incorporate social and individual factors, such as social support and individual motivational attitudes towards PA. Equivalent to 3–6 METs, MVPA causes rapid breathing and substantial increase in heart rate (Thivel et al. 2018); and therefore, after occurrence of thermoregulatory processes, perspiration. This could be a reason for adolescent girls to engage less in exhausting and intensive activities during recess, because they do not want to attend class with wet or dirty clothes afterwards. The result is a high proportion of ST (46.6%) and LPA (31.3%) during recess which is consistent with findings of other studies, with 52.9% in ST and 39.4% in LPA respectively (Ridgers et al. 2013). In comparison to lesson time, the girls are more active during recess and accumulate 8% of daily MVPA, which is similar to findings from other studies (Kobel et al. 2017; Bailey et al. 2012), but amounts of low PA and ST are too high in both segments.

Reduced sitting time would diminish the salient amounts of SB during school time, and comes along with increased PA levels. Facing the aforementioned reasons of low MVPA levels of girls during school time, it could be a future objective of interventions to target the incorporation of low-intensity activities, such as standing, walking, etc., in non-PE classes, to increase the LPA amounts of girls during lesson time as well as in recess to accomplish the national and global recommendations for PA

(Pfeifer and Rütten 2017; WHO 2011). Therefore, classroom teachers should be provided with class-related material and knowledge to enhance the active interruption of long ST periods and to diminish the total ST of children.

The major strength of this study is the detailed insight into device-based assessed PA and ST behaviour during school time of secondary school girls. As the second of its type in Germany, this study expands the status quo of PA and ST of students due to its detailed analysis of a large sample size and the disclosure of methodological decisions, which establishes a foundation for further investigations in the school setting.

This study has several limitations. Mediating factors of PA and ST, such as seasonal variability and environmental factors, were not considered in the analysis. Although studies showed that seasonal effects were not seen as important factor for PA during recess (Ridgers et al. 2006), a weather-related effect could have influenced the girls' PA engagement during the school day, since assessments were conducted in autumn and beginning of winter (Atkin et al. 2016). Cleary evident is the association of body weight with PA (Kobel et al. 2015), but anthropometric data were assessed later during the study and were not available for this analysis. For unstructured times, such as recess, travel time and leisure time, no further information was given about contextual factors, such as school route, school environment, and neighborhood. Furthermore, school policies and characteristics, such as active breaks and activity-supportive profiles were not controlled for. Schoolyard size was not determined, yet several studies showed inconclusive results with regard to the effects of playground size on PA behaviour during recess (Kobel et al. 2015). Because girls were monitored by an accelerometer, it is possible that they behaved more actively as usual during wearing periods.

Conclusion

The findings of this study provide further insight into a girl's PA behaviour during a regular weekday by providing detailed information on PA levels and ST during regular school time, the travel to school, and school break times. The results with regard to the fulfillment of global activity guidelines reinforce the need of two important issues: a) a consistent procedure for processing and analysis of accelerometer data, and b) national guidelines for PA and ST during school time. Mentioning this, it will be the task for researchers to raise teachers' and pupils' awareness towards the idea that school is not only an academic institution but also an activity environment.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical statement This material is the authors' own original work, which has not been previously published elsewhere. The paper is not currently being considered for publication elsewhere. The paper reflects the authors' own research and analysis in a truthful and complete manner. The paper properly credits the meaningful contributions of co-authors and co-researchers. The results are appropriately placed in the context of prior and existing research. All sources used are properly disclosed (correct citation). All authors have been personally and actively involved in substantial work leading to the paper, and will take public responsibility for its content.

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4.2 Publication 2

Authors: David J. Sturm, Joachim Bachner, Stephan Haug, & Yolanda Demetriou

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Summary: The self-determination theory provides a framework to understand behavioral changes in educational settings. To identify the complex mechanism of behavioral changes in physical activity valid measurement tools are needed, which specifically address the students as recipients of the motivational instructions by PE teachers. The objective of this article was to validate the translated and adapted version of the 12-item scale for satisfaction of the Basic Psychological Need Satisfaction and Frustration Scale by B. Chen et al. (2015) using a MCFA. Based on cross-sectional data of 481 students, results speak in favor of a three-factor model at both levels with eleven items showing acceptable fit and significant factor loadings at the student level as well as at the class level. Significant correlations with physical activity, indicating good criterion validity and acceptable internal consistencies, could be computed at both levels. Further application to different genders and age groups would broaden the robustness of the scale.

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collected the data and chose the methods for the analysis, which was conducted with the support of Stephan Haug and Joachim Bachner. David Sturm used the MCFA procedure to validate the first German scale for need satisfaction in PE. He wrote the published article under consideration of feedback by all co-authors.

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Article

The German Basic Psychological Needs Satisfaction in Physical Education Scale: Adaption and Multilevel Validation in a Sample of Sixth-Grade Girls

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Abstract: (1) Background: Self-determination theory (SDT) claims that need supportive behavior is related to the satisfaction of the basic psychological needs: autonomy, relatedness and competence. The student–teacher relationship is of special interest to understand mechanisms of physical activity behavior change in physical education (PE). (2) Methods: In this cross-sectional study, 481 girls answered a German version of the Basic Psychological Need Satisfaction (BPNS) in PE Scale. Contrary to previous studies, the psychometric properties of this scale were examined by multilevel confirmatory factor analysis. (3) Results: A model with three latent factors on both levels showed acceptable fit and all items showed significant factor loadings. Although one item was excluded due to psychometric reasons, the scale showed good internal consistencies; α = 0.85 at the individual level and α = 0.84 at the class level. Subscales' internal consistency at the individual levels was good, while at class level, the scores differed from poor to good. Small significant correlations of BPNS with moderate to vigorous physical activity support criterion validity. (4) Conclusion: The 11-item scale is a valid measurement tool to assess BPNS in PE and further application in the school setting would broaden the insights into the psychological impacts of SDT in PE.

Keywords: self-determination theory; basic psychological need satisfaction; questionnaire; multilevel validation; physical activity; questionnaire

1. Introduction

Numerous studies have pointed out the insufficient physical activity (PA) levels of children and adolescents in industrialized countries [1–4]. In light of the long-term consequences of physical inactivity, the World Health Organization (WHO) [5] predicts a generation of people suffering from chronic diseases all of which often exacerbated by too little PA. In Germany, there is a marked difference between actual and target conditions of PA, which is significantly more distinct for girls with a low socioeconomic status (SES), especially in the age group between 14 and 17 years [2]. Programs that promote children's and adolescents' PA are needed from an early age on [6]. The school setting provides the opportunity to implement appropriate programs [7], since every child and adolescent, independent of age and SES, is necessarily involved in activities embedded in the curriculum. Physical education (PE) teachers are well suited to motivate and educate children in adopting an active and healthy lifestyle, but how this support works in practice is in need of clearer definition in the context of PE.

Clearly, we must also consider the environmental factors and individual circumstances which influence PA behavior [8]. Initially, the environment must provide an opportunity and motivational processes must be triggered so that the individual engages in PA. A sub-theory of the self-determination theory (SDT) explains the types of motivation. The organismic integration theory differentiates the degree of behavior regulation on a self-determination continuum, ranging from amotivation to intrinsic motivation (see Figure 1) [9]. Total lack of motivation characterizes amotivation. At the level of external regulation, the individual acts completely heteronomously, influenced by external interventions, such as reward and punishment. In this sense, an individual shows controlled extrinsic motivation, which includes also introjected regulation. Characterized by a successive increase of autonomy, the identified and integrated regulation accounts for autonomous forms of extrinsic motivation. Ultimately, intrinsic motivation is characterized by the most autonomous behavior activated by individual volition, personal interest or an exciting challenge [9].

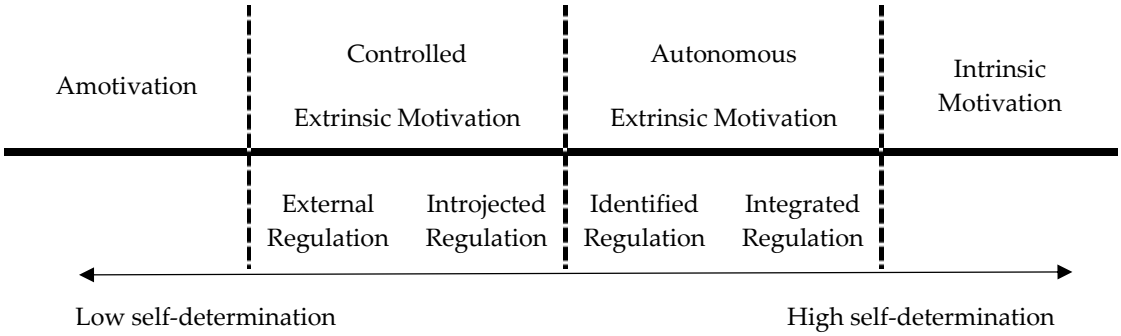

Figure 1. The self-determination continuum [10].

According to SDT, every individual has the natural, constructive tendency to interact with other individuals in their environment, to act effectively in this milieu and experience themselves as proactive and autonomous [9]. The three basic psychological needs (BPN) autonomy, competence and relatedness derive therefrom. Philosophical definitions of autonomy do not necessarily equate it with an individual's independence from their (social) environment. The preferred definition of autonomy is based on Ryan and Deci [9], i.e., if a person conforms to the stimuli and norms of their environment, they will likely adjust their own behavior to it voluntarily. Relatedness consists in the desire to feel connected with others, integrated and accepted as a member of the community. This belongingness is characterized by the recognition and positive value accorded to the related social environment [9]. The need for competenc*e* is defined as the subjective certainty that one can meet challenges in different situations based on one's own competence [9].

In the context of PE, researchers have proven the positive correlations between support and satisfaction of BPN [11,12], which was recently underlined by a meta-analysis by Vasconcellos et al. [10]. BPN satisfaction (BPNS) in turn leads to autonomous forms of motivation [13]. For adolescents in particular, these types of motivation have been shown to be determinant in promoting PA behavior [14,15]. A closer look into the relations of BPNS and PA-related constructs reveals unambiguous results. In their systematic review, Teixeira et al. [16] claim that competence satisfaction in the school setting predicts more exercise participation across all ages. An experiment in PE context by Hagger et al. evinced the direct influence of perceived autonomy support towards leisure time PA [17]. Moreover, perceptions of relatedness, autonomy and competence serve as motivational predictor towards PA for adolescents [18].

In order to evaluate these theoretical considerations and to establish the SDT in a domain-specific sample, instruments to assess the BPNS are mandatory. Based on the original Basic Psychological Need Satisfaction and Frustration Scale (BPNSFS), several scales were developed by adapting them to specific criteria of domain, language and age. A confirmatory factor analysis (CFA) of the original 24 items by Chen et al. exhibited a good fit for a hypothesized 6-factor model, assuming separate dimensions for satisfaction and frustration for each of the three needs [19]. Internal consistencies of the satisfaction subscales of the three needs were at $\alpha = 0.81$ and above. Haerens et

al. validated the scale in a sample of Dutch-speaking students in the context of PE and established the hypothesized three-factor structure on both dimensions, showing good internal consistencies of $\alpha = 0.87$ for the satisfaction subscale [20].

Given our focus on the satisfaction of the three innate psychological needs, the entire BPNSFS was not appropriate for the incorporation in a comprehensive questionnaire. Furthermore, negative need fulfillment has been pointed out as a distinct dimension, which justifies in light of adverse health outcomes a separate investigation [19,20]. Besides, two scales assessing the BPNS are relevant in the sports context. The Psychological Need Satisfaction in Exercise Scale [21] and the Basic Psychological Need Satisfaction Scale in Exercise [22], of which the latter one was validated and adapted for the PE context in Greek [23]. Containing 12 items, the BPNS-PE supported a three-factor structure and had high internal consistencies, which was recently confirmed by CFA in a Spanish [24] and English sample in PE [25]. Trigueros et al. examined an adequate fit for a four-factor solution of the Spanish Scale of the Satisfaction of Psychological Needs in Physical Education [26], including a fourth subscale to assess the newly introduced need of novelty [27], and estimated an acceptable reliability by Cronbach's alpha of $\alpha > 0.70$.

One limitation of previous validations derives by using CFA for data assessed in the school setting, since students are clustered in classes. Ignoring the clustered nature of data could lead to biased estimates and misinterpretations, since already small intercorrelations have an impact on model estimates and variances [28]. Furthermore, Haerens et al. provided indications that the need satisfaction had a significant variance on the class level by a multilevel analysis of their intervention effects [20]. Consequently, it is recommended to account for the clustered data structure by using a multilevel CFA (MCFA) [29].

As educational policy is a matter of the respective federal states in Germany, the curriculum differs between states. In secondary schools in Bavaria, two PE lessons (each 45 min) per week are mandatory at class stages 5 to 10. A male or female PE teacher carries out the gender-separated PE lessons, respectively. Girls represent a specific risk group regarding the effects of age, gender and SES on PA [2]. Therefore, single-sex interventions are necessary in order to meet the needs and interests of girls.

To date, no measurement instrument exists that is rigorously validated to examine the BPNS of German-speaking adolescents within the PE context. Questionnaires are needed that are specifically designed for adolescents by addressing their stage of development and language. The purpose of the study is to provide initial evidence of reliability and validity of scores derived by the German Basic Psychological Need Satisfaction in Physical Education Scale (GBPNS-PE). According to Huang's MCFA approach [30], the factor structure and scale dimensionality of the GBPNS-PE were examined as well as the criterion validity in relation to device-based assessed PA by basic multilevel analysis. Moreover, internal consistencies were estimated for the individual (within) and the group (between) level.

2. Materials and Methods

2.1. Participants

The sample derived from the single-sex intervention study CReActivity, which aimed to promote PA especially for girls [31]. We sampled 507 girls (aged 11.61 ± 0.55, range: 9 to 14) from 33 all-girl PE classes of the sixth grade from secondary schools (Realschule) in the area of Munich, Germany. Twenty-six students were excluded from the analysis due to missing values.

2.2. Measures

2.2.1. Basic Psychological Needs Satisfaction

The BPNS in PE was assessed by an adapted and translated version of the BPNSFS by Chen et al. [19]. Two English-speaking researchers translated the 12 satisfaction items into German independently and discussed differences between the two versions. For the purpose of the present

study, we adjusted the scale by adding the stem "Im Sportunterricht…" ("In PE lessons…") at the top of the questionnaire and adapted towards age-appropriate style and language. In this case, the recommended back-translation technique was not beneficial. Therefore, the scale was pilot tested with the pretest procedure. Consisting of three subscales with four items each, the scale surveys the satisfaction of autonomy, competence and relatedness. Items were rated on a 5-point Likert scale representing the level of agreement with the statements from 1 (completely disagree) to 5 (completely agree).

2.2.2. Physical Activity

PA was assessed by accelerometry. Participants wore an ActiGraph GT3X or GT3X-BT (see Figure 2) for seven consecutive days except during water-based activities on their right hip. Participants had to put on the device after getting up, until nine pm or until they went to bed. Sampling rate was set to 30 Hz or 10 s for the older devices, respectively. ActiLife was used to initialize the devices and download the data [32]. A participant was included in the PA analysis if she achieved a valid wear time of at least 4 days with 8 hours wear time, of which one day was on the weekend. Data were observed during a period from five a.m. to nine p.m. Average duration of moderate-to-vigorous physical activities (MVPA) was analyzed using the cut points (≥3361 cpm) by Hänggi et al. [33]. Further details are described in Demetriou and Bachner's work [34].

Figure 2. Students wore the ActiGraph GT3X-BT on the right hip attached with an elastic belt.

2.2.3. Socio-Economic Status

Participants reported parents' occupations and job description. A trained committee of four student research assistants coded the written answers according to the International Standard Classification of Occupation 2008 (ISCO-08). After revision by two researchers, open conflicts were solved and coded under consideration of the International Socio-Economic Index (ISEI) score [35].

2.2.4. Age and Anthropometric Measures

Participants reported birth date before a research assistant assessed anthropometric data using a weight scale and stadiometer.

2.3. Procedures

The assessments were conducted at the beginning of the PE lessons. Individual codes ensured the anonymity of the participants. With regard to a previously defined protocol, research employees gave instructions to fill out the questionnaire and supervised the pupils during process time in order

to answer any questions about the questionnaire without disturbing the other students. The PE class started after the research employee collected all completed questionnaires.

2.3.1. Recruitment Procedure

The Ethics Committee of the Technical University of Munich in Germany approved the study, registered with 155/16S. Principals and parents councils approved the assessments in schools. Parents or legal guardians as well as children gave written informed consent to participate in the study.

2.3.2. Statistical Analysis

Taking into account the clustered nature of the sample, we considered Huang's [30] multilevel approach to analyze the data. Based on Hox' five MCFA steps [29], Huang [30] provides the R code [36] to analyze the individual (named level 1 or within-group level) and the group level (named level 2 or between-group level) simultaneously, using the lavaan package [37].

Firstly, an adjusted single-level CFA was conducted under consideration of the pooled within-group covariance matrix instead of the total covariance matrix. In a second step, we specified the null model, ergo the factor structure of step 1 on both levels, using the pooled within- and the between-group covariance matrices. Here, we constrained equal factor loadings, variances and covariances for every manifest variable and latent factor. Thirdly, we incorporated new group-level latent variables with denial to covary in the so-called independence model, to estimate the variance at group level. In step 4, we reversed the denial and used all degrees of freedom at the between-group level to create a fully saturated model. As a last step, we specified the actually hypothesized models. Initially, including one latent factor to the between-group level ensured the correlation of the latent group-level factors [30].

In addition, exploring the scale dimensionality justifies model structures with one or three latent factors at level 2. Some estimated residual variances for the random intercepts at level 2 were negative but also close to zero. These variances were fixed to zero to allow the model to converge and find admissible solutions. This procedure is justified due to the small sample size at level 2 and intraclass correlations (ICCs) close to zero [29].

Several fit indices were adduced to evaluate the goodness of fit for the model, since all of them have limitations regarded separately [38]: the χ^2 likelihood ratio statistic, the comparative fit index (CFI) [39], the Tucker–Lewis index (TLI), the root mean square error of approximation (RMSEA) and its associated 90% confidence interval [40], and the standardized root mean square residual (SRMR). Hu and Bentler's reference work was applied to judge fit indices [41]. Thereby, CFI and TLI values greater than 0.95, RMSEA and SRMR values less than 0.08, support a good model fit [41]. For comparison of alternative models, the Akaike information criterion [42] was applied, which indicates better fitting models by smaller values.

Reliability scores for the scales at both levels respectively were calculated by the alpha function from the psych package [43]. Since the estimated pooled within the matrix was not positive definite, we computed the nearest positive definite matrix, using function nearDP from the Matrix package [44], to avoid miscalculated alpha scores. Correlations on both levels were investigated to analyze the contributions of each subscale predicting MVPA, using the statsBy function from the psych package [43]. Correlations of SES, body mass index (BMI) and age were controlled by using the rcorr function by the Hmisc package [45]. Whether missings were completely at random (MCAR) was investigated by using the Little's MCAR test [46] executed by the LittleMCAR function from the BaylorEdPsych package [47]. A two-sided significance level of <0.05 was set for all analysis.

3. Results

Proportion of missing values from 1.04% to 2.50% and Little's MCAR test ($\chi^2 = 259.12$, df = 310, $p = 0.99$) support that the missings are completely at random [46]. The average BMI value of 19.49 (±3.68, interquartile range (IQR) = 4.68, $N = 386$) kg/m² reflects a normal-weight sample. Responses of students whose height and weight were measured did not differ significantly from students, both

apparently overweight and normal-weight girls, which refused to be weighed. Participants come from households with an average SES of 49.80 (±15.96, median = 48, IQR = 25.00, *N* = 412).

Table 1 shows descriptive statistics of all German items, including an explanatory back-translation to English. Items' means ranged from 3.02 (±1.01) to 4.18 (±0.95). Average standard deviation is 1.03. Skewness and kurtosis values were low to moderate. ICCs vary from zero to 0.21 with an average of 0.04 (SD = 0.07; median = 0.011). We set three negative ICCs to zero, since the ICC should vary between 0 and 1 by definition:

$$= (\ _B^2 + \ _W^2)^{-1} \ _B^2, \quad (1)$$

where Σ_W^2 represents the within-group variance. Because the between-group variance Σ_B^2 is estimated by a scaled difference between two diagonal entries of two empirical covariance matrices (the empirical within- and between-covariance matrices), it does not have to be positive for any sample size. Here, the estimated within-variance is larger than the estimated between-variance and led to negative ICCs.

Firstly, we evaluated the fitted models of the 12-items scale that converged to an admissible solution. In all models, item R4 had the lowest factor loadings. In addition, the distribution of the item was right-skewed, which contradicts the assumption of the model. Inspection of the item explained the right-skewness due to social desirability. Therefore, we removed R4.

Table 1. Descriptive statistics for the items of the German Basic Psychological Need Satisfaction in Physical Education Scale.

Items	M	SD	Skewness	Kurtosis	ICC
Autonomy (Composite Reliability: 4 items = 0.78)					
A1: …können wir uns regelmäßig aussuchen, was wir machen möchten. (…we can regularly choose what we like to do.)	3.02	1.01	0.17	−0.01	0.219
A2: …machen wir häufig genau das, was ich wirklich machen will. (…we often do exactly what I really like to do.)	3.06	1.06	0.03	−0.47	0.059
A3: …lerne ich Sportarten, die wirklich gut zu mir passen. (…I learn sports, which really suit me.)	3.55	1.17	-0.32	−0.74	0.060
A4: …machen wir häufig das, was mich wirklich interessiert. (…we often do what really interests me.)	3.29	1.05	-0.09	−0.44	0.103
Relatedness (Composite Reliability: 3 items = 0.79)					
R1: …habe ich das Gefühl, dass die Klassenkameradinnen, die ich mag, auch mich mögen. (…I have the feeling the classmates that I like, also like me.)	4.04	1.00	−0.86	0.17	0.011
R2: …fühle ich mich mit den Klassenkameradinnen verbunden, die mich mögen und die ich auch mag. (…I feel connected with the classmates that like me and I like.)	3.88	1.05	−0.67	−0.25	0 **
R3: …fühle ich mich mit Klassenkameraden verbunden, die mir wichtig sind. (…I feel connected with the classmates who are important to me.)	3.97	1.07	−0.88	0.11	0 **
R4 *: …verstehe ich mich mit meinen Klassenkameradinnen sehr gut. (…I get along with my classmates very well.)	4.18	0.95	−0.98	0.42	-
Competence (Composite Reliability: 4 items = 0.85)					
C1: …bin ich gut. (…I am good.)	3.87	0.95	−0.48	−0.31	0.004
C2: …fühle ich mich talentiert. (…I feel talented.)	3.28	1.12	−0.25	−0.53	0 **
C3: …schaffe ich das, was ich mir vorgenommen habe. (…I can achieve what I aimed for.)	3.68	1.00	−0.36	−0.31	0.023
C4: …kann ich auch schwierige Aufgaben meistern. (…I can master difficult tasks.)	3.66	0.98	−0.28	−0.31	0.006

Note: *N* = 481; M = Mean; SD = standard deviation; ICC = intraclass correlation; * excluded in reduced scale ** per definition.

In the following, we only report the analysis of the reduced scale because even the best model fit of the 12-item scale did not pass the cut-point criteria comprehensively [41]. Table 2 represents the fit indices for the five steps, including three hypothesized models that converged to an admissible solution fitted to the reduced scale data.

Representing step 1, the level one model with three factors at a single-level showed acceptable fit indices, except of the TLI, which is below 0.95. Poor fit of the null model allowed the tentative assumption that there might be a between-group variance. In addition, the independence model did not fit well. Meaning, that there might be a substantively interesting structural model and a substantial group-level variance. Resulting fits of the saturated model are, except CFI, quite poor. Since we can rule out any error, this indicates that the initial fit in step 1 was too poor. Nonetheless, we were interested in modeling the relationships at level 2 and legitimized the further MCFA due to the fact that Muthén et al. forwent the preliminary steps 2, 3 and 4 by Huang [30] in his MCFA procedure [18]. Moreover, "even slight departures [of the ICC] from zero can signify that the multilevel nature of data should be accounted for" [28] (p. 8).

Model A has moderate CFI, TLI and a RMSEA close to the reference cut-point, but SRMR of 0.12 is clearly out of bounds. Model B did not meet the criteria for acceptable model fit, since TLI is below 0.90 and RMSEA higher than 0.08. The reduced scale fitted Model C well. CFI and TLI are close to the cut point of 0.95, RMSEA is below 0.08, although the 90% confidence interval exceeds 0.09, as well as the SRMR value is way below 0.08. Chi-square difference tests revealed a significant preeminence of Model C.

Table 2. Summary of the goodness of fit indices.

Fit index	Step 1	Step 2	Step 3	Step 4	Step 5		
	Level one model: three factors at single level	Null model	Independence model	Saturated model	A: Three factors on level 1, one factor on level 2, nested	B: Three factors on level 1, one factor on level 2, not nested	C: Three factors on both levels, not nested
Short Scale (11 items)							
χ^2	124.159	273.515	244.328	142.171	209.600	253.129	186.377
df	41	107	97	42	86	87	82
χ^2/df	3.03	2.56	2.51	3.38	2.44	2.91	2.27
CFI	0.954	0.918	0.927	0.950	0.939	0.918	0.948
TLI	0.939	0.915	0.917	0.870	0.922	0.896	0.931
RMSEA	0.071	0.085	0.084	0.105	0.081	0.094	0.077
90% conf	0.057–0.86	0.072–0.97	0.071–0.097	0.086–0.124	0.068–0.096	0.081–0.107	0.062–0.091
SRMR	0.054	0.091	0.136	0.104	0.119	0.065	0.058
AIC	11,021.06	12,058.25	12,049.06	12,056.90	12,036.33	12,077.86	12,021.11

Note: df = degrees of freedom; CFI = comparative fit index; TLI = Tucker–Lewis index; RMSEA = root mean square error of approximation; conf = confidence interval; SRMR = standardized root mean square residual; AIC = Akaike's information criterion.

Models with freely estimated loadings, variances and covariances did not converge to a solution for all tested factor structures. A model of type B with equality constraints for the within- and the between-group level, meaning that the same estimates are used at level 1 and 2, did not yield any admissible solution, since negative residual variances remained although variances were set to zero. A model of type C with a nested model structure, which means that the measurement model of level 1 is also included at level 2, revealed acceptable goodness of fit but most factor loadings were not significant and some loadings and covariances were not computed due to negative residual variances.

Table 3 presents standardized factor loadings and correlations of latent factors for the supported Model C. Factor loadings were significant and ranged from 0.54 to 0.90 at individual level and from 0.64 to 0.96 at class level. Significant correlates between factors vary from 0.37 to 0.60. Small non-significant correlations at the between level between factors appeared.

Table 3. Completely standardized factor loadings and correlations of latent factors for Model C: Three factors at level 1 and three factors at level 2, not nested.

		Level 1 (Individuals)			Level 2 (Classes)		
Factor	**Item**	**F1**	**F2**	**F3**	**F1**	**F2**	**F3**
Autonomy	A1	0.538			0.809		
	A2	0.720			0.904		
	A3	0.633			0.880		
	A4	0.871			0.961		
Relatedness	R1		0.587			0.644	
	R2		0.896			0.957	
	R3		0.773			0.670	
Competence	C1			0.847			0.890
	C2			0.801			0.942
	C3			0.677			0.920
	C4			0.765			0.876
Cor(F1,F2)			0.366			0.199 [a]	
Cor(F1,F3)			0.595			0.561	
Cor(F2,F3)			0.416			0.413 [a]	

[a] Note: All loadings were significant at $p < 0.05$, except marked with.

Reliability scores for the subscales at level 1 were adequate to good, ranging from 0.78 to 0.85 (see Table 1). At level 2, the subscales differ in reliability. At class level, an adequate score, $\alpha = 0.79$, for relatedness and excellent score, $\alpha = 0.95$, for autonomy could be derived, however, competence subscale drops off to $\alpha = 0.18$. Problematic items such as R3 and C3 correlate with the subscale negatively and were reversed automatically. Composite reliability for the total scale was $\alpha = 0.85$ at the individuals level and $\alpha = 0.84$ at the class level.

On average, girls spent 80.44 (±21.01) minutes in MVPA per day ($N = 374$). Small significant correlations with device-based assessed MVPA can be evinced at level 1 with 481 individuals. While correlations of autonomy and competence subscale were significant by 0.13 ($p = 0.01$) and 0.19 ($p > 0$) respectively, there was no significant correlation of MVPA with the relatedness subscale (r = 0.03, $p = 0.51$). At group level ($n = 33$), the subscales competence, by 0.28 ($p = 0.12$), and relatedness, by 0.25 ($p = 0.16$), showed smaller non-significant correlations while autonomy correlated significantly by 0.38 ($p = 0.03$). There was no significant correlation between SES and MVPA ($\rho = 0.06$, $p = 0.26$), while BMI and age showed a negligible significant correlation of r = −0.14 ($p < 0.01$) and r = −0.16 ($p < 0.01$), respectively.

4. Discussion

Low levels of PA and high sedentary time of children and adolescents in industrialized countries reveal the need to understand motivational tendencies and behavior in order to increase the number of effective and economic interventions promoting PA in all stages of life. One auspicious approach is set by the solid theoretical foundation of SDT, already applied in several contexts and domains [9]. Specifically, BPN-supportive elements in PE increase students' BPNS and in a further step, PA [48]. The evaluation of those mechanisms of PA behavior change is in need of validated measurement tools for specific contexts and samples.

This study validated the GBPNS-PE. In detail, indices for factor structure, internal consistency and criterion validity as well as scale dimensionality were determined. Considering the clustered data structure, we conducted a MCFA. Occurrence of inconclusive fit indices of the saturated model is a matter of interpretation. The ambiguous definition of the MCFA procedure raised concerns at this point.

Comparing the German sample with the other validation samples exhibits some differences in terms of items means and standard deviations regarding the BPNS. The item mean of 3.56 derived by the 9-item scale is comparable to the Dutch sample (M = 3.21) by Haerens et al. [20] but lower than the original validation with late adolescents by Chen et al. [19] in a US sample (M = 4.01) and a Belgium sample (M = 3.91). Standard deviations of those latter three samples vary from 0.73, 0.72 to 0.61, respectively, being lower than 1.03 of the German sample.

Our subscales had lower reliability values (0.76–0.84) as the original BPNS scale achieved higher alpha scores of 0.81 to 0.92 [22]. Additionally, the 12 satisfaction items of the BPNSFS achieved higher alpha scores ranging from 0.81 to 0.88 [19]. Moreover, our overall alpha score (0.85) is somewhat lower than Haerens et al.'s [20] scale with $\alpha = 0.87$, even though the 11-item scale and each subscale at level 1 showed satisfactory reliability scores. One strength of the MCFA is the estimation of reliability scores at level 2. As aforementioned alpha scores at level 2 (0.95, 0.65, 0.18) differ from level 1 (0.78, 0.79, 0.85), especially the low score for the competence subscale at the class level could be most likely explained by a lack of variability on level 2, indicated by low ICC values.

The large within-class variability of the relatedness and competence construct implicates that classes with few participants produce scores with low reliabilities at the class level. In support of this contention is the lower within-class variability of the construct autonomy. Seemingly, the girls within one class appraise autonomy to the same extent, while girls valuate the constructs relatedness and competence differently throughout the class. Probably justifiable due to group-dynamic processes influencing the climate of each class, the reliability score decreases at the group level. We interpret the decrease of the competence reliability scores at level 2 due to heterogeneous classes in terms of sports prowess. Talented girls are often high-performers in their classes in PE, while in other classes, the overall physical performance of girls might be weaker. Moreover, even though the curriculum puts PE into a frame, the teacher determines the demands of challenges in PE lessons. These demands differ from teacher to teacher, ergo from class to class.

The main reason to prefer the 11-item scale is due to the improved goodness of fit in comparison to the 12-item scale under consideration of the model assumptions. An explorative reduction of items (e.g., A3 and C3) improved the goodness of fit of all models but at the same time, this procedure cannot be justified due to a mainly nontransparent reduction of significant items resulting in an over-estimation of the model.

Model A could be used to interpret the data, since it represents the procedure of an adjusted single-level CFA [30]. However, expanding the thoughts towards a three-factor solution at two levels resulted in an almost equivalent fit by refraining a specification of a nested structure. In line with theoretical considerations of SDT, the three-factor structure at the individual level of the BPNS scale was also confirmed by previous findings [19,20]. The separated structure of three latent factors on both levels makes Model C preferable because the cut-point criteria are nearly surpassed. Despite two intercorrelations of two latent factors at level 2, we showed the equivalence of the three-factor structure explicitly across levels. Subsequently, we assume that both within and between classes, the satisfaction of autonomy, relatedness and competence are perceived as three distinct constructs in PE. Furthermore, Model C provides detailed information on the three factors at the class level, contrary to a one-factor solution at level 2 and its parsimonious summary.

While SES seems to be not related to MVPA, our data indicate a weak negative relationship of BMI and age with MVPA. However, current literature states a contradictory position and underlines the need to incorporate social and environmental factors in the analysis of PA behavior of youth by an adequate analysis [2]. Especially the complexity of motivational behavior and its mediation and moderation effects foster a comprehensive analysis. Therefore, we confine the purpose of the present study to the validation of the GBPNS-PE and seek to examine intervention effects of the CReActivity study in a future work.

Strengths and Limitations

This study provides detailed indications of the psychometric properties of GBPNS-PE for a specific target group in the school setting by an MCFA procedure. Nonetheless, an extension to other age groups, sex/gender and consideration of demographic domains would support generalizability of the psychometric properties of the scale, especially the incorporation of frustration items is sought in future investigations.

Three classes with less than seven individuals remained in the sample to retain a sufficient sample size on level 2, although clusters with few observations could bias the estimates and reliability

scores [49]. We considered several clusterings (schools, regional clustering, and exclusion of small classes) for all models, though negligible changes in model fits and reliability scores were observable.

5. Conclusions

This validation study provides initial proof for the three-factor structure of the BPNS scale in a multilevel design. Facing the limited periods available to assess comprehensive data in the school setting, the GBPNS-PE is an efficient solution to evaluate the need satisfaction of students in PE. Further investigations with a validation sample would establish the GBPNS-PE as a valid measurement tool in the German-speaking area and contribute to a higher robustness of the scale.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1. Dataset and R code are provided as supplementary material.

Author Contributions: Conceptualization, Y.D. and D.J.S.; methodology, D.J.S., J.B.; software, D.J.S., S.H.; validation, D.J.S., J.B. and S.H.; formal analysis, D.J.S.; investigation, D.J.S., J.B.; resources, D.J.S.; data curation, D.J.S.; writing—original draft preparation, D.J.S.; writing—review and editing, D.J.S., J.B., S.H., Y.D.; visualization, D.J.S.; supervision, Y.D.; project administration, Y.D.; funding acquisition, Y.D. All authors have read and agreed to the published version of the manuscript.

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4.3 Publication 3

Authors: David J. Sturm, Joachim Bachner, Denise Renninger, Stephan Haug, & Yolanda Demetriou

Title: A Cluster Randomized Trial to Evaluate Need-Supportive Teaching in Physical Education on Physical Activity of Sixth-Grade Girls: A Mixed Method Study

Journal: Psychology of Sport and Exercise

Doi: 10.1016/j.psychsport.2021.101902

Summary: This publication evaluated the efficacy of need-supportive teaching in PE on the girls' daily MVPA using a mixed method evaluation. In the cluster RCT participated 507 female sixth graders from 33 single-sex PE classes. During the intervention period, trained teachers conducted enhanced PE lessons, which were developed based on the self-determination theory. These lessons were observed systematically. Students' perceptions of need support and satisfaction in PE were repeatedly measured using self-report questionnaires. The students' daily MVPA was assessed using accelerometry. Semi-structured interviews provided a comprehensive understanding of how purposively sampled focus groups perceived teacher behavior in PE. After a separate analysis of qualitative and quantitative data, results were merged to investigate the intervention's efficacy and quality of implementation. Throughout the school year, the girls' MVPA decreased in both groups. Results of mixed measures converge on the finding that intervention teachers provided a slightly stronger need support than the control teachers. However, intervention components were not delivered consistently. Hence, the self-determination theory-based intervention in PE did not have enough power to lead to a significant increase in the girls' physical activity levels. Control group teachers also satisfied the students' basic psychological needs, which might have undermined the intended manipulation. Qualitative analysis provided enhanced

insights into how the students perceived their PE teachers and underlined the importance of need-support for students' perceived need satisfaction. The insights into this intervention justified further physical activity promotion initiatives since the importance to increase the number of the students that adhere an active healthy lifestyle is undisputed.

The article was submitted in September 2020 and was accepted in January 2021 and thereafter published in February 2021 by the international, peer-reviewed journal *Psychology of Sport and Exercise*.

Contribution: David Sturm was the leading author of this article. Yolanda Demetriou and Joachim Bachner designed the intervention study and acquired the funding. Joachim Bachner, Denise Renninger, and David Sturm collected the data. In consultation with Stephan Haug, David Sturm chose the methods for the quantitative analysis. In collaboration with Joachim Bachner and Denise Renninger, David Sturm conducted the qualitative analysis and triangulated the findings. He wrote the published article under consideration of feedback by all co-authors.

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A cluster randomized trial to evaluate need-supportive teaching in physical education on physical activity of sixth-grade girls: A mixed method study☆

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ABSTRACT

Objective: The purpose of this study was to evaluate the efficacy of need-supportive teaching in physical education on girls' daily moderate-to-vigorous physical activity using a mixed method evaluation.
Methods: 507 sixth-grade girls aged 9–14 years of 33 single-sex physical education classes participated in the cluster randomized control trial. During the 16-week intervention period, trained teachers conducted enhanced physical education lessons which were designed based on self-determination theory. In a randomized process, independent researchers using a computer-based algorithm allocated classes to the trial groups (IG n = 19 classes, CG n = 14). These lessons were subject to repeated systematic observations. The students' perceptions of basic psychological need support and satisfaction in physical education were measured using repeated self-report questionnaires. Students' daily moderate-to-vigorous physical activity (MVPA) was assessed by accelerometry. Semi-structured interviews provided a deeper understanding of how purposively sampled focus groups perceived teacher behavior in physical education. After a separate analysis of qualitative and quantitative data, results were merged to investigate the intervention's efficacy and treatment fidelity.
Findings: Throughout the school year, the girls' MVPA levels decreased in both groups. Girls who reported their complete physical activity data had a lower body mass index than girls who reported no, or only one or two sets of physical activity data. Results of mixed measures converge on the finding that the teachers in the intervention group provided slightly stronger need support than the control teachers, however, intervention components were not delivered consistently. Therefore, a significant intervention effect on daily MVPA could not be quantified. Autonomy satisfaction significantly predicted MVPA.
Conclusion: Qualitative insights of teaching behavior in PE underlined the importance of need support and revealed structural barriers, which compromised the implementation quality.
Trial registration: Ethics Committee of the Technical University of Munich 155/16S; Bavarian Ministry of Education IV.8-BO6106/52/12.
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1. Introduction

The promotion of physical health, mental health, and well-being is one of the goals for the sustainable development of people and planet set by the General Assembly of the United Nations (2015). Physical activity (PA) plays a major role in the prevention of chronic medical conditions and is a determinant for health and wellbeing in all life stages (Granger et al., 2017). Despite these well-known facts, low PA levels are prevalent throughout societies in industrialized countries (Guthold et al., 2020). These global perceptions are also evident in German youth, as shown by the national report card for PA (Demetriou et al., 2019). Studies reviewed in the report card indicate that only 20% of girls and boys reach the recommended moderate-to-vigorous PA (MVPA) of 60 min per day. Furthermore, about 80% of 5- to 17-year-olds spend more than two hours per day on sedentary or screen-based behaviors. Adolescent girls with a lower socioeconomic status (SES) represent a specific risk group for physical inactivity (Inchley et al., 2016; Kuntz et al., 2018), showing alarming sedentary behavior and a lack of involvement in sports

☆ The study has been approved by the Ethics Committee of the Technical University of Munich, registered with 155/16S.

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activities (Steene-Johannessen et al., 2020). This unhealthy behavior becomes even more severe with increasing age (Kemp et al., 2019). With regard to this empirical evidence and especially to the WHO's updated PA recommendation for children and adolescents (Bull et al., 2020), it is important to know how girls' PA can be positively affected within their living environment.

In this context, the active lifestyle of adolescents is influenced by policy, informational, social-cultural, and natural factors, which are outlined in the ecological model of four domains of active living (Sallis et al., 2006). For instance, how they perceive their immediate environment, in terms of walkability and accessible recreation facilities, influences their PA behavior in several living domains. At the forefront are intrapersonal factors, such as demographics, biological and psychological influences, which have an impact on adolescents' behavior. A social gradient is highlighted by the fact that girls with a lower SES engage in fewer sports activities during leisure time than peers with a higher family SES (Bann et al., 2019). In addition, girls with lower SES have a higher body mass index (BMI) (Kuntz et al., 2018), which is associated with lower PA throughout childhood (Jago et al., 2020). Consequently, efficient strategies are needed to motivate girls to be physically active.

Physical education (PE) already provides the opportunity and circumstances, however motivational psychologists claim that engaging in PA also depends on the motivational regulations of students (Ryan & Deci, 2017). Based on self-determination theory (SDT), these regulations differ in the degree of self-determined behavior and forms of regulatory processes ranging from amotivation to extrinsic motivation and through to intrinsic motivation (Legault, 2017). SDT researchers distinguish three teaching behaviors in PE which are intended to satisfy the three basic psychological needs (BPNs): autonomy, competence, and relatedness (Teixeira et al., 2020). Thus, the satisfaction of BPNs increases intrinsic motivation for PA.

Autonomy is defined as the need to perceive oneself as the "origin or source of one's own behavior" (Ryan & Deci, 2017). PE teachers support autonomy by offering choices, providing meaningful rationales, using non-controlling language, and facilitating self-evaluations (Aelterman et al., 2013; How et al., 2013; Reeve, 2016). The need for *competence* is defined as the belief in one's ability to meet certain challenges and tasks (Ryan & Deci, 2017). A competence-supportive PE teacher is well-structured and provides challenging and stimulating activities accompanied by need-based social assistance, which is based on a positive feedback culture (Brankovic & Hadzikadunic, 2017; García-Calvo et al., 2016). The need for *relatedness* refers to feeling connected with and loved by significant others or the understanding that one belongs to a social milieu (Ryan & Deci, 2017). A teaching style in which the interpersonal involvement encourages students to participate in teamwork and cooperation, and supports their emotional needs with warm, friendly, and responsive interactions is defined as relatedness-supportive behavior (Sparks et al., 2017).

In particular, Prusak et al. (2004) were pioneers in this respect, since they evidenced that female adolescent students in an autonomy-supportive PE environment were more intrinsically motivated and less amotivated than their counterparts in the control group. However, the evidence for the effectiveness of a need-supportive climate in all-girls PE is limited because intervention effects with regard to motivation (Lonsdale et al., 2017) as well as PA levels (Meng & Keng, 2016) are often negligible.

Nevertheless, evidence from mixed-gender samples showed that autonomy support in PE led to higher BPN satisfaction and subsequently to intrinsic motivation and higher device-based assessed PA during leisure time (Standage et al., 2012). Moreover, promoting choice enhances the PA of adolescents in the short-term and also increases their perceived autonomy during PE lessons (Lonsdale et al., 2013). Similarly, an autonomy-supportive climate increased the students' perceptions of autonomy, and their intrinsic motivation and their intentions to participate in sports and regular PA (Moreno-Murcia & Sánchez-Latorre, 2016). Finally, the results by Shannon et al. Klicken oder tippen Sie hier, um Text einzugeben. (2018) speak in favor of the integration of SDT principles, as they showed in a sample with a lower SES that a school-based intervention may increase children's MVPA levels.

More generally, Vasconcellos et al. (2020) evidenced a strong relation between need satisfaction and autonomous motivation in a meta-analysis of 265 SDT-based studies in the PE context. Another recent meta-analysis by Kelso et al. (2020, p. 1) summarized that "school-based PA interventions may be effective in increasing a variety of motivational outcomes." However, since the evidence regarding the effectiveness of need-supportive teaching in PE in terms of increasing PA is inconclusive, there is a need to further exploration of this association is necessary – especially because intrapersonal factors, such as age, BMI and SES, were barely taken into consideration in the evaluation of the aforementioned interventions.

For decades, evaluation researchers have advocated, in addition to an outcome evaluation, for a comprehensive process evaluation, which enables valuable feedback on the implementation and efficacy of intervention components (Durlak, 2016; Patton, 1990; Saunders et al., 2005). In this context, quantitative methods assessing perceptions and activity levels of a large number of students over a longer period of time allow researchers to identify mechanisms of behavioral changes in PA. At the point where quantitative methods come to a (statistical) limit, qualitative methods provide further insights into the inquiry (McCrudden et al., 2019). To date, few intervention designers of the educational setting have adapted their designs (e.g., Sebire et al., 2019; van Nassau et al., 2016). One of the few, Jong et al. (2019), demonstrated the benefits of a mixed method evaluation in a research field where recipients' attitudes are crucial for the intervention's success. Such an integration of methods detects sources of convergence and divergence of findings and thereby evaluates not only the treatment fidelity, but also creates a comprehensive picture of effective teaching behaviors. This enables a deeper descriptive understanding the relevance of need-supportive teaching for students' PA.

The promotion of female students' PA through modification of teaching behaviors in PE is the central focus of the presented CReActivity study (Demetriou & Bachner, 2019). The group of trained teachers were supposed to create a need-supportive climate during PE, while the teachers in the control group conducted PE classes according to the curriculum. The comprehensive evaluative measures of this study, also accounting for the clustered nature of the data, are a unique characteristic in the context of PA promotion in schools.

To date cluster randomized control trials (RCT) using a mixed-method evaluation are rarely used in the educational setting. The limited efficacy of the existing theory-based intervention studies promoting PA of girls in secondary schools compromises the evidence in this research field. This study addresses the previously presented gaps by a) examining the extent to which an SDT-based intervention and intrapersonal factors, such as SES, BMI and age, influence girls' MVPA levels, b) answering the question of whether trained teachers are able to support girls' BPNs during PE by following detailed lesson plans, and c) gaining a deeper understanding of how students perceive teachers' BPN support in PE.

2. Method

2.1. Researcher positionality

We position our research team externally of the particular school system, however, with substantial knowledge of educational psychology. All of the authors are highly educated and may be considered to be middle class or upper middle class. Our lived experiences and privileges differ in some ways from the students in our sample, which have a putative lower SES. Therefore, our backgrounds may influence our understanding and interpretation of the students' perceptions and statements. One researcher (the study's principal investigator) gained

teaching experience during his academic studies. One casual acquaintance with a teacher arose from that. We mitigated a possible interpretation bias due to the fact that the interviewer and the rest of the team had no relationships with the participating schools or particular teachers prior to the study. Three authors were directly involved in the data collection, while the other two were only engaged in the analysis and interpretation of results. To sum up, the members of our research team generally have the same starting point to approach the study within this research setting and likely to have different lived experiences in relation to participants.

2.2. Paradigm position and study design

Traditionally, findings from quantitative and qualitative methodologies differ in terms of their epistemic claims. On the one hand, "realists" seek to generalize observations by taking an objective, quantitative approach. In contrast, "relativists" foster the subjective, qualitative understanding of individual cases. In the context of mixed method research, this incompatibility has been frequently discussed (Hathcoat & Meixner, 2017). However, a critical realist perspective justifies the pragmatic methodological pluralism within a study (Ryba et al., 2020). In line with Giacobbi and colleagues' (2005) research philosophy on sports and exercise psychology, our team takes a pragmatic worldview. We recognize diverse methodological approaches to how to identify useful measures to motivate female students to be physically active. Based on Creswell's and Piano Clark's considerations (2018), we applied a convergent mixed-method design in which qualitative methods are embedded in the cluster RCT. Hereby, we emphasize the multilevel analysis of students' perceptions of need support and satisfaction in single-sex PE classes as well as device-based assessed activity levels, indicated as "QUAN". Within this empirical framework, the subsequent qualitative research provides in-depth descriptions of students' experiences with respect to need support in PE, which contribute to a meaningful understanding of the individual level data, and vice versa, indicated as "Qual". Systematic observations (qual) play a supportive, secondary role in the study, and serve to evaluate the treatment fidelity. The three strands were analyzed independently, then the results were synthesized for comparison in Table 4 and merged during the interpretation to create a clear picture about the intervention's effectiveness. We formalized the empirical model as follows (Johnson & Onwuegbuzie, 2004):

QUAN + Qual + qual

This integration strategy generates comprehensive interpretations of the inquiry (McCrudden et al., 2019) and allows us, based on the pragmatist epistemological framework to compare and contextualize the findings, which creates relevant knowledge for practitioners and researchers by using "different methodologies utilized to perform different tasks in the same research design related to different psycho-social system features (ontological)" (Ryba et al., 2020, p. 1). We would argue that our empirical approach is an innovative technique that identifies how and why students and teachers react to certain teaching methods. We share the understanding of Giacobbi et al. (2005) that within our given context, the application and consequences of our investigations must be reflected to ensure practical utility and social value of methods that promote the PA behavior of girls.

2.3. Participants

33 sixth-grade classes from twenty secondary schools in the area of Munich, Germany, were sampled. All girls were eligible to participate, but after informed consent, 507 students comprised the final sample. Table 1 shows the students' characteristics. The mean age of the overall student sample was 11.61 (SD = 0.55) years. 58.8% of the sample reported German as their primary language, 20.7% reported another language and 14.2% marked both options, while 6.3% did not report their language.

2.4. Measures

The data was collected during PE lessons held in the gym. After providing instructions, a member of the research team distributed the accelerometers to all eligible students and supervised the completion of the paper-pencil questionnaire. One week later, the PE teacher collected the devices from the students and forwarded them to the research team.

2.4.1. Socioeconomic status

As a proxy for family SES, participants were asked to describe their parents' occupations. Answers were coded according to the International Standard Classification of Occupations (2008) and rated under consideration of the International Socioeconomic Index score (Ganzeboom, 2010).

2.4.2. Anthropometric data

Participants reported their birth date. Weight was measured to the nearest 100 g with a digital scale and height with a stadiometer to the nearest 0.1 cm. Participants were measured in gym clothes without shoes.

2.4.3. Physical activity

For seven consecutive days, the students' PA behavior was measured by accelerometry, using the GT3X, GT9X, and wGT3X-BT ActiGraph models (ActiGraph, 2019). Data were considered as valid if at least three weekdays and one weekend day with at least eight hours of accelerometer wear time were recorded. The non-wear-time definition by Choi et al. (2011) and cut-points (MVPA > 3360 counts per minute) by Hänggi et al. (2013) were used to analyze the data. For further details on processing the PA data, refer to Bachner et al. (2021).

2.4.4. Basic psychological need support

BPN support provided by of the PE teacher was assessed using an adapted and translated version of the 9-item Adolescent Psychological Need Support in Exercise Questionnaire (Emm-Collison et al., 2016). We added the stem "Im Sportunterricht …" ("In PE lessons …") at the top of the questionnaire. Items were adapted to age-appropriate style and language by two English-speaking researchers. The scale was pilot tested with the pretest procedure. 5-point Likert scales were used, representing the level of agreement with statements ranging from *completely disagree* (1) to *partly agree* (3) through to *completely agree* (5). A confirmatory factor analysis (CFA)[1] supported a three-factor solution (X^2 = 142.31, df = 24; CFI = .93, TLI = .90; AIC = 9865.36, BIC = 9950.94; RMSEA = .11, 95% CI [0.09, 0.12]; SRMR = .05). The X^2 difference test revealed a significant preeminence against a one-factor solution ($p < .001$). Additionally, internal consistency of all subscales is acceptable with Cronbach's alpha ranging from $\alpha = 0.75$ to $\alpha = 0.79$ (see Table 2). Class-level ICCs for follow-up measures ranged from small (0.03 for relatedness satisfaction) to large (0.31 for autonomy support). All factor loadings were significant and ranged from 0.65 to 0.80.

2.4.5. Basic psychological need satisfaction

BPN satisfaction in PE was assessed using the German Basic Psychological Needs Satisfaction scale in PE (Sturm et al., 2020). From a multilevel CFA a model emerged with three latent factors on both levels, showing acceptable fit and significant factor loadings for all items. The subscales showed good internal consistencies at the individual level: α = 0.78 to 0.85. At the class level, the scores varied from poor to good. Small significant correlations between BPN satisfaction and MVPA supported criterion validity. Answers were rated on a 5-point Likert scale representing the level of agreement with statements ranging from

[1] Details of the CFA are provided in the online supplemental to this article.

Table 1
Student characteristics by treatment condition.

Variable	Intervention group (N = 308, 60.7%)							Control group (N = 199, 39.3%)						
	Min	M	Max	Median	SD	IQR	n	Min	M	Max	Median	SD	IQR	n
SES at T0	15.0	50.95	89.0	49.0	16.44	25.0	249	17.0	48.06	74.0	47.0	15.08	24.0	163
Age at T0	9.15	11.54	13.9	11.4	0.59	0.5	216	10.8	11.70	13.0	11.6	0.48	0.6	170
BMI at T1	13.7	19.21	40.0	18.5	3.50	4.3	248	12.8	19.83	33.0	19.1	3.89	5.2	182

Note: Numbers vary since some students refused to report personal data. SES = socioeconomic status; BMI = body mass index; Min = minimum, Max = maximum, IQR = interquartile range.

Table 2
Reliability indices and intraclass correlation coefficients of basic psychological need support and satisfaction.

Variable	Reliability Index			ICC (School)			ICC (Class)		
	T0	T1	T2	T0	T1	T2	T0	T1	T2
Autonomy Support	.75	.84	.86	.11	.17	.19	.23	.29	.31
Relatedness Support	.79	.85	.90	.07	.17	.14	.13	.22	.19
Competence Support	.76	.84	.88	.10	.18	.12	.16	.25	.18
Autonomy Satisfaction	.80	.84	.87	.11	.12	.14	.16	.24	.19
Relatedness Satisfaction	.80	.85	.89	.00	.01	.03	.00	.02	.03
Competence Satisfaction	.85	.86	.87	.00	.03	.03	.02	.07	.03

Note. Reliability indices are Cronbach's alpha, ICC = intraclass correlation coefficient.

completely disagree (1) to *partly* (3) through to *completely agree* (5).

2.4.6. Intervention dose delivered[2]

Two trained observers conducted systematic observations of two PE lessons taught by each intervention group (IG) and control group (CG) teacher and coded PA levels of four randomly selected students from each class, using a modified version of the System for Observing Fitness Instruction Time (SOFIT) coding protocol (McKenzie, 2015). PE lessons were assessed with the iSOFIT App (David, 2018), which audio-visually instructs the observers according to the defined observation protocol. The modification of SOFIT captures whether the teacher implemented the central constructs of the intervention program, and thus, we replaced the original categories "lesson context", "teacher interaction", and "teacher involvement" by the three constructs "autonomy", "competence" and "relatedness". In addition, the observation interval for BPN support was extended from 10 to 30 s, while the observation interval for PA and coding intervals remained 10 s. For each observation interval, the PA level (lying, sitting, standing, walking, and vigorous) of the respective student was assessed. Subsequently, we assessed whether teachers' behavior or lesson arrangement supported the respective BPN in the majority of the students. The two observer workshops included video tape assessments and instructions for theoretical foundations. Every observer (N = 9) received a booklet with descriptions and examples of need-supportive teaching behaviors, which included lesson elements of the intervention. Observations were scheduled during the intervention weeks 5-7 and 10 to 12. Observers were blinded, except for the two project leaders who substituted for the absence of a second observer in 13 cases. Their results were only used for reliability checks and were not included in the analysis. Observers simultaneously reviewed the entire lesson and reported class size, lesson content, as well as specific characteristics of the PE lessons and interferences of the observation.

2.4.7. Students' experiences with basic psychological need support

External expertise, theoretical foundations, and integration of quantitative findings from the Wave 1 assessment built the foundation for the development of guiding interview questions, which were pilot-tested and iteratively updated as new issues emerged while conducting the interviews. After the end of the 16-week intervention period, a trained, female research assistant conducted semi-structured interviews, following the flexible interview guide, with nineteen student focus groups consisting of 4-5 students each (CG = 36 students, IG = 41 students), representing each participating class. We chose a purposive sampling method in order to gain realistic and information-rich insights from two motivated students and two less enthusiastic students in terms of their engagement in PE. For this purpose, the teacher selected four students (Palinkas et al., 2015). In one class, a fifth student was chosen to account for the large number of students. The face-to-face interviews were conducted in separate rooms during school hours, without the attendance of teachers. Postscripts were completed afterwards.

2.5. Procedure

2.5.1. Recruitment and randomization

Schools were contacted one school year before the study was implemented. School principals and parent councils provided written informed consent to conduct the study and PE teachers were invited to participate. Randomization of the study sample in the IG and CG took place on the school level and was done prior to the pre-test data assessment. A computer-based random number producing algorithm was generated and completed by an independent researcher to ensure that all classes had an equal chance of allocation to either group. No matching was conducted. In the Wave 1 assessment, schools with affiliated classes were randomly assigned to either the IG or CG at the same time point. In assessment Wave 2, three assessment cohorts with a respective re-registration period were scheduled. Upon receiving teachers' consent, schools and the respective classes were randomly assigned within the respective cohort to either the IG or CG. Via teachers, parents and children received letters asking for consent to participate in the data collection process.

2.5.2. Data collection

Data were collected in two assessment waves in the school years from 2017/2018 to 2018/2019. Baseline (T0) measurements were conducted between October and December, followed by a 16-week intervention period, excluding holidays. The posttest (T1) took place between March and May after the end of the intervention period. The follow-up test (T2) was conducted 10-12 weeks later, between June and July, to finish the data collection within the respective school year. Since the evaluation of the Wave 1 assessment gave rise to a need to enhance the process evaluation, systematic observations with two observers and interviews with students were only conducted in the Wave 2 assessment. Apart from that, the same data collection schedule was applied (see Fig. 1). The trial was ended since evaluative measures suggested the need to readjust certain intervention components.

[2] Only systematic observations of the Wave 2 assessment were analyzed, since interobserver agreement of Wave 1 assessment could not be rated

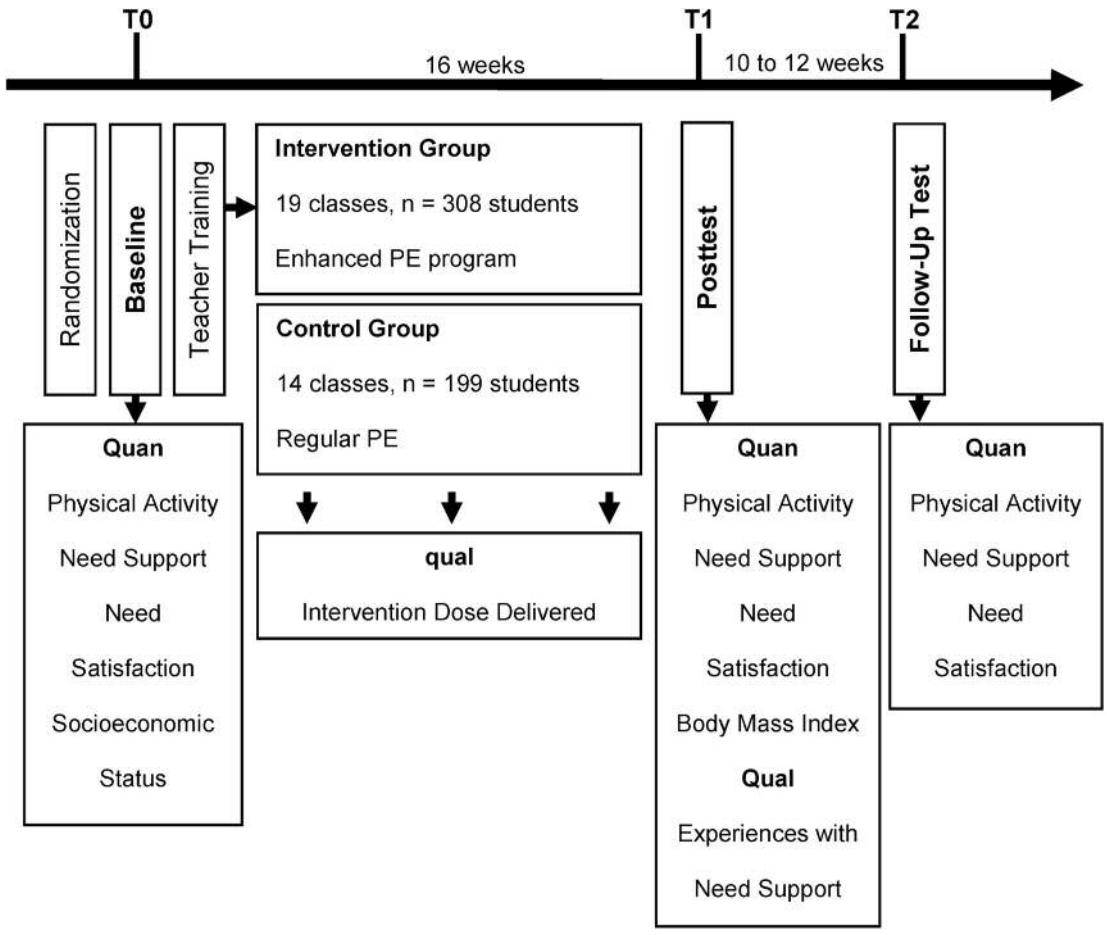

Fig. 1. Study design of the CReActivity study.

2.5.3. Treatment condition

Intervention teachers (N = 13) received an information booklet and 48 lesson plans in the domains of football, basketball, gymnastics, health and fitness, swimming, and dancing. Fig. 2 outlines general need-supportive teaching behaviors. Each lesson plan included specific instructions for need-supportive teaching and was created in accordance with the curriculum. Where necessary, supportive material for up to 30 students was provided. In an approximately two-hour teacher training session, a researcher introduced the theoretical framework and explained the implementation of the intervention components. Teachers should teach at least 16 lessons, each lasting 90 min, which could be freely selected from the 48 lesson plans. Reminder e-mails to provide documentation of all conducted lessons and elements were sent to the teachers every four weeks after the start of the intervention.

2.5.4. Control condition

Control teachers (N = 12) continued with their regular approach and teaching behavior in PE, since we could not ban or impose certain teaching behaviors, without revealing the intervention conditions.

2.5.5. Sample size

The sample size was calculated using the formula presented by Rutterford et al. (2015). Considering variable cluster sizes, we estimated a variation coefficient of the cluster size of 0.25 and an intracluster correlation (ICC) at the class level of 0.1. We set an alpha of 0.05 and a power level of 80%, which led to an estimated sample size of total 467 students. Therefore, we aimed to recruit 600 students (Demetriou & Bachner, 2019).

2.5.6. Blinding

Teachers were aware of their allocation to IG or CG. Control teachers were blinded to the elements of the teacher training, however the study aim of PA promotion could not be blinded. Students were blinded to allocation. Student research assistants, who were blinded to the condition allocation, collected observational data. The interviewer was not blinded to allocation.

2.6. Data analyses

Distributional assumptions were considered and data were screened for outliers. We did not eliminate specific data classified as outliers since the impact on model precision was low (see online supplementary; Finch et al., 2019). Missing data ranged from 0.4% to 4.7% across BPN support and BPN satisfaction variables. These missing data were completely random at all measurement points, except those of the BPN support scale at T0 (Little's $X^2 = 201.93$, degrees of freedom *(df)* = 165, $p < 0.05$) (Little, 1988). We still assumed that data were missing-at-random since only two relatedness items had an unusually high number of missing

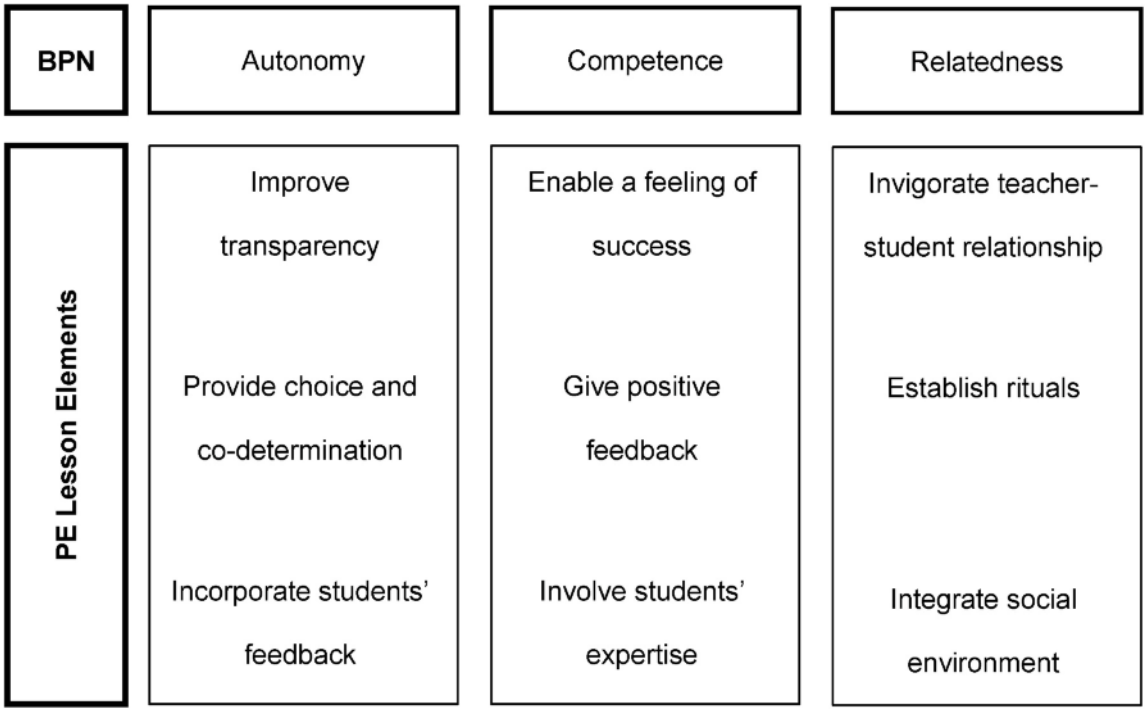

Fig. 2. Intervention Elements of the CReActivity Lessons.
The authors will provide access to the training manual upon request.

data (n = 17). Due to refusal of participation or various other reasons, such as illness, absence, or moving to another place of residence, 13.6% of the sample dropped out of the study. Less than half of the sample (42%) provided valid PA data for all three measurement points, and thus data was not imputed. One advantage of the linear mixed model is that it incorporates all available data, even if a participant drops out or misses an assessment (Gałecki & Burzykowski, 2013; Hox, 2010). This led to the final sample of 285 observations in the IG and 256 observations in the CG (see Fig. 3).

Since the adapted BPN support scale had not been previously validated, we initially tested the psychometric properties by a CFA. We estimated internal consistency for translated scales and created composite scores by averaging the respective items per subscale (Taber, 2018).

To examine the intervention effect of BPN support in PE on students' MVPA, we used linear mixed effects models, since this allows us to take the hierarchical structure of the data ($M = 15$ students per class, $SD = 6$) and repeated measurements into account. ICCs were computed to check the assumption of independence (Raudenbush, 1997). Considering the ICCs (see Table 2), a multilevel analysis is needed to obtain unbiased estimates (Julian, 2001). As recommended by the American Institutes for Research et al. (2020), we tested for baseline equivalence between IG and CG in all reported variables. There were no statistically significant differences between groups, but CG students were slightly older ($\Delta = 0.15$, $p < .01$, 95% CI [0.05, 0.25]). Subsequent analysis of baseline differences between dropouts and the remaining sample revealed that girls who did not provide any valid PA data were slightly older ($\Delta = -0.19$, $p < 0.01$, 95% CI [-0.36, -0.01]), had a significantly lower SES score ($\Delta = 5.59$, $p < 0.01$, 95% CI [1.37, 9.78]), had lower competence support ($\Delta = 0.24$, $p = 0.03$, 95% CI [0.02, 0.45]) and satisfaction scores ($\Delta = 0.23$, $p = 0.01$, 95% CI [0.01, 0.47]) at baseline than those who provided at least one valid PA data for one measurement point. Girls with complete PA data tended to have a lower BMI score than those who had valid PA for fewer than three measurement points ($\Delta = -0.51$, $p = 0.20$, 95% CI [-1.41, 0.48]). Further baseline differences in BPN support variables among these sub-groups were marginal and demonstrated no statistical significance.

Treatment efficacy was tested at the class level using a dummy code for intervention condition. Moreover, the interaction effects of treatment and the three BPN support variables were tested to analyze whether perceived need-supportive teaching moderated the intervention effect. To reduce the collinearity between psychological variables of need support and need satisfaction, we entered grand mean centered psychological predictors to the model (Raudenbush & Bryk, 2002). The three respective satisfaction scores as well as SES, BMI, and age were included as student-level predictors in the model. Time (measured as 0, 1, 2) was entered as independent variable, so that posttest and follow-up scores served as change scores from the baseline score. A condition-by-time interaction was included as a cross-level predictor in the model in order to examine the longitudinal changes between IG and CG.

We also tested a model with interactions between related support and satisfaction constructs, for example, autonomy support and autonomy satisfaction. In this case, variance inflation factors (VIF) of several predictors were still larger than the commonly used cut-off of 5 (Craney & Surles, 2002), which indicates poorly estimated regression coefficients. Those associated VIFs larger than five are mainly caused due to the repeated measures, as the VIFs of the baseline models were below 5. The X^2 differences test as well as the Bayesian information criteria

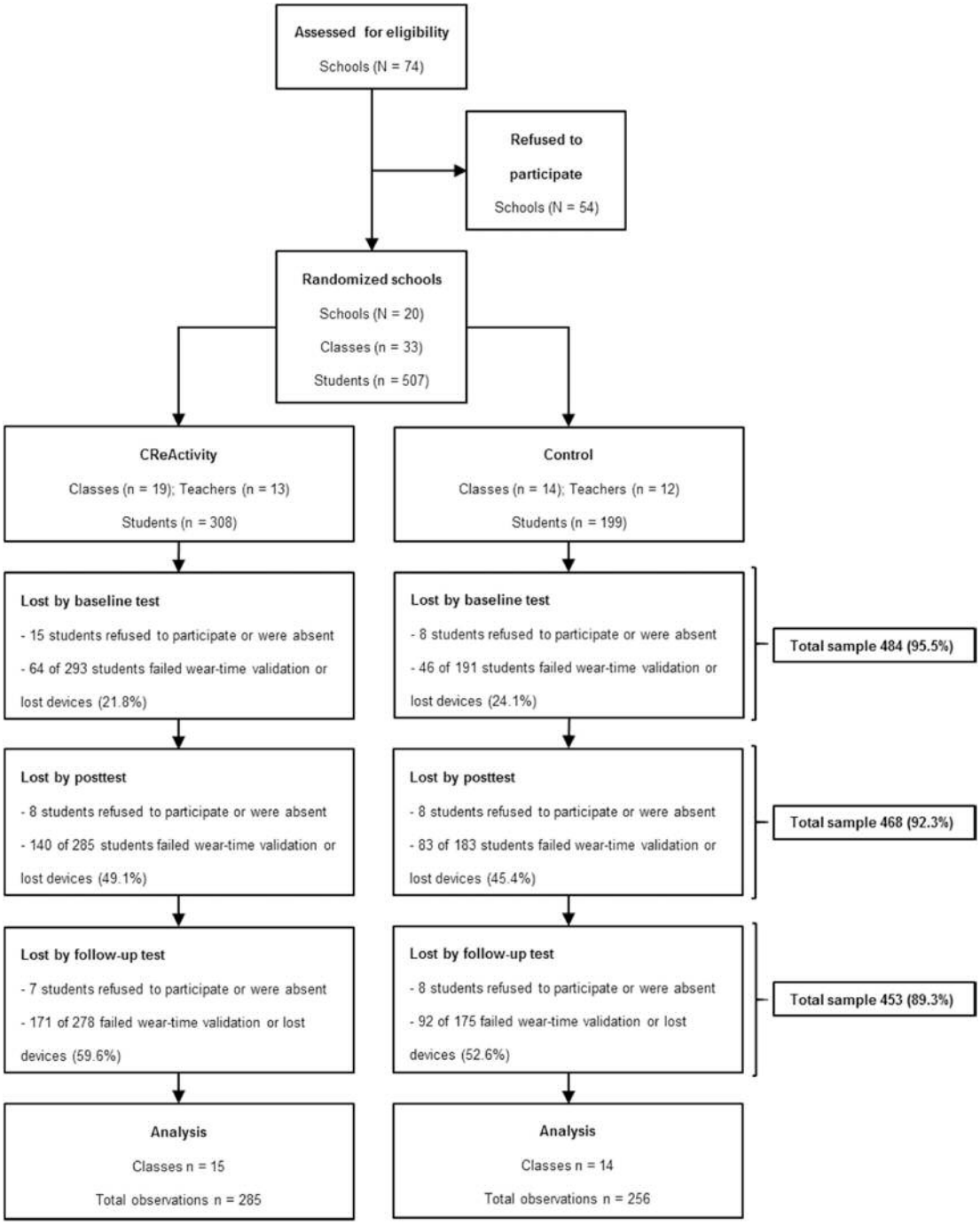

Fig. 3. Flow chart.

(BIC) were used to determine model fits (Gałecki & Burzykowski, 2013).

To further identify differences in all variables between IG and CG for every time point, we used multilevel repeated measures analysis with follow-up post-hoc pairwise mean comparisons (Bretz et al., 2011). To counteract the problem of inflated type I errors while engaging in multiple pairwise comparisons between measurements, we used the recommended Benjamini and Hochberg (1995) correction.

Descriptive statistics, CFA, linear mixed modeling and post-hoc repeated measures analysis were computed by R (R Core Team, 2018). Reliability scores were computed using the alpha function from package psych (Revelle, 2018). The CFA was conducted using the lavaan package (Rosseel, 2012). The parameters of the linear mixed model were estimated through restricted maximum likelihood using the lmer function of the lme4 package (Bates et al., 2015). The post-hoc analysis was conducted by using the multcomp package (Hothorn et al., 2008), and for the permutation test we used the infer package (Bray et al., 2019). For further information and codes we refer to the supplementary.

2.6.1. *Systematic observations*

According to the SOFIT procedure, the results of the first observer

were included in the analysis, while the second observer served as a reliability check (McKenzie, 2015). Interrater reliability was examined based on the interobserver-agreement percentage, which was calculated in Excel (Microsoft Corporation, 2018) using the formula by Thomas et al. (2015): (Number of compliant intervals)/(Number of total observed intervals - Number of missing intervals)*100.

To count the MVPA intervals, walking and vigorous intervals were summarized. The proportion of MVPA in PE was computed in relation to the observed lesson length. In order to rate the treatment fidelity, we analyzed the differences in BPN support and MVPA in PE between groups using the permutation test.

2.6.2. Interviews

Data were audio recorded, transcribed verbatim, and managed using f4transkript by three student research assistants (Dresing & Pehl, 2017). To address the second research question, interviews were analyzed using structured content analysis (Mayring, 2015). Based on the theoretical considerations of need-supportive teaching and detailed PE lesson elements, main and sub-categories with specific criteria were created. This allowed deductive coding of interviews. After reading the transcripts, two researchers used the differentiated system of categories to independently assign all relevant passages to the corresponding category. Similarly, these codes were marked as supportive, thwarting, or inconclusive. Conflicts and inconclusive codes were resolved in consultation of a third researcher, which led to unanimous interpretation of results. We considered the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist in order to support the methodological integrity[3] of the qualitative research methods (Tong et al., 2007).

3. Results

3.1. Quantitative results

The results from the model indicated no significant interactions between treatment condition and BPN support variables, which means that the relationship between treatment and MVPA is likely independent of the different levels of BPN support variables. Neither the treatment main effect was significant (95% CI [-7.34, 3.98]; see Table 3), nor BPN support variables had a significant effect on the daily MVPA of sixth-grade girls. In contrary to competence and relatedness satisfaction, we observed a significant effect size of autonomy satisfaction. A unit increase in autonomy satisfaction predicted an increase in MVPA by 3.81, which might vary in the 95% confidence interval between 1.00 and 6.65. Older students showed lower MVPA levels than younger ones (95% CI [-8.76, -0.87]). SES and BMI had no significant effect on the girls' MVPA level. The high level of residual variance indicates a high variability within the treatment. A high proportion of the variability within the treatment variance is explained by students' differences, while the class-level random effect was not significant and explained a negligible amount of variability. Normality of the random effects and residual error was assumed, as can be seen from the corresponding plots in the supplementary.

In comparison to the model reported above, the explanatory power and model precision decreased with the inclusion of interactions of BPN support and satisfaction in the model indicated by higher VIFs. Furthermore, those interactions did not show statistical significance. The model without BPN interactions (BIC = 4803.1) had a slightly better fit than the models with interactions (BIC = 4821.6). The X^2-difference tests revealed no significant differences between model fits ($p = .96$), meaning that these interactions provide no substantial contribution to explain the MVPA levels.

The multilevel repeated measures analysis revealed that MVPA levels significantly decreased from T0 to T1 (95% CI [-9.58, -0.88]) and from T0 to T2 (95% CI [-17.30, -7.96]; see Table 4). IG students' average value of daily MVPA diminished from 80.5 min at T0 to 71.5 min at T2, while the CG students averaged 80.3 min at T0 and 67.7 min at T2. The manipulation of BPN support was unsuccessful, as perceptions regarding BPN support and BPN satisfaction were not significantly different between the IG and CG at T1. At T2, observed differences in favor of the CG ranging from -.12 to -.31 showed statistical significance with confidence intervals ranging approximately from -.48 to 0. To establish whether findings were evident at an individual level, the Benjamini-Hochberg correction (1995) was applied.[4] In the IG, decreases from T0 to T2 in all BPN variables were significant, while in the CG, only relatedness satisfaction decreased significantly over time ($p < .05$).

Table 3
Results of linear mixed model on daily moderate-to-vigorous physical activity.

Fixed effects	Estimate	SE	t	95% CI	
Intercept	130.49	24.44	5.34	**84.32**	**179.46**
Treatment effect	-1.68	3.00	-0.56	-7.34	3.98
Standardized effects					
Autonomy support	-1.98	2.21	-0.90	-6.26	2.21
Competence support	-1.01	2.33	-0.43	-5.55	3.47
Relatedness support	-0.30	2.58	-0.12	-5.29	4.73
Autonomy satisfaction	3.81	1.46	2.62	**1.00**	**6.65**
Competence satisfaction	1.79	1.34	1.34	-0.82	4.41
Relatedness satisfaction	0.15	1.22	0.12	-2.18	2.60
Interaction effects					
Treatment*Autonomy support	-0.56	2.84	-0.20	-5.99	4.92
Treatment*Competence support	3.49	3.09	1.13	-2.37	9.67
Treatment*Relatedness support	-3.01	3.29	-0.92	-9.51	3.27
Covariates					
Time 1	-5.23	2.24	-2.34	**-9.58**	**-0.88**
Time 2	-12.61	2.41	-5.23	**-17.30**	**-7.96**
BMI	-0.09	0.30	-0.30	-0.66	0.49
SES	0.14	0.07	1.89	0.00	0.27
Age	-4.71	2.03	-2.32	**-8.76**	**-0.87**
Treatment*Time 1	2.23	3.09	0.72	-3.76	8.21
Treatment*Time 2	3.22	3.42	0.94	-3.42	9.83
Random effects	**Variance**	**SD**		**95% CI**	
Class	14.33	3.79		0	6.63
Student	178.20	13.35		**11.11**	**15.33**
Residual	204.25	14.29		**12.96**	**15.39**

Note. N = 541 observations, n = 29 classes; SE = standard error, CI = confidence interval, SD = standard deviation.

3.2. Systematic observations

During the intervention period, thirty-nine observations were conducted. One class could be observed only once, due to health issues of the teacher. Between 8 and 27 students ($M = 20$, $SD = 7$) actively participated in the lesson. At 82.88% ($SD = 8.72$), reliability of observations was acceptable for the interobserver agreement across all target domains ranging from 80.91% ($SD = 7.50$) for MVPA, and 81.42% ($SD = 13.52$) for competence to 83.59% ($SD = 12.21$) for autonomy, and 86.35% ($SD = 10.32$) for relatedness support. The average duration of observed PE lessons was 72.0 min ($SD = 7.7$), which accounts for 80% of the scheduled 90 minutes of PE. The classes of IG and CG showed similar MVPA levels in PE, since no significant difference was observable (95% CI [-7.3, 2.6]). Observers coded a higher proportion of BPN supportive intervals in the intervention classes (see Table 4). However, no

[3] See Appendix 1 for a detailed description of research practices used to ensure methodological integrity of the qualitative data.

[4] Refer to Section 5 in the supplementary for a detailed description of results.

Table 4
Mixed method convergence matrix.

		Questionnaire			Interviews	Observations (%)			Convergence
		IG	CG	Difference [95% CI]	Qualitative Interpretation	IG	CG	Difference [95% CI]	
Autonomy support	T0	3.38 (0.88)	3.46 (0.95)	-.07 [-.45, .30]	CG students perceived similar autonomy-supportive elements as IG students. IG teachers provided a more transparent PE, while teachers of both groups tried to provide choice and co-determination.	45.9 (25.3)	34.5 (17.8)	11.3 [-2.0, 24.2]	*Convergence*: Results indicate no difference between groups.
	T1	3.22 (0.99)	3.38 (1.08)	-.07 [-.24, .09]					
	T2	2.97 (1.10)	3.45 (1.10)	**-.31 [-.48, -.14]**					
Competence support	T0	3.73 (0.86)	3.73 (0.93)	.00 [-.34, .34]	Teachers of both groups created a competence-supportive lesson climate, even if not consistently. Overall, CG teachers thwarted the need for competence less than IG teachers, while the observed support speaks in favor of IG.	50.7 (15.7)	39.5 (20.6)	11.2 [-0.1, 22.3]	*Divergence:* Observations and interviews question the non-significant difference of questionnaires.
	T1	3.59 (1.02)	3.64 (1.04)	-.07 [-.24, .10]					
	T2	3.33 (1.10)	3.64 (1.08)	**-.25 [-.42, -.07]**					
Relatedness support	T0	3.59 (0.88)	3.76 (0.85)	-.15 [-.47, .17]	IG teachers implemented rituals successfully, which were rated mainly positive. Teachers of both groups tried to enhance meaningful relationships among students, however, peer-related homework was not assigned.	53.7 (22.4)	41.5 (21.5)	12.3 [-1.6, 26.8]	*Divergence:* Interviews and observations revealed a different direction of results.
	T1	3.47 (1.04)	3.66 (0.92)	-.02 [-.19, .14]					
	T2	3.26 (1.13)	3.68 (1.03)	**-.18 [-.35, -.02]**					
Autonomy satisfaction	T0	3.24 (0.85)	3.21 (0.87)	.08 [-.23, .38]	Although teachers' regulations were perceived differently among groups, students commonly stated the importance to have a say and certain freedom.	-	-	-	*Convergence:* Across groups similar perceptions were found.
	T1	2.97 (0.88)	3.07 (0.99)	-.13 [-.29, .02]					
	T2	2.79 (0.97)	3.01 (0.96)	**-.18 [-.34, -.03]**					
Competence satisfaction	T0	3.61 (0.86)	3.63 (0.82)	-.02 [-.20, .17]	Both student groups perceived an adequate task level and appreciated the opportunity for students to serve voluntarily as experts for specific tasks.	-	-	-	*Convergence:* Students of both groups had equal attitudes.
	T1	3.56 (0.88)	3.58 (0.81)	-.01 [-.14, .13]					
	T2	3.37 (0.91)	3.56 (0.84)	-.12 [-.26, .02]					
Relatedness satisfaction	T0	4.00 (0.81)	4.03 (0.80)	-.02 [-.06, .07]	Students of both groups liked to learn and succeed with assistance by peers. The teacher-student relationship highly influences students' behavior.	-	-	-	*Convergence:* Focus group statements were not contrary to self-reports.
	T1	3.75 (0.90)	3.79 (0.96)	-.04 [-.20, .11]					
	T2	3.47 (1.00)	3.60 (1.02)	**-.16 [-.33, -.01]**					
		Accelerometry				**Observed MVPA in PE (%)**			
Average MVPA per day (min)	T0	80.5 (21.0)	80.3 (21.0)	0.57 [-5.48, 6.65]		28.6 (8.65)	30.9 (7.18)	-2.4 [-7.3, 2.6]	*Convergence:* MVPA levels were similar in both groups, however, the longitudinal decline in the IG tended to be lower.
	T1	76.4 (21.0)	75.2 (19.3)	1.01 [-3.87, 5.92]					
	T2	71.5 (18.4)	67.9 (20.4)	1.92 [-3.37, 7.22]					

Note. Results presented as means (standard deviation). Bold type indicates confidence intervals that do not include 0. Convergence = agreement between the sets of results; Divergence = disagreement between the sets of results on either the relevance or the direction of the topic under consideration. Results of systematic observations in relation to observed lesson length. Differences tested using linear mixed effect models adjusted for class clustering. Abbreviations: IG = intervention group, CG = control group, CI = confidence interval, MVPA = moderate-to-vigorous physical activity, PE = physical education.

statistically significant difference in comparison to the control classes was observable.

3.3. Mixed method results

The integration of results shows differences in BPN support and convergent perceptions of BPN satisfaction (see Table 4). In comparison to quantitative data, interviews and observations revealed slightly different perceptions of competence and relatedness support. In part, IG teachers were able to implement certain intervention lessons and components, indicating a moderate implementation quality. CG teachers supported girls' BPNs almost equally so that a significant intervention effect based on BPN support was not quantifiable. Neither observational nor interview data provide indications for the longitudinal decrease of BPN variables in the IG.

3.4. Interviews

In the following, similarities and differences between groups are presented for each subcategory of the respective BPN. Overall, similar patterns of assigned codes for each category can be observed, except for a higher number of competence-thwarting codes in the IG (see Fig. 4). Average duration of IG interviews was about 19 min (range of about 9), while CG interviews lasted about 21 min (range of about 21) on average. See Table 5, 6 and 7 for correct implementation criteria and example codes for each subcategory.

Transparency. The number and quality of codes speak in slight favor of IG (7 vs. 3). According to some IG students, their teachers strived to provide transparent PE lessons. However, several other IG and CG students "sometimes" received a brief explanation of contents by referring to the curriculum (Interview 11, CG), but often the questions *why* and *how* remained unanswered. Students in both groups were able

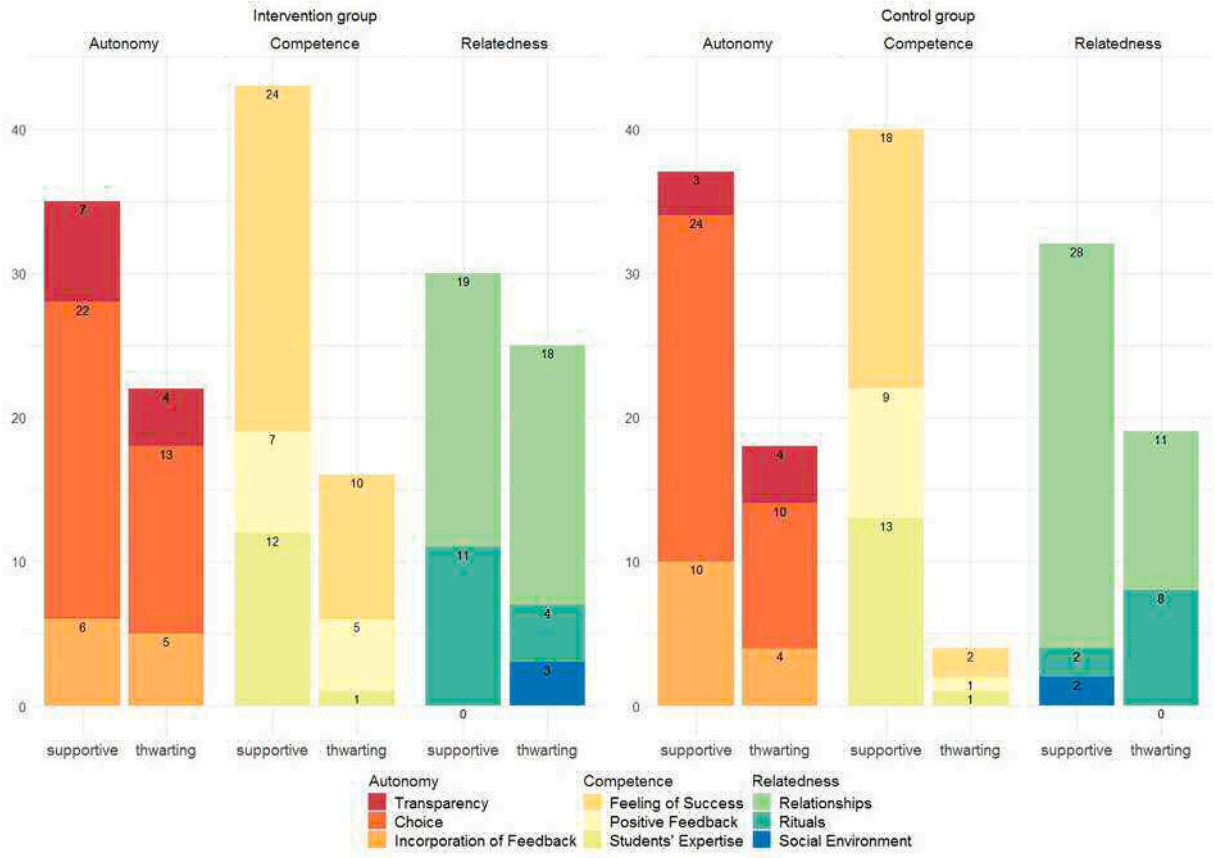

Fig. 4. Number of interview codes of need-supportive and need-thwarting lesson elements in intervention and control group.

Table 5
Subcategories of autonomy, criteria and typical examples of supportive and thwarting teaching behaviors.

Criteria for *correct* implementation	Example codes
Transparency	Supportive: *[…] and then she tells us what we will do and what we have to prepare for PE. (Interview 2, IG)*
Students are given information about the intended lesson content and the purpose of specific exercises.	Thwarting: I: *Does your teacher explain why you have to do this?* S: *No, not really. (Interview 13, CG)*
Choice	Supportive: S: *It is cool when we can decide what we want to do and we are not forced to play football, for example. That's not fun and we actually learn nothing. (Interview 12, CG)*
Students …	
…have freedom in choosing games and exercises.	Thwarting: S: *[…] but she decides what we are doing and then we have to do it. (Interview 14, CG)*
…co-create games and rules.	
…have various ways of scoring points in games/exercises.	
…can determine and adjust the task level.	
…can try new exercises inductively.	
Incorporation of feedback	Supportive: I: *So you always can talk with her [the teacher], if there is something you don't like?*
Teacher …	S1, S2: *Yeah.*
…promotes regular feedback sessions.	S1: *She always tries to make it better in the next lesson. (Interview 5, IG)*
…accepts negative feelings and heeds meaningful critique.	Thwarting: *[…] if we don't like the game, we mostly don't confront her, because she will say 'That's how it is!' anyway and then we just have to play the game. (Interview 6, IG)*

Note. S = student, I = interviewer, IG = intervention group, CG = control group.

to relate teachers' use of direct teaching methods as disciplinary action, which the frustrated students' needs.

Choice. Students in both groups predominantly reported on the promotion of choice and co-determination and less about external regulations (22 IG vs. 24 CG). Their teachers provided opportunities to follow their own interests, which appealed to the students. However, IG students did not co-create PE lessons as foreseen in the lesson plans. Students in both groups perceived unreasonable regulations as negative. Therefore, we interpreted teachers' behavior as similar in both groups.

Incorporation of Feedback. Interviews revealed that teachers of both groups offered opportunities for feedback (6 IG vs. 10 CG). However, few IG students occasionally perceived that their improvement suggestions or wishes were not considered or were temporarily put aside. Yet, CG students reported that they could not only ask for help and assistance any time but also had the feeling that they could come up with any concern or idea. Based on those experiences, students in both groups felt that their feedback made a meaningful contribution to their PE lessons.

Feeling of Success. The number of supportive codes speaks in favor of IG teachers (24 vs. 18). The IG teachers met the students' desire to start with "easy things" and then to "step up" (Interview 10, IG) by offering the chance for every student to meet challenges and tasks entailed in an entertaining, varying, and physically demanding PE lesson. However, students in both groups reported that they could adjust certain tasks to their own abilities, which enabled them to succeed. IG students also reported thwarting teaching behavior that obviously diverged from

Table 6
Subcategories of competence, criteria and typical examples of supportive and thwarting teaching behaviors.

Criteria for *correct* implementation	Example codes
Feeling of success	Supportive: *There was one group which was better and could practice a free handstand. Others assisted, and then there were some who practiced the handstand against the wall. (Interview 8, IG)*
Teacher chooses exercises …	
…that do not require previous experience.	*For me it's, like, when we learn something new […] and after some time are able to do it, that's a very nice moment, when you just know 'Cool, I can do this!' and 'Now I can learn something new.' and eventually I'll be able to do a lot of things and I can also teach them somehow to others and so. (Interview 6, IG)*
…that provide multiple options to score or to succeed.	
…that enable students with different strengths/skills to succeed in various ways.	Thwarting: I: *Are there some situations in which you have the feeling that you have learned something?* – S: *Not really. (Interview 7, IG)*
…in which students accomplish certain tasks through teamwork.	
Positive feedback	Supportive: *[…] mostly at the end of the lesson, but also in direct conversations she says: 'Looks great!' or 'You are doing well!' (Interview 18, CG)*
Teacher …	
…focuses on student's intraindividual progress and provides useful tips if deficits are observable.	*She often tries to encourage us, because we are exhausted. She actually always tries something, even if there are some persons who don't like it. (Interview 10, IG)*
…also takes e.g., effort, durability, ambition into account.	Thwarting: *For the past few weeks she has been saying: 'Yeah, you are my worst class!' (Interview 3, IG)*
…communicates face-to-face instead of yelling across the gym.	
Students' expertise	Supportive: *One student is very good, she does gymnastics, and demonstrated the exercise. (Interview 8, IG)*
Students …	Thwarting: I: *If there is someone who is good in PE. Does your teacher allow her to demonstrate the exercise?*
…serve as role models for specific exercises.	S: *No, not really. (Interview 7, IG)*
…co-create the learning process by sharing personal experience and serving as co-teacher.	

Note. S = student, I = interviewer, IG = intervention group, CG = control group.

Table 7
Subcategories of relatedness, criteria and typical examples of supportive and thwarting teaching behaviors.

Criteria for *correct* implementation	Example codes
Relationships	Supportive: *For example, when someone does not make it, we do not laugh immediately or say 'you cannot do it', but we say: 'hey, next time you will make it!' or 'I can help you if you want!' (Interview 4, IG)*
Teacher …	Thwarting: *And then she doesn't say 'Please, be silent.' instead she yells 'Shut up.' That's not nice." (Interview 7, IG) […], from one second to another, she argues heatedly and insults us. And from time to time she reduced some kids to tears in PE. (Interview 6, IG)*
…chooses partner- and group exercises.	
…celebrates team spirit and enhances community spirit.	
…promotes respect, acceptance and fairness.	
…acknowledges students who help their peers improve.	
…asks for students' opinions and takes their ideas into account.	
Rituals	Supportive: *She asks about how we feel and then we have to answer by either raising or bending our legs. Straight leg means 'good' and bend means 'ok'. (Interview 5, IG)*
Teacher and students arrange a collaborative and warm welcoming and farewell ritual.	Thwarting: *We just enter the gym and greet each other. But that's it. (Interview 6, IG)*
Social environment	Supportive: S: *It is quite nice, when we learn new things that I can show at home […].*
Teacher assigns manageable homework, which encourages students to be active with friends and family.	I: *Things you could not do before?*
	S: *Yes, and maybe become even better at it. (Interview 6, IG)*
	Thwarting: I: *How do you like homework in PE?*
	S1: *Silly.*
	S2: *So I think, I have on Wednesdays and Thursdays gymnastics for two and half hours. How should I manage all the homework? I have something different to do than homework. (Interview 3, IG)*

Note. S = student, I = interviewer, IG = intervention group, CG = control group.

the provided intervention elements, which explains the higher number of thwarting codes in comparison to the CG (10 IG vs. 2 CG).

Positive Feedback. IG students reported encouraging and comforting teacher behavior, except on the part of for two teachers. Teachers' praise, appreciation, encouragement, assistance as well as rewards were very meaningful for the students. CG students also reported very positively about their teachers' feedback culture. The students' statements described mostly encouraging teacher behavior. In this subcategory, we did not identify any qualitative difference between the groups.

Students' Expertise. In both groups, students regularly had the opportunity to demonstrate techniques and exercises (12 IG vs. 13 CG). When other students explained the exercise, it was easier for the students to understand it because "my [classmate] explains it differently" (Interview 2, IG). The girls seemed motivated "to point someone in the right direction" (Interview 13, CG). However, students complained that "always the same students" (Interview 3, IG) demonstrated the exercises, which was "sometimes a bit unfair, because [the teacher] only chooses the best ones" (Interview 5, IG). Furthermore, students felt uneasy when they had to present challenging exercises in front of the class. This somewhat limited the primarily positive feedback on this subcategory in both groups.

Relationships. Positive relationships were invigorated in both groups (19 IG vs. 28 CG). Students supported each other mutually and this cooperation encouraged the students to learn and to succeed. Seemingly, the students got along well, hung together, showed a motivated performance in PE, and they "want to help one another" (Interview 11, CG). Differences in this sub-category might have been caused by the thwarting influence of a poor teacher-student relationship, especially illustrated by two IG focus groups (18 IG vs. 11 CG).

Rituals. Every IG focus group reported on the intended intervention ritual while, with one exception, the CG focus groups negated the question regarding a ritual. This explains the different number of assigned codes (11 IG vs. 2 CG). IG interviews implied that students felt welcomed and integrated, but if the ritual took too long, motivation switched completely. Moreover, the importance to create and establish a ritual that everyone likes became obvious.

Social Environment. No focus group reported on homework which involved assistance by peers or family. Students complained that PE homework would limit their actual leisure time, since they already pursued an active lifestyle or had other obligations. Several students reported that they did exercises or sports in their free time that they were introduced to in PE. Overall, the low number of codes indicates that teachers usually assign do not homework in PE.

4. Discussion

The purpose of this study was to explore the extent to which an SDT-based intervention and intrapersonal factors, such as SES, BMI and age, influence adolescent girls' MVPA levels and to evaluate this intervention from various angles by analyzing the concordance of quantitative and qualitative measurements. Teachers of intervention classes were trained and taught SDT-based PE lessons over a 16-week period. Outcomes were assessed by questionnaires, accelerometry, systematic observations, and semi-structured interviews.

Given our objective that the CReActivity intervention increases the MVPA levels of the IG girls compared to the CG girls, our quantitative and qualitative results do not provide enough evidence for a positive intervention effect on MVPA in this study sample. Nevertheless, we assume a certain dose-response relationship due to the positive tendency of a slightly lower decline in MVPA for IG students. Compared to a comprehensive multi-component school intervention, which significantly increased adolescents' MVPA level by seven minutes in comparison to the CG (Sutherland et al., 2016) our single-component intervention gave rise to a – however non-significant – difference of almost two minutes per day between groups at follow-up.

A recent meta-analysis of 17 RCTs promoting daily MVPA established that school-based interventions are not effective (Love et al., 2019). Although we developed PE lessons especially designed for the girls' needs, teachers' support of the BPN could not be significantly strengthened by our intervention components. Our findings are in line with previous research which showed the limited influence of SDT-based interventions in PE on daily MVPA of adolescents (e.g., Meng & Keng, 2016; Okely et al., 2017; Roth et al., 2019b). Yet, a range of SDT-based interventions in PE reported significant intervention effects on motivational and activity-related outcomes (Lonsdale et al., 2013; Saugy et al., 2020; Standage et al., 2012).

Yet, before we try to elaborate these psychological mechanisms, the question of whether teachers were able to support girls' BPNs must be answered. Questionnaire data indicated that the IG students' perceived BPN support did not increase from baseline to post-intervention. Moreover, BPN support significantly decreased after the intervention period. This might be attributed to a possible relaxation effect in terms of the IG teachers because they did not have to follow the intervention guidelines anymore. Based on observational data, IG teachers used elements of BPN support more frequently, although no significant differences between the groups were measured. Since observations were scheduled in consultation with teachers, it is possible that lessons were especially prepared in order to fulfill the observers' expectations. Our results particularly indicate that CG teachers similarly support students' BPNs. The interview data further revealed only slight or negligible differences in need-supportive teaching between the groups. This can attributed to the fact that within the state-wide curriculum, a need-supportive teaching style is already embedded to some extent. Yet, considering the cogency of the statements, IG teachers did not or were not able to consistently implement the intervention components.

Nevertheless, of particular interest is how the girls perceived the need-supportive components by their PE teachers. As one exception, the rituals interview subcategory shows a distinct difference in favor of the IG. Rituals could serve as a condition for relatedness satisfaction in PE. A warm welcoming and farewell, optimally created by students, is socially inclusive and creates a firm and trustful atmosphere as well (Gibbons, 2014). Students highly appreciated when the teacher communicated on equal terms and adopted a friendly and supportive role. Two IG teachers seemingly had a tense relationship with their students, resulting in a higher number of thwarting codes in the relationships subcategory. Several statements illustrated that these teachers failed to create a feeling of success, resulting in a higher number of thwarting codes in the category of competence. Apparently, the combination of competence and relatedness satisfaction is an incentive for PA, which substantiates the assertion that relatedness satisfaction provides the basis for competence and autonomy satisfaction (Ryan & Deci, 2000).

Throughout the focus groups, girls envisioned their ideal PE class as a conceptual framework in which they contribute their ideas and interests to help co-create the lesson. Rather than just the opportunity to choose from certain games or exercises, a more promising method is to provide "real" co-determination, because it positively influences students' autonomy satisfaction and engagement in PE (Ağbuğa et al., 2016; Reeve, 2016). Moreover, our study confirmed that autonomy satisfaction significantly predicted girls' MVPA. Current literature underlined that competence satisfaction leads to higher motivation (Franco & Coterón, 2017), positive perceptions of one's own PA and performance (Leptokaridou et al., 2015). Besides having fun with their friends, students liked to "burn off energy" by doing exercises they liked. Students wanted adequate requirements as well as challenging tasks, since they were motivated by achieving certain challenges after persistent exercise.

Teachers' need-supportive behavior has a dynamic structure and it seems somehow difficult to strike a balance in PE (Ntoumanis et al., 2018). For example, the frequently discussed aspect of picking teams in PE (Barney et al., 2016), illustrates that in some situations the support of one need (e.g., competence) simultaneously thwarts another need (e.g., autonomy). Teachers decide whether they allow students to choose their teams to create autonomous and self-regulated situations in which social values such as fairness and teamwork are learned—or if they choose the groups on their own to equalize team strength and/or promote social inclusion.

Furthermore, students' evaluation of their PE classes is influenced by their personal perception of the teacher-student relationship and less by specific sport, exercises or lesson contents (Gairns et al., 2015). Of course, the freely selected PE contents chosen among the IG teachers might lead to certain variations, yet it is more important to consider the fact that not all students perceive the same need-supportive teaching behavior as equally satisfying (van den Berghe et al., 2015). As can be seen from the aforementioned baseline differences with regard to competence satisfaction and support between dropouts and students who reported on their PA we suppose – in line with the literature – that unmotivated girls perceive teachers' need support as being weaker and thus could negatively bias the rating (Shen, 2015). However, this sub-group of students particularly profits from a supportive approach, while a controlling teaching style could hinder their motivation even further (Meyer et al., 2016; Perlman, 2015). Based on the integration of mixed method results, we conclude that besides being affected by need-supportive teacher behavior, motivational and PA outcomes are also influenced by need-thwarting and need-indifferent teacher behavior, which should be investigated in future studies (Bhavsar et al., 2019). Another convergent conclusion is that students assign certain relevance to teachers' BPN support in terms of promoting motivation for PA. This pattern holds even though the findings diverge for competence and relatedness support. Moreover, the mixed method analysis revealed inconsistent implementation qualities throughout the intervention classes. In essence, these conclusions justify further RCTs to identify the mechanism of changes in PA behavior in adolescent samples and highlight the maxim to increase the implementation quality of content-specific SDT elements in PE.

Adolescents' PA behavior is influenced by several intrapersonal determinants (e.g., age, gender, ethnicity, body size) (Roth et al., 2019a). Contrary to the literature (Jago et al., 2020; Robbins et al., 2020), our student-level predictors BMI and SES showed no significant effect on MVPA. Only a significant age effect supported the evidence that older students are less active than younger ones (Finger et al., 2018). Interestingly, the girls who dropped out during the intervention period or failed to meet the wear-time validation are older and have a lower SES. This lets us assume that these girls do not want to reveal their likely lower PA levels. Since these students might not be adequately represented, we can only speculate about the extent to which the intervention affected their PA behavior. Moreover, this explains the relatively high MVPA levels of the female sixth graders. A recent study showed that

certain motivational profiles facilitate PA behavior in adults (Emm--Collison et al., 2020). Bachner et al. (2020) confirmed this aspect in our sample and evidenced that autonomously motivated girls are more active. Thus, it is fair to say that a self-determined motivated girl is more likely to show more engagement in PA than a girl with an extrinsic motivational profile.

4.1. Strengths and limitations

We incorporate the strength of a mixed-method evaluation within this cluster RCT and thereby – as the first study of its type in Germany - provide a meaningful description of device-measured PA behavior of girls and its BPN-based processes in PE. Hence, we scrutinize the SDT approach by corroborating qualitative findings and quantitative evidence in the interpretation.

The challenges in implementing need-supportive interventions in the educational setting, several of which apply to this study, were discussed by Ntoumanis et al. (2018). For instance, the replicability of this study is only partially possible because many factors could not be controlled. Chances are that teachers' individual characteristics affected the student outcomes. A mediation model in which teacher behavior would be predicted by the intervention and lead to positive student outcomes would have addressed this issue. In addition, our study did not include objective measures of teacher characteristics (e.g., education, experience) and personality dispositions that might be linked to teaching styles in PE classes. Only volunteer teachers who were motivated to participate in the study responded to the recruitment letter. This selection procedure possibly biased the findings since those teachers likely show more engagement in PE, which applies to teachers of both IG and CG. Moreover, the selection process for the focus groups was not ideal. Motivated students probably said positive things about PE, while less enthusiastic students likely said negative things about PE. The statements of these unequal sub-groups were leveled out by the structured content analysis, which lacks the opportunity to identify discrepancies among these students.

Although the mediating role of BPN satisfaction with regard to the effect of BPN support on motivational and PA outcomes has been partially proven (Vasconcellos et al., 2020), our data did not properly describe models including interactions between support and satisfaction. When analyzing non-significant model estimates, we can assume that interactions are too weak to explain MVPA levels in this case. We refrain from further describing those rather complex interactions, since the explanatory power of the model is limited due to presumably biased regression coefficients caused by collinear predictors.

Incongruent results of the different methods stem from the fact that perception and valuation of primarily psychological constructs differ from child to child and also from students to observers. Specifically, the evaluation of the underlying teaching structure in PE is a sophisticated task for observers. Although observations provide reliable results, the dichotomous assessment of need support does not reflect the complex behaviors in PE. In future studies, we would encourage improved observation software and consistent observer training to increase the reliability of observations.

4.2. Recommendations for future PE interventions

Teachers experienced difficulties integrating new teaching methods into their routine because curricular requirements limit the time in which they should have prepared and implemented the intervention lessons. This theory-practice gap might have compromised the implementation of CReActivity components. A solution could be a certified, interactive workshop, which would impart theoretical considerations with long-lasting effects, as shown in the autonomy-supportive intervention program (ASIP) developed by Cheon and Reeve (2013). Teachers who participated in the ASIP training behaved significantly more autonomy supportive and significantly less controlling in PE, showed greater teaching motivation and increased well-being (Cheon et al., 2016, 2012; Ntoumanis et al., 2017). Moreover, students of ASPI teachers benefitted significantly in terms of increased motivational and performance-based outcomes (Ntoumanis et al., 2018; Tilga, Kalajas-Tilga, Hein, Raudsepp, & Koka, 2020).

Assessing PA levels during PE by accelerometry would possibly allow the identification of a short-term effect on PA during the PE class. Generally, the low accelerometer compliance is a serious issue in RCTs (e.g., Cohen et al., 2015; Okely et al., 2017; Sutherland et al., 2016), which limits the cost-effectiveness of the study. In addition, the necessary wear-time validation for accelerometry data led to a significant post-randomization loss of participants, which violates the "true" principles of intention-to-treat analysis (Fergusson et al., 2002; McCoy, 2017). Although we addressed the dropouts and missing values by our statistical modeling and a sub-group analysis, this "false inclusion" procedure limits our assertions to female sixth-graders who reported their PA (Batista Barretto dos Santos Lopes, Klaus et al., 2019). Because of the discrepancies in BMI and SES between completers and dropouts we cannot generalize our findings to dropouts, which limits the external validity (Findley et al., 2020). Consequently, we would recommend recruiting a minimum of 800 students to achieve the statistically necessary sample size. Since, to our knowledge, a best practice for the application of intention-to-treat principles in cluster RCTs using accelerometry data does not exist, interdisciplinary dialogues are necessary to reshape and facilitate "trial planning, design, conduct, data analysis and interpretation of the results, regarding the treatment effects that the trial seeks to address" (Oude Rengerink et al., 2020, p. 2).

5. Conclusion

We scrutinized the effect of SDT-based lesson elements on the MVPA of female students and accounted for intrapersonal and socio-ecological factors which generally influence the longitudinal change in PA behavior. Moreover, we thoroughly describe and evaluate a complex school-based intervention in PE, and thus make a significant contribution to the design, methodology and implementation of future PA interventions in the educational setting.

The CReActivity study was not effective in increasing the daily MVPA of female sixth graders. A maximization of implementation fidelity is necessary to produce a basis for potential intervention effects on actual PA behavior. Further investigations are required to clarify the mechanisms of the teaching behaviors of need thwarting and need indifference, as well as need support on students' motivation and PA. The major task for researchers is to reconcile the perceptions of teachers, parents, and students when developing the intervention in order to circumvent environmental barriers to promoting PA in the school setting. Accordingly, researchers should integrate evaluations which are explicitly designed to extend the insights of the SDT mechanism of changes in PA behavior, which again are cannot be completely measured with quantitative methods.

Authors' contributions

DS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing - original draft, Writing – reviewing & editing; JB: Conceptualization, Data curation, Investigation, Methodology, Writing – reviewing & editing; DR: Data curation, Formal analysis, Methodology, Writing – reviewing & editing; SH: Formal analysis, Validation, Methodology, Writing – reviewing & editing; YD: Conceptualization, Funding acquisition, Project administration, Resources, Supervision, Writing – reviewing & editing

Ethics approval and consent to participate

The Ethics Committee of the Technical University of Munich approved the study (project number 155/16S). The Ministry of Cultural

Affairs and Education of the State of Bavaria in Germany approved the research with regard to content, participants and data protection, registered as IV.8-BO6106/52/12. The study was retrospectively registered in the German Clinical Trials Register (trial ID: DRKS00015723, date: 2018/10/22). All participants provided written informed consent.

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Declaration of competing interest

The authors declare that they have no competing interests.

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Appendix A. and supplementary data

Supplementary data, CONSORT checklist and Appendix 1 associated to this article can be found online at https://doi.org/10.1016/j.psychsport.2021.101902.

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5 General Discussion

The aim of this dissertation was to implement and evaluate the CReActivity program to answer the question of whether a need-supportive teaching style in PE is beneficial for the girls' physical activity levels. In addition, this thesis discusses the accelerometer-measured physical activity levels and the methodological rigor of evidence. Finally, the limitations of this study imply comprehensive future research perspectives and thereby recall the duty and need to motivate students for physical activity.

In general, it is important to consider the methodological background of accelerometer-measured physical activity data due to various processing and intensity cut-points when comparing results (Bachner et al., 2021). For the German research community a best-practice of accelerometry assessment was recently published by Burchartz et al. (2020), which is in large parts consistent with the methodology of this study. But due to the aforementioned lack of accelerometer-assessed physical activity data from German adolescent samples and methodological differences across studies a comparison of results is not meaningful. In order to somehow classify the girls' average of MVPA, 87.5 min on weekdays (*SD* = 23.2) (Bachner et al., 2021), I note–considering the limit comparability–that Brooke et al. (2014) presented in their meta-analysis of 36 studies an average of 82.3 min (*SD* = 44.0) in MVPA.

The high average values of daily MVPA might be surprising. It seems that the recruited sample is quite active in comparison to the outlined prevalence of inactivity in Germany (see 1.3; Kuntz et al., 2018, Bucksch & Sudeck, 2020). Yet, to avoid misunderstandings, the self-report questionnaires utilized in the KiGGS and HBSC study provide only an estimated prevalence of children and adolescents meeting physical activity guidelines, while accelerometer data measured the amounts and intensities of the physical activity behavior. A population-based conclusion on the fulfillment of physical activity

guidelines across studies is only convincing if researchers harmonize the analysis of accelerometer data and use consistent methodologies for physical activity surveillance.

This study provides an accurate and valid measure of girls' physical activity behavior and patterns throughout the week (Bachner et al., 2021). The analysis in Publication 3 further indicates that intrapersonal factors are associated with the girls' physical activity behavior. Girls who did not provide any valid physical activity data had a significantly lower socioeconomic status and were slightly older than those who provided at least one valid physical activity data. Moreover, the students who had complete physical activity data had a lower body mass index than those students who reported none, one or two physical activity data. In line with these findings, teachers reported that exactly those refused to participate in the study who showed less motivation and interest in sports, which were older and overweight girls. This lets us assume that exactly the high-risk group of students (Cooper et al., 2015; Kuntz et al., 2018; Schwarzfischer et al., 2017), who knew that they were not active, did not want to reveal their low physical activity levels in our study. This indicated that the physical activity levels might be biased due to a selective sample, and thus the students at higher risk for inactivity were likely underrepresented in this study. From an empirical perspective, these findings tap into a general limitation that the claims cannot be generalized onto the sample of girls but are reduced to female sixth graders who are willing to report their physical activity. Nevertheless, these findings confirm the consideration of the YPAPM that personal demographics, such as age, socioeconomic status and body mass index influence the physical activity behavior of adolescents (S. Chen et al., 2014).

Although the linear mixed models could not evidence a significant intervention effect on MVPA, the intervention group performed almost four minutes more in MVPA than the control group on a daily average during the follow-up week. Several single-component school-based interventions report non-significant or negligible intervention effects on the

girls' physical activity (Camacho-Miñano et al., 2011; Voskuil et al., 2017). Although not specifically focused on girls, the meta-analysis by Metcalf et al. (2012) also suggests small to negligible intervention effects of physical activity programs on objectively measured physical activity of adolescents. In addition, the direct effect of need-supportive interventions in PE on daily MVPA could not be evidenced by our study, which is in line with several self-determination theory-based interventions in PE (Saugy et al., 2020).

It seems as if the success of need-supportive interventions is challenged by several issues affecting the quality of implementation (Ntoumanis et al., 2018). Within the social-psychological sciences and in particular within the behavioral research the proof of causal relationships, e.g. between teachers need support and students' behavioral changes in physical activity is only of theoretical nature drawn from epidemiologic research (Gopalan et al., 2020). Indeed, empirical indications provide meaningful descriptions of complex relationships between the groups of need supportive techniques or of singular intervention components and physical activity. But an if-then relationship between the pedagogical behavior of teachers and students' physical activity behavior is almost unprovable because the construct of physical activity behavior is caused and influenced through multiple, interrelated factors, whose complexity is almost impossible to measure (Bauman et al., 2002).

For example, the teacher-student relationship influences how students' perceive the PE lesson (Sparks et al., 2015). If the evaluation of PE is biased due to a positive or negative teacher-student relationship, it is less meaningful to generalize or adopt the evaluated intervention components. Thus, further perspectives and process evaluative measures are necessary to identify the extent to which these relationships, e.g. between the teachers and students, might affect the efficacy of related behavior change techniques. The innovative mixed-method procedure allowed us to create a high-quality description of differences

between the groups, teachers, and students. The disagreement between the sets of results revealed slightly different perceptions of competence and relatedness support between and within groups, while methods agreed on similar levels of autonomy support across groups. Especially, the qualitative insights provide a meaningful explanation of how the students perceived the intervention components. Moreover, the recently published classification of self-determination theory-based behavior change techniques by Teixeira et al. (2020) helps readers to classify and compare the presented teaching strategies with other studies in the field.

5.1 The Self-Determination Approach in Physical Education

Clearly, one has to acknowledge that (statistically) significant differences between the groups were neither quantifiable at posttest nor observable during the intervention period, indicating that control group teachers might have equally supported the students' needs. But we have taken advantage of the mixed-methods approach, which provides a description of need-supportive components, which are eligible for instruction in PE, and thereby informs the development of future PE interventions.

The focus groups of both groups equally attributed a certain relevance for teaching methods which perfectly fit to the understanding of need-supportive teaching. The girls appreciated a need-supportive climate in PE in which teachers provided 'real' choice and co-determination, improved transparency, and incorporated the students' feedback. This overlaps with strategies of the aforementioned theoretical dimensions of good teaching (Herrmann et al., 2016). Thus, teachers are encouraged to play a need-supportive role, seeking for student-oriented variation and point out behavior rules to increase their influence on the girls' engagement in PE.

Within the ongoing pedagogical discussion it is argued that the implementation of theory-based teaching methods, for example frequent reflection sessions, should not

diminish the actual movement time in PE (Wolters et al., 2009). Teachers mentioned that they had to adapt the intended contents of the lesson plans because the students desired more intensive activities, such as games or funny exercises. Moreover, teachers could not completely adhere to the implementation procedure because curricular requirements, such as taking grades or exercises for Bundesjugendspiele[4] need to be fulfilled. Experts emphasize that teachers' routines are "either different or not sufficiently need supportive" (Ntoumanis et al., 2018, p. 16), when it comes to such unforeseen events, which differ from the implementation protocol. Specifically, several teachers could not implement the intervention lessons during the entire intervention period and did not report the adaptations of lesson plans. The experts further stated that the success of need-supportive interventions depends on how the teachers communicate and interact with their students in such situations (Teixeira et al., 2020). Reeve (2016) further mentions that the need-supportive transformation of a teacher starts by being less controlling and, in a subsequent step, being more supportive. Considering the evidence of the systematic review by Lai et al. (2014) on school-based interventions focusing on physical activity, an intervention period of more than one year is recommended to show a sustainable effect on students physical activity. With regard to this, the training dose of one hour and teacher support during the 16-week intervention period might not have been sufficient. Moreover, the systematic review by Dudley et al. (2011) highlights the need to provide professional development and ongoing support for teachers in order to achieve a beneficial teaching style. However, the implementation of a comprehensive and consistent teacher training throughout the school year faces structural barriers, as the teachers must fulfil their official duties. Teachers prioritize the perceived extra-curricular demands of the researchers lower in comparison to the PE curriculum

[4] Annual sport event for children and adolescents at German schools.

(Lander, Hanna, et al., 2017). Teachers even refuse to participate in studies since they receive no adequate compensation for their additional expenses of time and effort. This calls for joint collaborations of key stakeholders at the policy level and researchers in order to create a more health-oriented education of teachers and students.

Beyond, simultaneous advances in the field claim that need-controlling and need-indifferent behavior of coaches predicts how exercisers perform (Bhavsar et al., 2019). Several studies clarified that need thwarting and the frustration of basic psychological needs influences motivation negatively, indicating serious implications for education (Hein et al., 2015; van den Berghe et al., 2016). Hence, the question of "What's next?" may be answered through a further investigation of these constructs.

After all, the question of why the intervention group students perceived significantly less need support than the control group students, but at the same time showed the tendency to be more active at follow-up remains unaddressed. Maybe the comeback to "business-as-usual" was less need-supportive than the CReActivity lessons or few teachers created over the school year a negative teacher-student-relationship which in the end affected the evaluation of the PE lessons. Additional analysis that explores the mediating relations within this intervention exceeds the scope of this thesis, but would display insights into why the intervention group students showed these controversial behaviors. In the end, the evaluation of preventive and health-enhancing measures, such as physical activity programs, is still of central importance (Kliche et al., 2011) and the need to further investigate the educational setting in Germany is emphasized in order to clarify, *what* works *how* and for *whom* in *which* contexts (Langford et al., 2015).

5.2 Limitations

The hypothesized structure of the analyzed model in Publication 3 was of particular interest to evaluate the intervention efficacy. But the sample size was not sufficient to proof a statistical significant intervention effect for this rather small difference in the main outcome In addition, several reasons (items perceived equally, missing values) led to a certain dependency and collinearity among variables which were not ideal in the statistical analysis. Although we addressed collinearity using grand mean centering of basic psychological need variables, the collinearity limits our model precision because the inflated variance biased the computed estimates. These real and not ideal conditions impeded the identification of a significant treatment effect.

Drawn upon the results from systematic observations and interviews, different perceptions of teaching styles were obvious. We can conclude that the extent to which the teachers implemented the need-supportive teaching style differed. Although our teacher training modified teachers' behavior to a favorable direction and all teachers completed the intervention period, detailed quantitative measures of components of the quality of implementation, such as intervention fidelity, program reach, or dosage (Durlak, 2016) might explain the null intervention effect. However, these aspects and teachers' education or characteristics (e.g., personality traits, teaching experience) that might be linked to their teaching behavior, were not assessed.

The vast majority of schools in the sampled area refused to participate due to gym construction, insufficient PE personnel capacity, or other implemented studies. These structural and institutional barriers likely impaired the recruitment of a sufficient sample size. Moreover, time pressure, grading, insufficient gym capacities, or a lack of sports material challenged teachers in creating attractive and diverse PE lessons and thus limited the implementation of the intervention components.

The limitation that the schools allowed us only using the PE lesson time for our measurements prohibited to investigate a direct effect on the students' MVPA during PE since we had to distribute and collect the devices during PE lessons. This means that the first day, to antagonize novelty, and the last day, which had less than eight hours wear-time, of measurement were excluded by the wear-time validation algorithm. Subsequently, we could not measure physical activity data during PE lessons. But, as part of the evaluation, the physical activity levels during PE were assessed using the SOFIT observations, which provides at least a limited insight on the girls' physical activity levels during PE. Another potential limitation is the non-randomized mixture of ActiGraph models (i.e., GT3X and GT3X-BT) across control and intervention groups, which might have led to different estimates of physical activity.

5.3 Future Research Perspective

The school setting is an attractive domain since it provides a cost-effective and socially compatible opportunity to reach the next generations before fatal consequences occur. Apparently, PE is a main area to be physically active because all children and adolescents are necessarily involved through the curriculum. So far, the school communities attempt to create an active, healthy school environment, which counteracts the limited leisure time of children and adolescents. These measures are seldom scientifically evaluated and thus a major opportunity to fill the inconsistent picture of the students' physical activity levels is missed.

In the social sciences, the rigor theoretical foundation serves as the conceptual basis to understand and investigate complex relationships (Glanz & Bishop, 2010; Torraco, 2002). Interventions indicate, per se, the application of theory into practice. Single-component interventions allow researchers to identify and validate specific theory-based behavior change techniques but have a significantly lower impact on adolescents' physical activity

behavior compared to multi-component interventions. On the other hand, the analysis of a multi-arm study design requires comprehensive evaluative measures, a larger sample size and advanced statistical expertise (Allore et al., 2005), for example in conducting a mediation analysis (Klos et al., 2020). Considering also the aforementioned epistemic issues in the behavioral sciences, this might lead to a fundamental debate among researchers and stakeholders of how to combine the urgent need of physical activity promotion with the scientific objectives and rigor of evidence.

At the same time, the continuous progression in the digital age reinforces the need to address screen-based behaviors not only in reducing consumption of social media. Several advantages come along with smart devices. A recent systematic review of "eHealth", i.e., the incorporation of internet, PCs, tablets and other mobile technologies in health-enhancing interventions, could evidence a short-term, however limited, effect on health-related risk factors, such as physical activity behavior, nutrition and media consumption. For adolescent boys a moderate effect was recognizable, while girls showed less response (Champion et al., 2019, e206). However, this research area is in the early stages of development (Drehlich et al., 2020), and long-term effects are in need of further investigations. This idea could be a methodological advancement for school-based interventions because smart devices might facilitate assessments and organizational tasks and could be utilized as teaching material in PE (Yang et al., 2020) in order to assist teachers implementing a need-supportive teaching style.

Reducing the high amounts of sedentary time during school hours–especially in classrooms–may become a primary or secondary objective of physical activity promotion interventions. Since findings on classroom-based strategies and measures promoting physical activity and reducing sedentary time are not consistent (McMichan et al., 2018), educational and public health scientists are supposed to consider enhancing research on how

to impart health-enhancing teaching methods in academic learning environments (Watson et al., 2017). Hence, interdisciplinary collaborations are necessary in order to encourage parents, teachers and stakeholders to tackle the inactive behaviors of our children and adolescents.

Some practical and methodological implications of the study have already been mentioned before and yet there are a few topics to consider in future studies. A monitoring of teacher personality, education and attitudes regarding need support in PE would allow us to quantify the moderating effects on the treatment efficacy. And yet there is the question of whether the behavior of teachers can be generally modified and to which extent does this change enhance the students' motivational and physical activity-related outcomes? Cheon et al. (2012) with their teacher-oriented autonomy-supportive intervention program in PE, conducted in secondary schools in Seoul, South Korea, provide a clear indication for improved teacher behavior which also affected the students' motivational outcomes. Similar results were found, for example, in Spain (Franco & Coterón, 2017; Moreno-Murcia & Sánchez-Latorre, 2016), and Finland (Kokkonen et al., 2019), however those studies did not investigate the direct effect on accelerometer-measured physical activity. Within the social-ecological framework of the YPAPM, further RCTs are necessary in order to demonstrate whether the self-determination theory-based motivational mechanism of physical activity behavior change works in the German school system.

Based on the evaluation of the CReActivity study, the implementation of a need-supportive teaching style in PE turns out to require less content-specific but more behavioral input in terms of communicative and social skills (Cheon & Reeve, 2013; Ntoumanis et al., 2018). Instead of providing detailed lesson plans, a more meaningful strategy of implementation might be to enhance teachers' skills and competences (Cheon et al., 2018). In addition to their already high education, a comprehensive professional training might

impart the knowledge and skills they need to successfully implement the intervention components (Kealey et al., 2000). Hereby, it is recommended to account for both, context and content-specific preferences and circumstances in which the teachers are working (Kealey et al., 2000). This could minimize the differences among intervention teachers and maximize the quality of implementation. Lander, Eather, et al. (2017) concluded in their systematic review on the effects of teacher trainings that the role of teacher trainings is unclear and understudied. Thus, the mediating role of the teacher training and the supposed behavioral changes of teachers should be given more attention.

6 Conclusion

This thesis revealed that the CReActivity intervention promoted a slightly lower decrease of MVPA in the intervention group compared to the control group, even if the effect of need-supportive teaching in PE of sixth-grade girls is limited and non-significant. However, before we can conclude whether the self-determination theory approach is a valid strategy to increase the girls' physical activity, further investigations are necessary. This might explain why their physical activity levels decrease during one school year to such high extents and how PE teachers' behavior may lead to behavioral changes in physical activity.

The urgent need for preventive measures such as physical activity promotion in adolescence is undisputed. Given the sedentary school routine, physical activity programs should arbitrarily focus on the reduction of sedentary time. Persisting the idea of school-based multi-component interventions calls for interdisciplinary dialogues and collaborations in order to apply efficient, computational techniques to test the efficacy of multiple intervention strands while increasing the chance for an immediate health benefit for the students. Moreover, combined forces of researchers and stakeholders are required to reduce the structural barriers that hinder the implementation of theory-based interventions and solve the methodological issues regarding the physical activity surveillance.

In respect of the idea that the school is not only an educational institution but also an activity institution, we have to identify efficient strategies that create a health-enhancing work and learning environment as well as to integrate those strategies in a long-lasting and holistic way.

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8 Appendix

8.1 List of Publications

1. Sturm, D. J., Kelso, A., Kobel, S., & Demetriou, Y. (2020). Physical activity levels and sedentary time during school hours of 6th-grade girls in Germany. *Journal of Public Health.* Advance online publication. https://doi.org/10.1007/s10389-019-01190-1
2. Sturm, D. J., Bachner, J., Haug, S., & Demetriou, Y. (2020). The german basic psychological needs satisfaction in physical education scale: Adaption and multilevel validation in a sample of sixth-grade girls. *International Journal of Environmental Research and Public Health*, *17*(5), Article 1554. https://doi.org/10.3390/ijerph17051554
3. Sturm, D. J., Bachner, J., Renninger, D., Haug, S., & Demetriou, Y. (2021). A cluster randomized trial to evaluate need-supportive teaching in physical education on physical activity of sixth-grade girls: A mixed method study. *Psychology of Sport and Exercise*, *54*, Article 101902. https://doi.org/10.1016/j.psychsport.2021.101902

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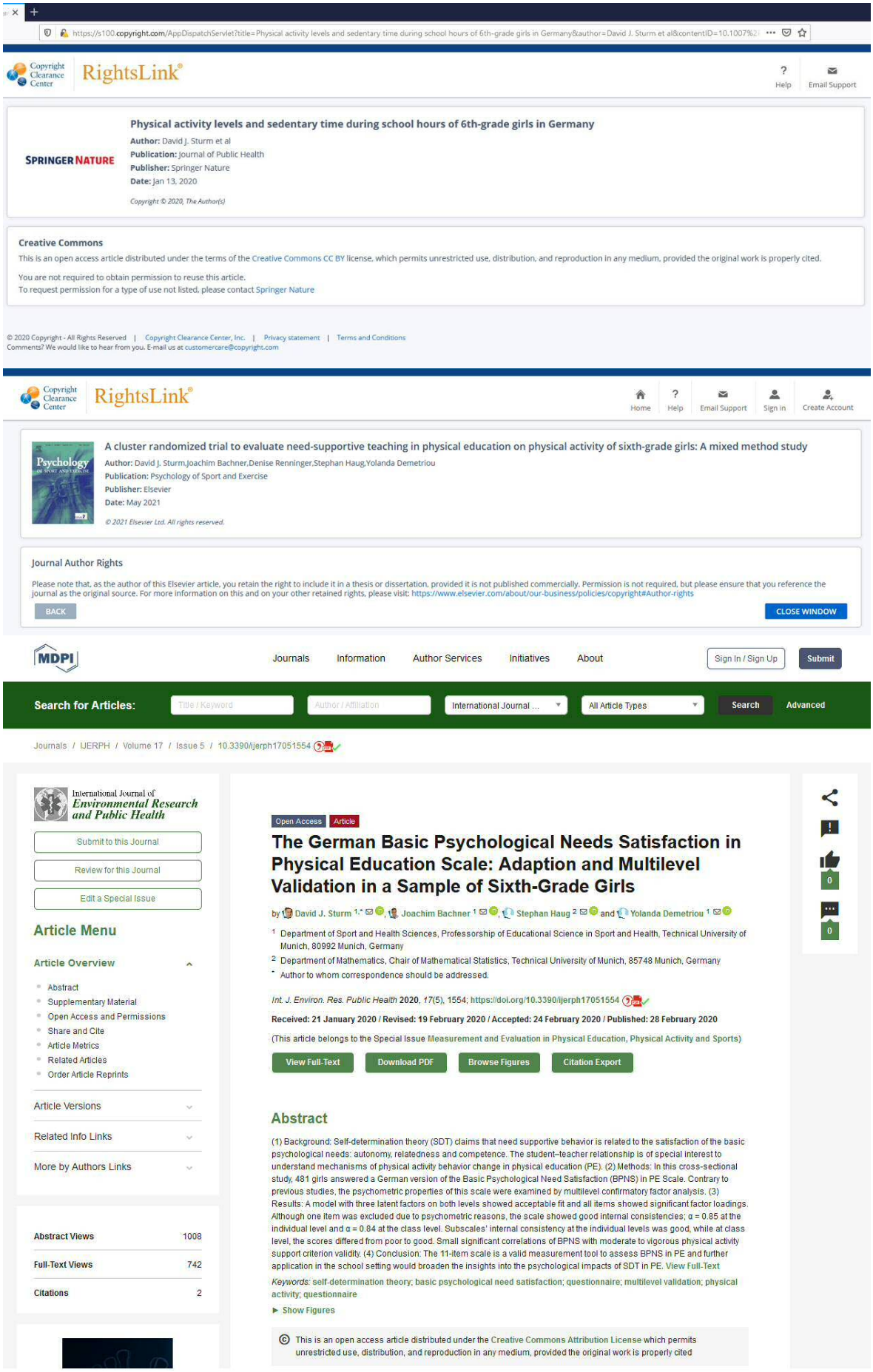

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Physical activity levels and sedentary time during school hours of 6th-grade girls in Germany

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A cluster randomized trial to evaluate need-supportive teaching in physical education on physical activity of sixth-grade girls: A mixed method study

Author: David J. Sturm,Joachim Bachner,Denise Renninger,Stephan Haug,Yolanda Demetriou
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Open Access Article

The German Basic Psychological Needs Satisfaction in Physical Education Scale: Adaption and Multilevel Validation in a Sample of Sixth-Grade Girls

by David J. Sturm [1,*], Joachim Bachner [1], Stephan Haug [2] and Yolanda Demetriou [1]

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Abstract

(1) Background: Self-determination theory (SDT) claims that need supportive behavior is related to the satisfaction of the basic psychological needs: autonomy, relatedness and competence. The student–teacher relationship is of special interest to understand mechanisms of physical activity behavior change in physical education (PE). (2) Methods: In this cross-sectional study, 481 girls answered a German version of the Basic Psychological Need Satisfaction (BPNS) in PE Scale. Contrary to previous studies, the psychometric properties of this scale were examined by multilevel confirmatory factor analysis. (3) Results: A model with three latent factors on both levels showed acceptable fit and all items showed significant factor loadings. Although one item was excluded due to psychometric reasons, the scale showed good internal consistencies; α = 0.85 at the individual level and α = 0.84 at the class level. Subscales' internal consistency at the individual levels was good, while at class level, the scores differed from poor to good. Small significant correlations of BPNS with moderate to vigorous physical activity support criterion validity. (4) Conclusion: The 11-item scale is a valid measurement tool to assess BPNS in PE and further application in the school setting would broaden the insights into the psychological impacts of SDT in PE. View Full-Text

Keywords: self-determination theory; basic psychological need satisfaction; questionnaire; multilevel validation; physical activity; questionnaire

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