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Physical Activity and Mental Health in School-Aged Children: A Prospective Two-Wave Study during the Easing of the COVID-19 Restrictions

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Preamble

Please note that partial results along with contents of this dissertation have been previously published as an original and peer-reviewed scientific journal article in the special issue *Child and Adolescent Mental Health during the Covid-19 pandemic* of the quartile 1 (Q1) ranked *Child and Adolescent Psychiatry and Mental Health* journal edited by *Springer Nature & BMC* and are now accessible to the scientific community. The published article covers the scientific contribution addressed in this work. The present dissertation has referenced relevant paragraphs and content, following the guidelines and procedures of safeguarding good research practice to prevent plagiarism or dual publication. The published article is cited as follows:

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Further information on the original publication can be found in Chapter 7. In addition, this work complied with American Psychological Association (APA) ethical and reporting standards.

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List of Abbreviations

b	Beta coefficient (coefficient estimate)
CI	Confidence interval
Cohen's d_z	Effect size used to indicate the standardized difference between two means
Cov	Covariance (of slopes and intercepts)
COVID-19	Coronavirus disease 2019
f^2	Effect size
FAS III	Family Affluence Scale III
HRQoL	Health-related Quality of Life
KIDSCREEN	KIDSCREEN-52 questionnaire
M	Mean
min	Minutes
N	Number of samples to be tested
n	Number of participants in the sample
p	Probability value (p-value)
PA	Physical activity
SD	Standard deviation
SDQ	Strengths and Difficulties Questionnaire
t	T-test
Var(u_{0j})	Variance of intercepts
Var(u_{1j})	Variance of the slops
Z	Wald statistic (standard z-score)
-2LL	-2 Log-likelihood

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1. Summary

This dissertation investigated the reciprocal relationship between psychological variables (i.e., mental health and health-related quality of life) and physical activity to gain a better understanding of the mental health conditions of school students that may be influenced by, or have an impact on, their physical activity levels during the gradual easing of the COVID-19 restrictions in Germany.

Physical activity and exercise are essential strategies for enhancing physical, psychosocial, and mental health, particularly among children and adolescents. Such findings indicate that physical activity might be a beneficial approach to promoting the physical and emotional recovery of young people affected by the COVID-19 pandemic, which caused crucial changes in their daily routines and mental state. However, the literature remains unclear if mental health fosters, or is fostered by, regular physical activity during the phase-out of COVID-19 regulations and has not yet been established through longitudinal research. Understanding whether mental health before loosening the measures is associated with (the elevation of) physical activity during their easing is therefore crucial to effectively promote mental health in children and adolescents. To address the gap in the existing literature, this work aimed to examine the reciprocal association between physical activity and mental health during the easing of COVID-19 regulations. In particular, it was postulated that mental health during the pandemic would affect the extent to which children and adolescents resume physical activity after gradually phasing out the regulations. Furthermore, this work intended to explore whether physical activity engagement would predict mental health improvement after the pandemic.

To address the research questions, a quantitative longitudinal prospective study was conducted with repeated measurements in two waves (T_{week1} = pretest; T_{week6} = posttest) over six weeks during the easing of the COVID-19 restrictions, performed under real-life conditions in a German elementary and grammar school, targeting school students aged 6-18. The pretest data was collected in February 2022, shortly before the German government gradually eased the COVID-19 measures. The subsequent posttest took place six weeks later in April 2022. In total, N=170 children and adolescents (and their legal guardians for lower-graded youths) participated in the study (retention rate from pretest to posttest: 100%).

Internationally validated questionnaires recommended by the International Consortium for Health Outcomes Measurements (ICHOM) were used to collect data on psychological variables. Specifically, health-related quality of life was assessed by applying the *KIDSCREEN-52* questionnaire, and mental health by employing the *Strength and Difficulties Questionnaire* (with the subscales of emotional problems, conduct problems, hyperactivity, and peer problems). Physical Activity was continually assessed during the research period utilizing smart electronic devices equipped with an integrated pedometer.

Multilevel growth modeling was employed as the primary statistical analysis method. The study showed that physical activity levels improved steadily after the relaxation of COVID-19 limitations ($p < .001$). The increase was not explained by pretest mental health issues and health-related quality of life, except for emotional symptoms ($p = .041$). Students displaying more emotional symptoms had a more substantial rise in physical activity at the study end. Hyperactivity dropped significantly ($p = .004$), and physical well-being ($p = .004$), perceived autonomy ($p < .001$), and reported quality of school environment ($p = .008$) increased following the loosening of the COVID-19 limitations. However, participants' physical activity did not predict any of these improvements.

The negative impacts of COVID-19 restrictions on physical activity improved when children and adolescents were permitted to return to school. This can be mainly attributed to the educational environment, which offers numerous options for both official and informal physical activity rather than focusing on students' mental health.

Zusammenfassung

Diese Dissertation untersuchte die wechselseitige Beziehung zwischen psychologischen Variablen (i.e., psychische Gesundheit und gesundheitsbezogene Lebensqualität) und körperlicher Aktivität, um ein besseres Verständnis über die psychische Gesundheit von Schülern zu erlangen, die auf die regelmäßige körperliche Aktivität während der Lockerung der COVID-19-Restriktionen in Deutschland Auswirkungen hatte oder davon betroffen war.

Physische Aktivität und Bewegung sind wesentlich Strategien zur Verbesserung der körperlichen, psychosozialen und geistigen Gesundheit, insbesondere bei Kindern und Jugendlichen. Diese Ergebnisse deuten darauf hin, dass physische Aktivität eine wirksame Strategie sein könnte, um sich körperlich und geistig von der COVID-19-Pandemie zu erholen, die entscheidende Veränderungen im Tagesablauf und in der psychischen Verfassung der Jugendlichen verursacht hat. In der Literatur bleibt jedoch unklar, ob die mentale Gesundheit während des Auslaufens der COVID-19-Bestimmungen regelmäßige PA fördert oder durch diese begünstigt wird. Um die psychische Gesundheit von Kindern und Jugendlichen wirksam zu fördern, ist es daher von entscheidender Bedeutung, zu verstehen, ob die mentale Gesundheit vor der Lockerung der Maßnahmen mit regelmäßiger physischer Aktivität während der Lockerung der Maßnahmen zusammenhängt (bzw. dieses fördert). Um die Lücke in der Literatur zu schließen, wurde in dieser Studie die wechselseitige Beziehung zwischen physische Aktivität und psychischer Gesundheit während der Lockerung der COVID-19-Beschränkungen untersucht. Insbesondere wurde hypothetisiert, dass die psychische Gesundheit während der Pandemie ausschlaggebend dafür ist, inwieweit Kinder und Jugendliche nach dem Auslaufen der Vorschriften wieder physisch aktiv sind. Darüber hinaus wurde untersucht, ob physische Aktivität eine Verbesserung der psychischen Gesundheit nach der Pandemie vorhersagen würde.

Zur Beantwortung der Forschungsfragen wurde eine quantitative prospektive Längsschnittstudie mit wiederholten Messungen in zwei Wellen (T_{week1} = Pretest; T_{week6} = Posttest) über sechs Wochen während der Lockerung der COVID-19-Beschränkungen durchgeführt, die unter realen Bedingungen in einer deutschen Grundschule und einem Gymnasium für Schüler im Alter von 6-18 Jahren durchgeführt wurde. Die Pretest-Datenerhebung fand im Februar 2022 statt, kurz bevor die deutschen Behörden die COVID-19-Maßnahmen lockerten und aufhoben. Die Follow-up-Untersuchung (Posttest) erfolgte sechs Wochen später (April 2022). Insgesamt nahmen *N*=170 Kinder und Jugendliche (und deren Erziehungsberechtigte bei Jugendlichen in unteren Klassenstufen) an der Studie teil (Verbleibequote vom Pretest bis zum Posttest: 100 %).

Daten zu psychosomatischen Symptomen wurden über international validierte und vom International Consortium for Health Outcomes Measurements (ICHOM) empfohlene Fragebögen erhoben. Die gesundheitsbezogene Lebensqualität wurde insbesondere mit dem *KIDSCREEN-52-*

Fragebogen und die psychische Gesundheit mit dem *Strength and Difficulties Questionnaire* (mit den Subskalen emotionale Probleme, Verhaltensprobleme, Hyperaktivität und Probleme mit Gleichaltrigen) erfasst. Die körperliche Aktivität wurde während des Studienzeitraums kontinuierlich mit Hilfe von Smart Devices mit eingebautem Schrittzähler gemessen.

Multilevel Growth Modeling diente als zentrale statistische Analysemethode. Die Ergebnisse dieser Arbeit zeigen, dass PA nach der Lockerung der COVID-19-Beschränkungen sukzessive anstieg ($p < .001$). Der Anstieg wurde nicht durch psychische Gesundheitsprobleme und gesundheitsbezogene Lebensqualität während des Pretests erklärt, mit Ausnahme der emotionalen Symptome ($p = .041$). Schüler, die mehr emotionale Symptome aufwiesen, hatten am Ende der Studie einen stärkeren Anstieg physischer Aktivität. Hyperaktivität nahm signifikant ab ($p = .004$), und das körperliche Wohlbefinden ($p = .004$), die wahrgenommene Autonomie ($p < .001$) und die berichtete Qualität des schulischen Umfelds ($p = .008$) stiegen nach der Lockerung der COVID-19-Beschränkungen. Die physische Aktivität der Schüler sagte jedoch keine dieser Verbesserungen voraus.

Die negativen Auswirkungen der COVID-19-Beschränkung auf die physische Aktivität verbesserten sich, nachdem die Kinder und Jugendlichen in die Schulen zurückkehren konnten. Dies kann insbesondere auf das schulische Umfeld zurückgeführt werden, das viele Möglichkeiten für körperliche Betätigung sowohl auf formaler als auch auf informeller Ebene bietet, anstatt sich auf die psychische Gesundheit der Schüler zu beschränken.

2. Introduction

2.1 Study Rationale

Mental health problems (e.g., emotional, behavioral, and mental disorders) significantly contribute to health-related disability in children and adolescents (Erskine et al., 2015; Gore et al., 2011; M. G. Sawyer et al., 2001). In particular, a global prevalence of mental health disorders is observed in 13-20% of children and youths (Polanczyk et al., 2015). Moreover, the overall prevalence of behavioral and emotional disorders among school-aged children in Germany expanded significantly to approximately 17,6 % (Barkmann & Schulte-Markwort, 2012; Ravens-Sieberer et al., 2021a). Consequently, diagnoses have increased substantially, and a growing number of children and youths now require pharmacological and psychotherapeutic treatments (e.g., Atladottir et al., 2015; Olfson et al., 2014). Previous research has demonstrated that childhood mental health issues result in considerable costs for both individuals and society and cause major impairments in several aspects of life, including family dynamics, quality of life, and the broader social context (Houtrow & Okumura, 2011). Specifically, mental health issues have significant effects on healthcare and insurance costs, resulting in a heavy economic burden on healthcare systems worldwide (United Nations International Children's Emergency Fund [UNICEF], 2021) (see Figure 1).

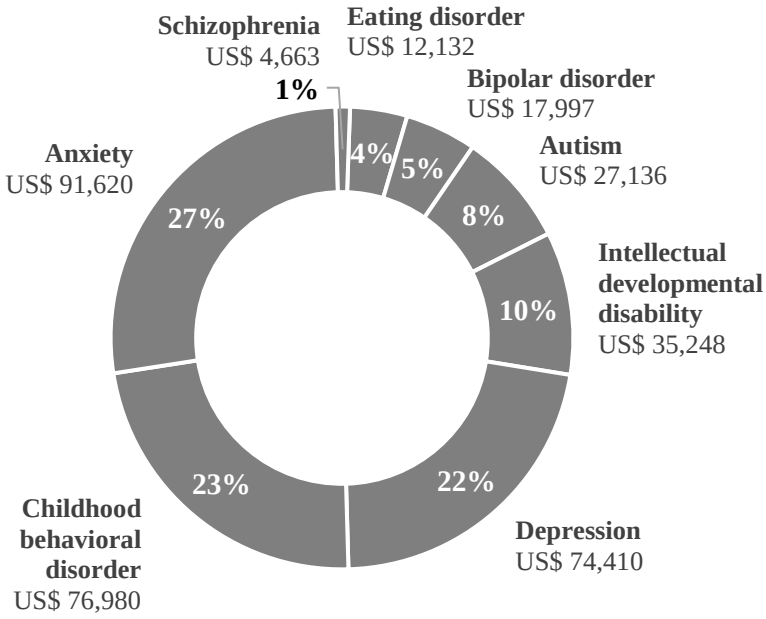

Figure 1 Global estimate of cost of mental health conditions for children and adolescents in US$ millions (cf. UNICEF, 2021).

The economic burden arises mainly from the regular use of health services, leading to substantial direct and indirect expenses (Belfer, 2008). In 2010, the overall expenditure for mental diseases in Europe

amounted to € 798 billion, with children and adolescent mental disorders accounting for € 21 billion (Olesen et al., 2012).

The emergence of a mental disorder in children and adolescents often occurs amid considerable upheavals (cf. Ravens-Sieberer et al., 2008). The unforeseen outbreak of the coronavirus disease 2019 (COVID-19), characterized by the need for social distancing, self-isolation, and the closure or limited access to many schools, is such a profound experience that might provoke or intensify mental health disorders in children and adolescents (cf. Asmundson & Taylor, 2020; S. Li et al., 2020; Ravens-Sieberer et al., 2015). Although the non-pharmaceutical emergency measures at varying levels of intensity (e.g., wearing masks or physical distance) have brought a notable benefit in preventing the spread of COVID-19, youths have still been affected by the adverse impacts of prolonged school closures and home confinement on their mental health (J. Wang et al., 2021). In particular, they encountered a series of complex adjustments in daily activities, social interactions, and everyday school rhythm and routine (Ezpeleta et al., 2020). Against this sobering backdrop, the burden on children and adolescents, particularly those already suffering from mental health problems, is expected to endure long after the pandemic is over (Witt et al., 2020). Studies have shown that children who experience quarantine are more likely to report depressive or posttraumatic stress symptoms and are prone to poor mental health and avoidance behaviors (Coughlin, 2012; Sprang & Silman, 2013). In addition, research (e.g., Pelikan et al., 2021) has demonstrated an increased risk for psychosomatic complaints in youths through psychosocial stressors during isolation, such as parental conflicts (Brill et al., 2001), lack of support from parents and teachers (Gerber & Pühse, 2009), increased school pressure, academic demands (Karvonen et al., 2005), or loneliness (Guessoum et al., 2020). Childhood and adolescence involve numerous biopsychosocial changes and challenges (Arnett, 2016), with adolescence being a vulnerable period for social development with an increased need for social interactions (Orben et al., 2020). So, coping with a pandemic and complying with these restrictions could be experienced as being incongruent with developmental tasks in this age group. Indeed, the COVID-19 pandemic significantly affected children's and adolescents' mental health detrimentally. Typically, the global prevalence of mental disorders among this target group is 13.4% (Polanczyk et al., 2015), which has, however, significantly increased during the pandemic. Recent reviews suggest that clinically elevated anxiety (21%) and depression (25%) symptoms have doubled on average (Racine et al., 2021) and indicated high pooled prevalences of depression (29%), anxiety (26%), sleep disorders (44%), and posttraumatic stress symptoms (48%) (Ma et al., 2021). Pandemic-related burdens included significantly lower health-related quality of life (40% vs. 15%), increased mental health problems (18% vs. 30%), and higher anxiety levels (24% vs. 15%) compared to pre-pandemic levels (see Figure 2) (Ravens-Sieberer et al., 2021a; Kopp et al., 2024). During the pandemic, the impairments in quality of life and mental health were consistent (Ravens-Sieberer et al., 2021b).

So far, preventive (Beardslee & Gladstone, 2001) and treatment (Michael & Crowley, 2002) efforts for childhood and adolescent mental disorders are only moderately effective, suggesting that alternative or complementary approaches must be sought (Libby et al., 2012). Regular physical activity (PA) and exercise during childhood and adolescence are, however, fundamental means of improving mental health (Harber et al., 2017; Kopp et al., 2020; Sallis et al., 2016; Schulz et al., 2012; Zahl et al., 2017). In particular, PA is a commonly recognized factor that affects psychological dispositions, given its crucial role in children's psychosocial development (Samdal et al., 1998). Physically active individuals typically report higher well-being (García-Hermoso et al., 2020), self-esteem (Dale et al., 2019), and health-related quality of life (Marker et al., 2018). Conversely, low levels of PA have been linked to increased risks of depression (Jerstad et al., 2010), anxiety (Carter et al., 2021), and psychological distress (Martikainen et al., 2013). In clinical studies, PA interventions in children and adolescent samples resulted in a notable decrease in depression and mental disorders (cf. Bonhauser et al., 2005; Byers et al., 2002; Guh et al., 2009; Kopp et al., 2024; Lindwall & Lindgren, 2005; Parfitt et al., 2009). Furthermore, for treating neurotic problems, such as anxiety and posttraumatic disorders, PA has indicated a beneficial impact comparable to psychological therapy and antidepressants in the target groups (Cooney et al., 2013; Krogh et al., 2011). These results imply that PA is an essential predictor of mental health (Hallal et al., 2006). However, even though the COVID-19 measures effectively mitigated the spread of the virus and contained the disease, they also led to increased sedentary behavior (e.g., Margaritis et al., 2020) and substantially reduced PA (Neville et al., 2022; Rossi et al., 2021). Research indicated that only 3.6% of children and 2.6% of adolescents met the recommended 60 minutes of daily moderate-to-vigorous PA during the COVID-19 pandemic (Moor et al., 2006), down from 12.7% before (Rhodes & Bruijn, 2013). In Germany, sports engagement declined by 6.5% and 14.6% among children and adolescents, respectively (see Figure 2) (Schmidt et al., 2020). The diminished PA was followed by detrimental alterations in children's physical fitness and a higher body mass index (BMI) (Basterfield et al., 2022; Kopp et al., 2024).

Considering the relationship between PA and mental health, the literature suggests that engaging in higher PA levels can be beneficial in preserving mental health during (Chtourou et al., 2020; Shen et al., 2020) and recovering from the COVID-19 pandemic (Basterfield et al., 2022). Indeed, higher levels of moderate-to-vigorous PA during the pandemic improved health conditions (Chen et al., 2020) and quality of life (López-Aymes et al., 2021), and reduced levels of insomnia, depressive symptoms, and anxiety symptoms among children and adolescents (X. Chi et al., 2021; Kang et al., 2021; Kopp et al., 2024). Adolescent athletes who had to refrain from participating in sports showed a decline in their mental health and overall quality of life, but condition improvements occurred upon resuming sports (Watson et al., 2023). Similarly, school-aged children showed enhanced fitness and health-related quality of life upon returning to sports clubs (Basterfield et al., 2022). This study suggests that higher PA levels following the COVID-19 pandemic might mitigate the pandemic's negative impact on the mental health of children and adolescents.

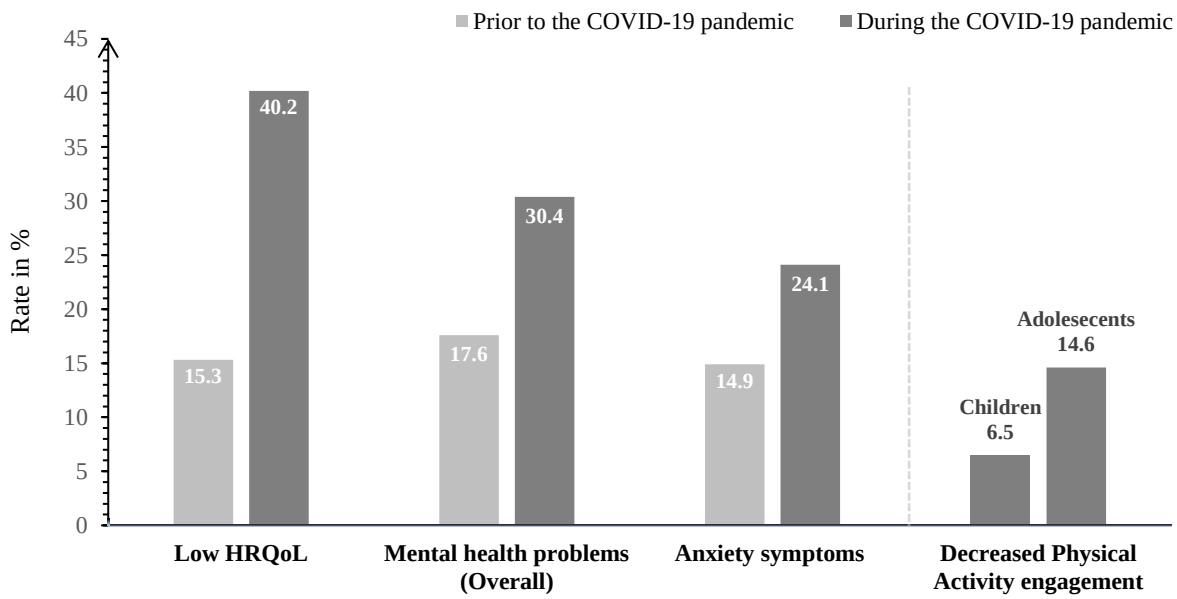

Figure 2 Self-reported (low) health-related quality of life (HRQoL), Mental health problems, and anxiety before and during, and decreased PA engagement of German children and adolescents during the COVID-19 pandemic. Adapted from Ravens-Sieberer et al., 2021b.

Despite the importance of these findings, the association between PA and mental health in children and adolescents aged 6 to 18 is a relatively new field of research and is still in its infancy (Ortega et al., 2008; Ottova et al., 2012). Whereas empirical studies support the relationship between PA and mental health for adults (Hallal et al., 2006), research among youths is scarce, and findings cannot be applied analogously to children and adolescents (Ortega et al., 2008; Ottova et al., 2012; Ravens-Sieberer et al., 2006). Furthermore, a lack of large or the use of non-representative samples also makes it difficult to determine the specificity of this association (Buchan et al., 2021; Chekroud et al., 2018). However, recent studies indicate increasing PA levels since lifting COVID-19 restrictions, but the pandemic's impact on this rise remains still unclear (Basterfield et al., 2022; Watson et al., 2023). Evidence shows that pre-pandemic mental health determined PA levels during the pandemic (Wunsch et al., 2021). Therefore, mental health during the pandemic may serve as an indicator of how quickly children and adolescents revert to their pre-pandemic PA levels once the regulations are lifted. So, understanding the reciprocal relationship between mental health and PA seems essential. Hence, this scientific contribution aims to identify whether (1) mental health before the easing of COVID-19 restrictions is associated with PA (improvement) during the easing of restrictions and (2) the level of PA predicts the improvement of mental health after the pandemic. In addition, the study intends to explore if the level of PA gradually increases with the easing of restrictions. If the worsened mental health slows the increase of PA, it is necessary to implement more rigorous PA promotion programs that are especially tailored to this particular group (cf. Kopp et al., 2024).

These research objectives are addressed in a 6-week quantitative longitudinal study conducted in a German elementary and grammar school under real-life conditions using a sample of students aged 6-18. In particular, longitudinal studies in a naturalistic setting, such as schools, are still needed to strengthen the transferability of previous findings to children and adolescents (Biddle & Asare, 2011). Schools are widely recognized as crucial settings for promoting PA among young people (World Health Organization [WHO], 2018). The vast majority of students spend most of the day at school. Therefore, options for PA are usually offered in various areas of everyday school life, including recess periods, regular courses, active breaks between classes, and after-school programs (cf. Kopp et al., 2024; McKenzie, 2019; Schlund et al., 2021).

The results of this study should reveal valuable clues and implications for the field and provide important information about predicting objective behavior in children and adolescents. This work and its research topics were part of a non-funded research project concisely sumarized in the subsequent section and published as an original article in a scientific journal with a Q1 ranking (see Chapter 7).

2.2 Academic Research Initiative and Dissertation

To advance knowledge and foster interdisciplinary collaboration, this work is based on a collaboration between the Saarland University (i.e., Saarland University Hospital Homburg (UKS)) and the German University of Applied Sciences for Prevention and Health Management (DHfPG) in Saarbrücken, Germany. The focus of the present dissertation is intricately woven into a joint research initiative involving the UKS, the Division of Sport Psychology of the University of Vienna, Austria, and a private school campus comprising an elementary school and a grammar school in Munich, Germany. The project, centered in the area of psychiatry, aimed at understanding the reciprocal relationship between mental health variables and PA during the easing of the COVID-19 restrictions in a sample of students aged 6-18. The primary purpose was to offer suggestions for supplementary therapeutic interventions for children and adolescents experiencing crises, as there is limited understanding of the potential influence of mental health factors on, or their susceptibility to, physical activity during critical periods like the COVID-19 crisis in this age cohort. So, this research sought to acquire knowledge about the complexity and interrelationships between PA and mental health among youths during the easing of the COVID-19 restrictions. The project involved a longitudinal component and naturalistic conditions in both schools while using a mixed methodology to fill the gaps in the literature. (cf. Kopp, 2021).

The dissertation author initiated, planned, and executed the research project. This also applied to hypothesis formation, study set-up, and journal publication in the field of child and adolescent psychiatry. The study protocol received approval from the Ethical Committee of the Saarland Medical Association (No. 52/22) and Bavarian State Medical Association (No. mb22069).

2.3 Structure of the Present Dissertation

The further sections of this work are organized as follows. Chapter 2.2 introduces the theoretical and conceptual framework based on this research, including the research potential and aims of the present study. Chapter 3 provides a detailed methodological overview of the underlying longitudinal study and summarizes the research methods and statistical analyses. Chapter 4 presents the research findings. The following Chapter 5 discusses the study results, addresses existing (methodological) limitations, and provides recommendations for future research and a brief conclusion. Finally, Chapter 7 addresses the original publication of this work as a scientific journal article and acknowledges the supervisor. A curriculum vitae can be found in Chapter 8.

2.4 Theoretical Background

This section explicates the theoretical and scientific context upon which this research is built. In particular, this chapter introduces the concepts and epidemiology of mental health and mental health problems in children and adolescents. Moreover, it involves identifying and analyzing the existing literature related to the present research to 1) develop a research question and hypothesis and 2) provide a clear and logical rationale for the study.

2.4.1 Mental Health and Mental Disorders in Children and Adolescents

The World Health Organization (WHO) and the United Nations (UN) have prioritized the promotion of mental health and the prevention of mental health disorders. These objectives are specified in the Comprehensive Mental Health Action Plan 2013-2020 published by the WHO and the 2030 Agenda for Sustainable Development established by the UN (cf. Kaman, 2021; United Nations [UN], 2015, WHO, 2013). Mental health refers to a "state of well-being whereby individuals recognize their abilities, are able to cope with the normal stresses of life, work productively and fruitfully, and contribute to their communities" (cf. World Health Organization, 2003, p.3). This holistic understanding is, however, based on a paradigm shift in medicine, where the effectiveness of therapy is not solely determined by physical and medical indicators but also by subjective measures of health (cf. Kaman, 2021; Sullivan, 2003). The assessment of an individual's subjective state of well-being has become increasingly important in the field of medicine and healthcare over the recent decades (Kaman, 2021). Within the field of mental health, health-related quality of life (HRQoL) is increasingly recognized as an important indicator in medicine (cf. Bullinger, 2002) and a crucial outcome of epidemiological, clinical, and health-economic research on children and adolescents, medical treatments, health care services, and overall public health (e.g., Baumgarten et al., 2019; Cooper et al., 2020; Crane et al., 2018; Quitmann et al., 2012). HRQoL is generally considered a latent trait that cannot be directly observed

(Ravens-Sieberer et al., 2021b). In particular, this term refers to a subjective, multidimensional construct encompassing overall health and well-being. This comprises children's and adolescents' perception of physical, emotional, mental, and social well-being in various settings, such as among family, with friends, and at school (Erhart et al., 2009; Groß et al., 2023; Guyatt et al., 1993). So, HRQoL includes the perception and judgment of one's life from the individual's perspective, as well as one's subjective well-being or affective mood. Notably, assessing treatment options has shifted focus to include HRQoL, especially for chronic disorders like psychiatric illnesses that may accompany patients throughout their lives (Saarni et al., 2007). This shift in focus was significant as medical intervention affects not only the patient's physical health but also their emotional and social well-being. Therefore, it is crucial to consider the perspectives of children and adolescents when evaluating treatment success and optimizing treatment plans for individual cases. Recent epidemiological studies indicate that the majority of children and adolescents exhibit high levels of well-being and possess a favorable mental health status (e.g., Baumgarten et al., 2019; Cosma et al., 2020). Nevertheless, the increasing prevalence of mental and behavioral issues in this target group is still a growing global public health concern (Patel et al., 2018) and the primary cause of health-related disability in children and adolescents aged up to 24 globally (Spencer, 2013). Mental disorders (also referred to as mental illness or mental health issues) are characterized as disturbances in cognition, emotion regulation, and/or behavior (cf. Manderscheid et al., 2010) related to dysfunction in the psychological, biological, or developmental processes. They cause significant impairment in mental functioning (e.g., alternations in thinking, mood, or behavior) and are associated with distress in social, occupational, or other vital areas of life (U.S. Department of Health and Human Services [USDHHS], 1999). In particular, they vary in prevalence, diagnostic presentation, symptom distress, and severity levels, ranging from mild to moderate or severe (American Psychiatric Association [APA], 2013). The condition can be considered severe when one or more major life activities are seriously affected (Substance Abuse and Mental Health Services Administration [SAMHSA], 2020). Research has shown that over 50% of all mental health problems arise before the age of 14, with over 75% emerging before the age of 24 (cf. Kessler et al., 2005). This is not surprising given that childhood and adolescence are particularly vulnerable stages of maturation, during which the brain experiences rapid physical, cognitive, social, and developmental challenges. These comprise biological (e.g., puberty) and identity developments, social role changes, building relationships with peers, and gaining independence from parents (S. M. Sawyer et al., 2012). Prominent developmental transformations are mainly seen in the prefrontal cortex and limbic brain regions, critical for cognitive functioning and emotion regulation processes (Johnson et al., 2009; Spear, 2000). Specifically, 17.6% of German children and adolescents show symptoms of emotional and behavioral disorders affecting their mental health (Barkmann & Schulte-Markwort, 2012). Notably, individuals experiencing mental illness are at considerable risk of self-harm and suicidal behaviors (Nock et al., 2010).

In the conceptualization of psychopathology in children and adolescents, a predominant theme has been the differentiation of mental disorders as a function of their general phenotypic expression.

This resulted in the classification of disorders as either internalizing or externalizing disorders, depending on their general symptom manifestation (Angold et al., 1999; Reynolds, 1992). Internalizing disorders are characterized by relatively covert, cognitive symptoms that are difficult to observe and, therefore, manifest themselves as inwardly directed symptoms, such as depression (e.g., major depressive disorder, dysthymia) and anxiety disorders (e.g., generalized anxiety disorder, separation anxiety disorder, phobias, obsessive-compulsive disorder). The etiology of internalizing disorders can be complex, implicating genetic, environmental, social, and psychological risk factors (Barrett & Cooper, 2014). For instance, the imbalance of neurotransmitters, such as serotonin, dopamine, and norepinephrine, which regulate positive emotions, can be attributed to depression and anxiety disorders (Remick, 2002). In contrast, externalizing disorders are overt, highly observable either directly or indirectly, and typically appear as outwardly directed behavioral excess, such as Attention-deficit/hyperactivity disorder (ADHD), antisocial personality disorder (ASPD), conduct disorders (CD), and oppositional defiant disorder (ODD) (cf. Achenbach et al., 2016; Reynolds, 1992). Behavioral issues are some of the most frequent and challenging symptoms in the field of child and adolescent psychiatry and are responsible for 5.7% of the total disease burden globally in children and adolescents, ranking as the sixth leading cause of disability-adjusted life years (DALYs) (Erskine et al., 2015). Clinically relevant symptoms of depression, anxiety, ADHD, and conduct disorders were found in 11.2%, 10.6%, 5.7%, and 12.2% of children and adolescents aged 7 to 19 years, respectively (Robert Koch-Institut [RKI], 2017). In general, boys tend to have more externalizing symptoms (e.g., CD, ADHD) during childhood, while girls are more prone to experiencing emotional problems (e.g., anxiety and depressive disorders) by adolescence (Green et al., 2005). Notably, the occurrence of mental health disorders also increases in older children (i.e., adolescents). In particular, the prevalence of emotional, anxiety, conduct, and hyperkinetic disorders seems to rise from 5-10-year-olds to 11-16-year-olds (cf. J. V. Ahn, 2021). As childhood and adolescence are critical junctures in the progression of psychopathology and mental health, changes in schooling, social behaviors, and psychological changes with childhood development and puberty may affect mental health outcomes and help explain this trend (Green et al., 2005). Given that symptoms usually recur and often track into adulthood (Belfer, 2008), they cause substantial disabilities in general functioning and burden both individuals and their families (cf. J. V. Ahn, 2021; Booster et al., 2012; Caci et al., 2014). Evidence also indicates comorbidities between both disorders, meaning an internalizing-externalizing co-occurring disorder (Cosgrove et al., 2011). Support for such an internalizing-externalizing model for psychopathology has also been observed in children and adolescent samples. In particular, Hewitt et al. (1997) reported statistically significant comorbidity between internalizing (anxiety and depression) and externalizing (ADHD and CD) disorders. As a result, this research focused on both types of disorders due to their high prevalence and the problematic symptoms they pose in child and adolescent psychiatry, especially during crises such as the recent Corona pandemic.

2.4.2 Mental Health in Children and Adolescents during the COVID-19 pandemic

The COVID-19 crisis caused significant changes in the daily lives of children and adolescents, including adjusting to social distancing regulations, staying at home, and school closures, and had a massive impact on the mental well-being, resulting in psychological distress of this target group (e.g., Fegert et al., 2020; Fore, 2020). Although young people experienced minor physical health effects from COVID-19, the pandemic containment measures severely affected their mental health (Howard-Jones et al., 2022). Specifically, the combination of partial home and online schooling has lowered the opportunity for children and adolescents to interact socially and participate in PA. As a result, the interaction between peers, which is crucial for their development, was greatly limited (Orben et al., 2020). Multiple studies have indicated a substantial rise in the overall occurrence of mental problems among children and adolescents during the COVID-19 pandemic. Studies indicated a significant increase in clinical symptoms of anxiety (21%) and depression (25%) symptoms (Racine et al., 2021). Additionally, significant rates of depression (29%), anxiety (26%), sleep disorders (44%), and posttraumatic stress symptoms (48%) were reported in the pooled data (Ma et al., 2021). In Germany, about two-thirds of children and adolescents felt impacted by the pandemic and reported more mental health issues (i.e., conduct problems, hyperactivity, peer problems, and emotional stress), with 18% before the pandemic and 30% during the pandemic. Furthermore, anxiety levels were higher, with 24% during the pandemic compared to 15% before it. In addition, they experienced a significant decrease in their HRQoL, with 40% reporting a decline compared to 15% pre-pandemic (cf. Ravens-Sieberer et al., 2021a). Throughout the pandemic, the declines in HRQoL and mental health were stable (cf. Kopp et al., 2024). Furthermore, children and adolescents reported experiencing significant psychosomatic complaints, such as irritability, headaches, stomachaches, feeling low, and sleeping problems (Ravens-Sieberer et al., 2021b). These findings are of severe public health concern since childhood and adolescence mental health issues are linked to a higher risk of mental disorders in adulthood (Mulraney et al., 2021).

2.4.3 Assessment of Mental Health and Health-related Quality of Life in Children and Adolescents

In the fields of clinical practice and research, it is crucial to have reliable and valid assessments to detect children and adolescents at risk of developing behavioral problems and those who have already been affected. This enables early prevention and intervention strategies to be implemented effectively (cf. Kaman, 2021). In recent years, notable improvements have been made when assessing mental health and HRQoL among this target group. Epidemiological studies commonly employ screening instruments or rating scales to evaluate mental health disorders or HRQoL. These measures generally allow for a dimensional evaluation that yields metric symptom scores. The Strengths and Difficulties Questionnaire (SDQ; Goodman et al., 1998) is a widely used screening instrument for mental health, while the KIDSCREEN-52 questionnaire (Ravens-Sieberer et al., 2008; THE KIDSCREEN GROUP EUROPE,

2004) is commonly used for HRQoL assessment. The KIDSCREEN was designed to be easily understood across different cultures, age groups, and genders. Since the questionnaire accounts for the participants' maturity and cognitive development, it complies with the guidelines set by the WHO for child-appropriate measurement of HRQoL (Ravens-Sieberer et al., 2008). Both instruments are appropriate for larger samples (Deighton et al., 2014), have demonstrated good reliability and validity, and are recommended by the International Consortium for Health Outcomes Measurements (ICHOM) (Krause et al., 2021). Although the questionnaires evaluate symptoms and impairments resulting from mental problems or measure HRQoL, they do not provide clinical diagnoses based on the ICD-11 Classifications of Mental and Behavioral Disorders (WHO, 2019) or Statistical Manual of Mental Disorders (American Psychiatric Association [APA], 2013). Diagnostic interviews are, however, necessary to achieve clinical evaluations, but they require time, resources, and are rarely feasible at a population level. As a result, questionnaires are used in research studies such as the present research (Hunter et al., 1996). Despite the availability of adequate measures, assessing mental health in children using questionnaires is still a challenging task, as language skills or cognitive development may impede their self-evaluation. In particular, some may give "correct" answers instead of honest ones, making it challenging to identify mental health disorders accurately. To improve the prediction of these disorders, gathering information from multiple sources, such as parents, teachers, and self-reports by children and adolescents, is helpful (e.g., Bryant et al., 2015). Therefore, this work employed age-appropriate, self-report, and proxy versions (for parents) of the respective questionnaires.

2.4.4 Effects of Physical Activity on Mental Health Outcomes in Children and Adolescents

The treatment of mental health disorders usually involves psychotherapy, pharmaceutical interventions, or both approaches. However, in recent years, health behaviors such as physical activity (PA) have been increasingly recognized as a therapeutic intervention for treating mental health disorders (e.g., Biddle & Asare, 2011). PA refers to any physical movement produced by the contraction of skeletal muscles, leading to energy expenditure (cf. Caspersen et al., 1985; National Institute for Health and Care Excellence, 2009). This definition of PA encompasses a range of activities across multiple domains with distinct impacts on health. In health research, several terms describe PA, which are often used interchangeably. These terms include exercise, physical fitness, motor activity, locomotor activity, physical movement, physical performance, physical effort, sports athletics, sport participation, and physical fitness. However, exercise and physical fitness are the most commonly used paraphrases (Chekroud et al., 2018). Both terms refer to PA, whereas exercise is a subset of PA (e.g., aerobic, weight training, resistance training, fitness training, running, jogging, and walking) that is planned, structured, and repetitive and has the improvement or maintenance of physical fitness as a final or intermediate objective. In contrast, physical fitness encompasses a set of attributes that can be categorized as either health-related or skill-related (cf. Caspersen et al., 1985). In this research, PA refers to all terms related

to bodily movement found in literature and all terms specifying subcategories of PA. Regarding the different features, PA can vary based on the type (e.g., yoga or football), frequency (e.g., times per day or week), duration (e.g., minutes or hours per session), and intensity, measured by an age-related maximum heart rate. For children and teenagers aged 6 to 17, the WHO (2018) recommends 60 minutes or more of moderate-to-vigorous physical activity (MVPA) daily.

Regardless of the variety of different terminologies, features, and recommendations, PA is a crucial indicator of school-aged children and youth's physical and mental health (Janssen & Leblanc, 2010; Ortega et al., 2018; Tremblay et al., 2011). An emerging body of research highlights the importance of PA for cognitive function (Biddle & Asare, 2011), as it improves the functioning of the hypothalamus-pituitary-adrenal axis (Chaddock-Heyman et al., 2014). In particular, regular PA has been found to positively impact children's neurological development by increasing neurotrophin production, resulting in improved cognitive processing speed, response control, and working memory (Vaynman et al., 2006). By contrast, low cognition in childhood has been linked to mental health problems in adolescence and adulthood (e.g., Batty et al., 2005). In both clinical and non-clinical samples, research also indicated a correlation between (moderate-to-vigorous) PA and improved mental health in youth (Whitelaw et al., 2010). In particular, participating in higher levels of PA significantly improved physical and mental health and psychosocial well-being in children and adolescents compared to those who followed a sedentary lifestyle (e.g., Hallal et al., 2006; Janssen & Leblanc, 2010). Wellbeing is a complex multidimensional construct that mainly includes physical, mental, and social constructs, self-acceptance, personal growth, life purpose, environmental mastery, autonomy, and positive relations with others (cf. Ryff & Singer, 2006). Moreover, the literature indicates that increasing PA might be a promising intervention for mitigating mental health disorders, such as depression and anxiety, among those aged 20 and below (e.g., Andermo et al., 2020; Biddle et al., 2019; Larun et al., 2006). Indeed, children and adolescents with more than 4 hours a week of vigorous PA showed lower levels of depression and anxiety (Parfitt et al., 2009). In particular, PA has an immediate effect on anxiety, taking between 4 to 6 hours for anxiety levels to return to their pre-activity state (Landers, 1997). Notably, those who performed both endurance and resistance exercises had a lower probability of developing symptoms of depression (e.g., Zahl et al., 2017), anxiety (Biddle et al., 2019), and psychological distress (S. Ahn & Fedewa, 2011) . PA also helps alleviate secondary symptoms such as low self-esteem (DeBate et al., 2009) and social withdrawal (Richardson et al., 2005). Consequently, it appears to improve specific mental health vulnerabilities effectively and can be seen as a beneficial complementary treatment to psychotherapy (Raglin, 1990) or medication in children and adolescents. Interestingly, research indicates that around 20% of individuals require 10-12 weeks or more before experiencing the benefits of medication (e.g., through poor adherence or improper doses) (Tedeschini et al., 2011). However, PA can help alleviate symptoms without side effects or waiting for medication benefits to take effect, mainly through various biological and psychological pathways (Kandola et al., 2019). Aside from mental disorder aspects, numerous studies indicate a positive association between PA and HRQoL

(e.g., Marker et al., 2018; Wu et al., 2017). HRQoL is becoming more often applied as a health measure in children and adolescents to evaluate their physical and social capabilities, mental health, and overall well-being. Gopinath et al. (2012) found that youths who consistently engaged in the highest levels of PA over a period of five years had a considerably greater improvement in their HRQoL. Furthermore, Vella et al. (2014) showed that children who maintained their involvement in sports from ages 8 to 10 had higher levels of parent-reported HRQoL by the age of 10. Consequently, regular PA behavior might be meaningful in the critical stage of childhood and adolescence in which psychological problems, such as internalized (e.g., anxiety and depression) and externalized disorders (e.g., ADHD), are evolving (Moor et al., 2006). As a result, it could be considered as a preventative treatment option to enhance mental health (Mikkelsen et al., 2017). A conceptual model by Lubans et al. (2016) attempts to outline the effects and underlying mechanisms between PA, mental health, and cognitive outcomes in children and adolescents (see Figure 3). The model proposes that the personal attributes of youths impact their individual PA levels. The features of the PA modulate these processes, operating through many proposed mechanisms. Mental health outcomes may be categorized into three subsets: cognitive function, well-being, and ill-being. The three potential mechanisms PA can improve children's mental health are psychological, neurobiological, and behavioral. These processes likely work together to produce mental health effects, and they are not necessarily mutually exclusive (cf. Lubans et al., 2016).

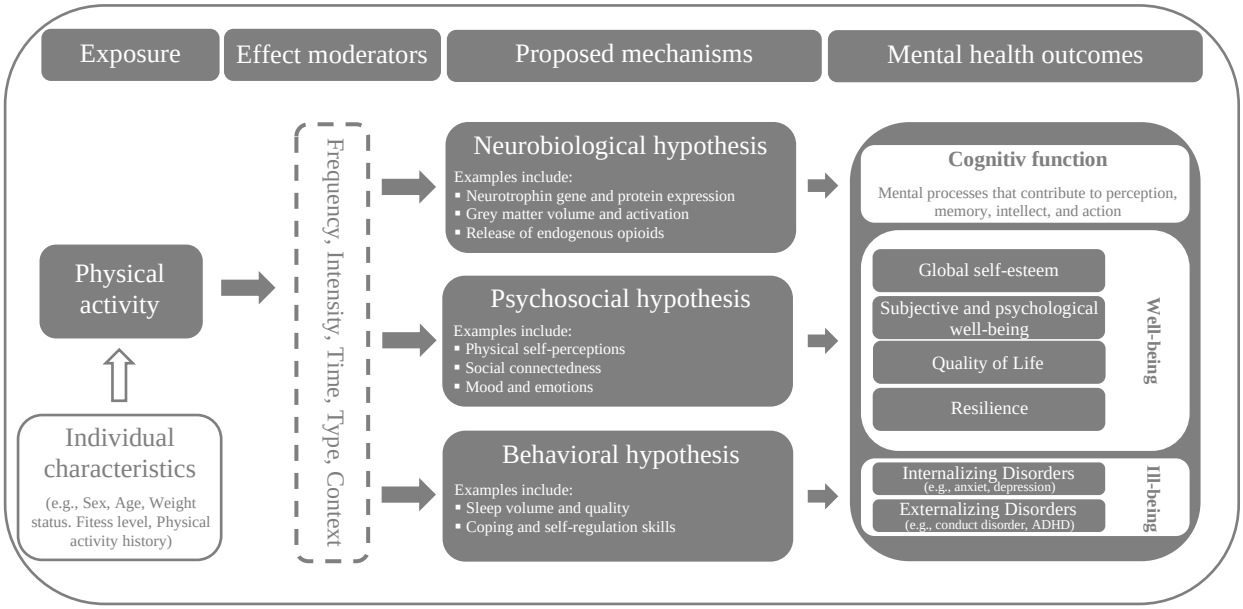

Figure 3 Theoretical framework illustrating the impact of PA on mental health outcomes in children and adolescents (cf. Lubans et al., 2016) *Note.* ADHD=attention-deficit/hyperactivity disorder.

Research on neurobiological mechanisms suggests that higher intensity or longer duration of PA can positively impact mental health. There are a couple of hypotheses for why this might be the case. The endorphin hypothesis posits that PA enhances psychological well-being by stimulating the release of beta-

endorphins, which alleviate pain and induce a state of euphoria (Kent, 2007). Studies have shown that extended exercise can activate endorphin secretion. Endorphins may produce energy conservation, which can help facilitate psychological effects. The monoamine hypothesis proposes that PA enhances the transmission of primary monoamines such as noradrenaline (norepinephrine), dopamine, and serotonin, which can alleviate symptoms of anxiety, depression, and sleep disorders (cf. Paluska & Schwenk, 2000). These neurotransmitters are mainly responsible for positive feelings. Serotonin affects emotional states, mood, and sleep, whereas dopamine is responsible for pleasure centers in the brain and motor control. Norepinephrine impacts attention, pain tolerance, attention, mood, and anxiety (Remick, 2002). In particular, PA has been shown to positively affect serotonergic and noradrenergic systems directly after exercise, with effects as antidepressant medication (DeBoer et al., 2012; McEwen, 2007; Strüder & Weicker, 2001). For instance, PA promotes the modulation of monoamines, including serotonin, dopamine, and norepinephrine, while supporting neurogenesis, synaptogenesis, and angiogenesis and increasing myelination (Hosker et al., 2019). Additionally, PA affects well-being and ill-being by releasing endogenous opioids and interacting with other neurotransmitter systems (Dishman & O'Connor, 2009). Furthermore, PA has the potential to improve well-being through various psychosocial mechanisms, drawing upon both hedonic (Lyubomirsky et al., 2005) and eudemonic (Ryff, 1989) perspectives. Theoretical frameworks suggest that fulfilling basic psychological needs for social connectedness (e.g., social interaction), autonomy, self-acceptance (e.g., perceived attractiveness and body image), environmental mastery (e.g., self-efficacy and perceived competence), and purpose in life can achieve well-being in children and adolescents (Deci & Ryan, 2002; Ryff & Keyes, 1995). The behavioral mechanism hypothesis suggests that PA can lead to changes in mental health outcomes by affecting relevant behaviors. Proposed mechanisms for mental health improvement include improved sleep (Gaina et al., 2007; Lang et al., 2013; Mcneil et al., 2015), self-regulation, and coping skills resulting in behavioral management strategies (cf. Lubans et al., 2016). So, PA may help children and adolescents divert their attention from stress and negative thoughts (DeBoer et al., 2012; Paluska & Schwenk, 2000), thereby reducing anxiety states. Hence, PA might serve as a "time out" from daily worries, promoting self-regulation and breaking the cycles of anxiety and worry (Breus & O'Connor, 1998).

However, although PA has numerous benefits to psychology, epidemiological evidence indicates that the level of PA tends to decline from childhood to adolescence. Indeed, according to a study conducted by the Health Behavior in School-aged Children (HBSC-Team Deutschland, 2011) team in Germany, children and adolescents up to the age of 15 showed low PA levels, with the decline slightly more significant for girls and young teenage women respectively (Farooq et al., 2020). Specifically, more than 42% of girls and 30% of boys engaged in sports for less than 2 hours a week. Furthermore, PA levels continued to decline as adolescents progressed in age. In Europe, less than 10% of 15-year-old girls engage in at least 1-hour PA daily (Currie et al., 2008). During the COVID-19 pandemic, there was a notable decline in sports participation among German children and adolescents,

with a reduction of 6.5% and 14.6% respectively. Notably, a study conducted among Canadian youths revealed that a mere 3.6% of children and adolescents reached the WHO-recommended 60 minutes of moderate-to-vigorous physical activity (MVPA) daily during the crisis (cf. Guthold et al., 2020; Moore et al., 2020; WHO, 2020). Collectively, a meta-analysis of findings from several nations shows that, on average, the level of physical activity among children and adolescents declined by 20% throughout the pandemic (cf. Kopp et al., 2024; Neville et al., 2022). The resulting physical inactivity and sedentary were accompanied by severe consequences and physical and mental illnesses (Basterfield et al., 2022). However, research studies have shown that children and adolescents who engaged in PA during the COVID-19 restrictions reported better health (Chen et al., 2020), higher quality of life (López-Aymes et al., 2021), and lower levels of insomnia, depression, and anxiety (cf. Kang et al., 2021; Kopp et al., 2024).

2.4.5 The Role of Schools as a Physical Activity Setting

Schools can play a vital role in significantly encouraging PA among children and adolescents and can prevent or delay mental illness onset (WHO, 2018). Moreover, research suggests that schools are a prime location to support youth in living „healthier, more satisfying, more productive lives“ (Allensworth & Kolbe, 1987, p. 409). There are several ways to promote PA over the course of a school week, including physical education lessons, during break time, active breaks between classes with short bouts of PA, before- and after-school programs, classroom-based PA, and travel to and from school. Literature indicates that interventions aimed at these discrete periods can significantly increase children's PA levels (Sallis et al., 1997), potentially contributing up to 50% of the PA required to meet the recommended guidelines proposed by the WHO (Fairclough et al., 2012). In particular, Lavizzo-Mourey (2012) suggested that incorporating PA into students' daily routine is achievable by implementing classroom activity breaks, MVPA, and before- and after-school activities, providing adequate activity spaces and equipment, and developing behavioral skills. Concerning mental health, it was found that exercises such as aerobic workouts, endurance training with treadmills or rowers, and weightlifting during educational lessons can decrease the number of days with high mental health burdens. The most beneficial exercise types were found in school team sports (e.g., playing basketball, soccer, or tennis with a group of friends), cycling, and aerobic/gym exercises, reducing self-reported mental health burden by 22.3%, 21.6%, and 20.1%, respectively (Chekroud et al., 2018). Notably, engaging in aerobics or a combination of aerobics and resistance training reduces the likelihood of developing symptoms of depression in children and adolescents (e.g., S. Ahn & Fedewa, 2011; Kremer et al., 2014; Zahl et al., 2017) and improves self-esteem (e.g., Petty et al., 2009; Biddle et al., 2019). The environment in which PA is delivered is pivotal to fostering engagement (Maddock et al., 2008). Approximately half of schools globally can create a suitable setting that offers appropriate PA during

regular school days (Aubert et al., 2018; Schlund et al., 2021). Consequently, this study collects data from children and youths attending both an elementary school and a grammar school.

2.4.6 Reciprocal Relationship between Physical Activity and Mental Health in Children and Adolescents

PA is broadly considered to positively affect mental health, HRQoL, and well-being, although this relationship's direction and underlying mechanism are not fully understood. Therefore, the possibility of reverse causality (i.e., mental health impacts active behaviors) or a bidirectional relationship should also be taken into account. Even though the association is well-researched in adults (Santomauro et al., 2021), causality in this relationship among children and adolescents is still undetermined (Abu-Omar et al., 2017; Biddle et al., 2019). However, research has shown evidence for the reverse effect that depression‘s affective symptoms can lead to reduced PA (e.g., Stavrakakis et al., 2012). Yet, most of the relevant findings are based on cross-sectional studies, with rare longitudinal approaches determining causality and direction of associations. Focusing on bidirectional association, Tilga et al. (2021) found a positive effect of PA on HRQoL one year later but no effect of HRQoL on PA. Omorou et al. (2016) observed significant relationships in both directions in adolescents using three time points (each one year apart). The results showed that PA had a positive impact on HRQoL and that HRQoL also had a positive impact on PA. Furthermore, Jensen et al. (2014) reported that higher levels of HRQoL at the baseline predicted future PA engagement up to one year later. During the COVID-19 pandemic, Wunsch et al. (2021) analyzed HRQoL before and during the COVID-19 pandemic. The results indicated that HRQoL before the pandemic had a positive association with PA engagement during the pandemic, but only in children younger than 10 years old, not in adolescents aged between 10 and 18. However, both cross-lagged panel models (CLPM) studies did not reveal a significant effect of PA on HRQoL. Overall, there is still inconsistency in the associations between PA and HRQoL, and only a few studies have examined longitudinal effects. Therefore, analyzing long-term reciprocal relationships in a sample of children and adolescents seems necessary (cf. Groß et al., 2023; Wade et al., 2020).

2.4.7 Assessment of Self-reported and Objective Physical Activity

Subjectively reported PA measures are commonly used to assess PA levels since they require minimal effort and expense for both staff and participants (cf. S. Ahn & Fedewa, 2011). Various methods are used to gather information about PA, including self-administered recall (usually via questionnaire), interview-administered recall, diary, proxy reports, or single frequency items about past PA behavior. While these self-reported methods have been shown to be reliable and valid in studies (Biddle & Asare, 2011; Kilpatrick et al., 2005), they are susceptible to recall reporting and misclassification bias (Biddle

& Asare, 2011) or are subject to social desirability (Dyrstad et al., 2014). Moreover, young children tend to struggle with following PA protocols and mainly require assistance to comply with complex or time-consuming PA procedures. Recently, objective technologies for measuring PA behavior, such as smart devices (e.g., smartwatches or smartphones) equipped with pedometers, heart rate monitors, and accelerometers, have been more readily available for tracking the activity levels (cf. Fedewa & Ahn, 2011). Consequently, more studies adopt those objective measures in their research (Parfitt et al., 2009). Smart devices are increasingly popular for monitoring PA, such as step counts. In Germany, these gadgets are remarkably prevalent among children and adolescents (Mercer et al., 2016). Specifically, 66% of children aged 6 to 9, 92% of early adolescents aged 10 to 13, and 98% of adolescents aged 14 to 18 (as shown in Figure 4) frequently utilize these devices to monitor and measure their daily PA levels (cf. Statista, 2021). Smart devices are widely used for monitoring activity and behavior patterns in children (Mackintosh et al., 2019) and adolescents (Ridgers et al., 2018), mainly because they are feasible and user-friendly (cf. Kopp et al., 2024; Mackintosh et al., 2019; Ridgers et al., 2018; W. Wang et al., 2022). Research indicated that particularly smartphones and/or smartwatches are accurate and precise instruments for determining the number of steps taken in real-life situations (Degroote et al., 2018; Fuller et al., 2020). So, smart devices with pedometers are exceptionally reliable for measuring PA as they avoid inherent (recall) biases and inaccuracies in subjective, self-reported measures (Fuller et al., 2020). Therefore, this research employed smart devices with a built-in pedometer to track objective PA behavior in children and adolescents and relied on parents to (self-)report their children's activity levels.

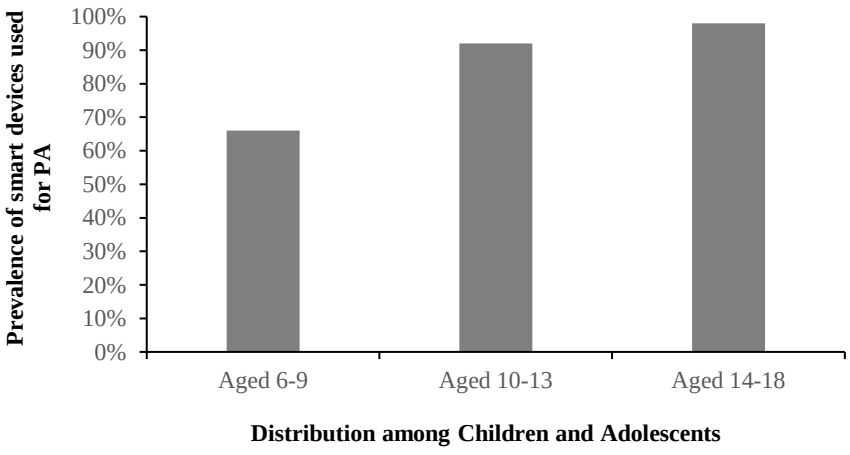

Figure 4 Prevalence of smart devices among children and adolescents in Germany (cf. Statista, 2021).

2.5 Research Potential and Aims of the Present Study

Given the established correlation between PA and mental health, literature proposes that participating in PA could be a valuable approach to preserving mental health during the Corona crisis (Chtourou et al., 2020; Shen et al., 2020), as well as facilitating physical and psychological recuperation from the pandemic. Indeed, research has shown that children and adolescents who participated in higher levels of moderate to vigorous PA throughout the pandemic showed improved health conditions (Chen et al., 2020), higher quality of life (López-Aymes et al., 2021), and lower levels of insomnia, depression, and anxiety (X. Chi et al., 2021; Kang et al., 2021). However, adolescent athletes who were prevented from participating in sports experienced a decline in their mental health and HRQoL, but these negative trends were reversed once they were allowed to resume their sports activities (Watson et al., 2023). Similarly, school-aged children who returned to sports club participation experienced an improvement in their physical fitness and HRQoL (Basterfield et al., 2022). These findings indicate that raising PA levels after the COVID-19 pandemic might help mitigate the negative impacts the crisis had on children‘s and adolescents‘ mental health. However, the findings are not generalizable. Most pertinent studies that have examined the relationship between PA and mental health are cross-sectional and primarily depend on retrospective data and methodological constraints (e.g., Guthold et al., 2020). Expressly, previous studies waived objective measures and were limited by self-reported levels of PA (e.g., Buchan et al., 2021; Doggui et al., 2021; Guthold et al., 2020), which are susceptible to social desirability bias (cf. Dyrstad et al., 2014) and may consequently restrict the generalizability of its findings. A recent study revealed a significant bias in people's self-reported PA, with an overestimation of up to 39% when compared to electronically monitored PA (Kopp et al., 2020). Consequently, gathering more objective data to validate the advantages of PA in terms of physical and mental recuperation from the pandemic is crucial. Moreover, recent research indicates that PA levels in children and adolescents continue to rise following the removal of COVID-19 regulations (Basterfield et al., 2022; Watson et al., 2023). However, it remains uncertain how the pandemic has influenced this increase. Evidence indicates that individuals' mental health before the pandemic was a reliable indicator of their PA levels during the pandemic (Wunsch et al., 2021). Therefore, it is plausible that mental health during the pandemic may serve as an indicator of how quickly children and adolescents revert to their pre-pandemic PA levels once limitations are lifted. Hence, additional empirical evidence is needed to 1) delineate the effects of mental health on PA and vice versa and 2) strengthen the transferability of past research to the domain of children and adolescents. (cf. Kopp et al., 2024).

The aim of this study, therefore, was to examine the reciprocal relationship between PA and mental health in children and adolescents and to determine whether PA affects or is affected by mental health. Even though some literature suggests PA may be an opportunity to promote mental health, or vice versa, after the COVID-19 pandemic, evidence of this relationship remains less reported in youths (Biddle et al., 2019) and has not been analyzed in depth, mainly through longitudinal research and during

a crisis (Chen et al., 2020; Kang et al., 2021; López-Aymes et al., 2021). In particular, this work hypothesizes that PA levels will gradually increase with the easing of restrictions. Furthermore, it is postulated that children's and adolescents' mental health prior to the easing of COVID-19 regulations will be linked to increased PA during the loosening of restrictions. Additionally, PA levels are expected to predict the improvement of mental health following the pandemic. If worsened mental health impedes PA elevation, targeted promotion programs are needed (cf. Kopp et al., 2024).

In order to address the methodological limitations of previous research, the present study intended to expand knowledge of the reciprocal relationship between mental health and PA among children and adolescents aged 6-18 in naturalistic settings, such as an elementary and a grammar school, using a longitudinal 6-week prospective study design with two measurement occasions. Longitudinal research approaches are scarce but necessary to understand the complexity and interrelationships between PA and mental health among youths, particularly during a crisis (Groß et al., 2023). The need for long-term mental health research in the young population was highlighted early in the pandemic (Wade et al., 2020). Schools are widely acknowledged as crucial for encouraging PA among students since they offer a multitude of formal and informal opportunities for engaging in PA. Moreover, they provide a practical real-life setting to reach children and adolescents with no additional cost to participants or their families (Andermo et al., 2020). While there has been an increase in understanding of children's responses to the Corona crisis, most research has concentrated on comparing results before the pandemic with those observed after its onset (Wolf & Schmitz, 2023), particularly at a single pandemic time point only. For this reason, the present study collected data on mental health problems, HRQoL, and PA in two waves before and during the easing of COVID-19 restrictions. As previous research relied on self-reports to conclude PA, this scientific contribution used pedometer data (average daily steps/weeks) from smart electronic devices as an objective measure to account for participants' actual PA data.

Figure 5 displays a concise summary of the research objectives. In particular, this overview comprises a summary of (1) the variables surveyed (as described in Chapter 3), (2) the independent and dependent variables employed, and (3) the statistical procedures (as explained in Chapter 4) utilized to address the research questions effectively.

						Independent Variables	Dependent Variables
Variables surveyed	Mental Health Variables (SDQ; Goldmann et al., 1998; Lohbeck et al., 2015)	Reciprocal Relationship between Physical Activity and Mental Health/HRQoL	Statistical Analyses	Conditional Growth models	Model 1	Mental Health Problems (SDQ variables T_{week1})	Physical Activity (i.e., Ø number of daily steps T_{week1} - T_{week6})
					Model 2 (incl. effect of time)	Mental Health Problems (SDQ variables T_{week1} - T_{week6})	Physical Activity (i.e., Ø number of daily steps T_{week1} - T_{week6})
				Hierarchical Multiple Regression Analysis		Physical Activity (i.e., Ø number of daily steps T_{week1} - T_{week6})	Mental Health Problems (SDQ variables T_{week6})
	Health-Related Quality of Life (KIDSCREEN-52; The KIDSCREEN Group, 2004)			Conditional Growth models	Model 1	HRQoL (Kidscreen variables T_{week1})	Physical Activity (i.e., Ø number of daily steps T_{week1} - T_{week6})
					Model 2 (incl. effect of time)	HRQoL (Kidscreen variables T_{week1} - T_{week6})	Physical Activity (i.e., Ø number of daily steps T_{week1} - T_{week6})
				Hierarchical Multiple Regression Analysis		Physical Activity (i.e., Ø number of daily steps T_{week1} - T_{week6})	HRQoL (Kidscreen variables T_{week6})
	Demographic Variables	Effect on Physical Activity		Conditional Growth Models		Demographic Variable	Physical Activity (i.e., Ø number of daily steps T_{week1} - T_{week6})
				Unconditional Growth Models		Time Variable	Physical Activity (i.e., Ø number of daily steps T_{week1} - T_{week6})

Figure 5 Structural summary of the present research, outlining the variables examined, the statistical methods employed, and the independent and dependent variables. *Note*. T_{week1} = Pretest variables; T_{week6} = Posttest variables. Model 1 and Model 2 are nested models and, thus, must be presented separately. In particular, Model 1 tests the effect of the respective SDQ or KIDSCREEN variable on PA during the six-week study period but not on its evolution over the six weeks. Model 2 adds the interaction between the variable and time to test how PA changes over six weeks depending on the psychological variable. Adapted from Kopp (2021).

3. Methodology

This section details the longitudinal study during the easing of the COVID-19 regulations in Germany in both an elementary and a grammar school. The study design included all measures required to address the research topics. As quantitative data analyses were performed, various research approaches and mixed methodologies were used. This chapter overviews the major demographic and topic-specific characteristics, measures taken, and the main statistical analyses performed.

3.1 The Present Research

3.1.1 Longitudinal Prospective Online Study Design

This work utilized a longitudinal approach that enabled repeated measurement of mental health, health-related quality of life, and PA behavior of children and adolescents in two waves (Time: T_{week1} and T_{week6}) during the easing of the COVID-19 regulations. Specifically, a 6-week prospective study design was chosen in a naturalistic setting in a German elementary and grammar school. School students' PA was assessed during the study period using electronic smart devices. Data were collected through age-appropriate questionnaires. Self-reported information on children's and adolescents' psychological variables and PA was gathered if participants were at least 11 years old. Furthermore, one parent of every elementary school kid provided parent-reported data (cf. Otto et al., 2017). Pretest results were gathered in February 2022, just before COVID-19 limitations were loosened and repealed by the government on March 1, 2022. Six weeks later, in April 2022, the posttest data collecting for the retest took place. The 6-week duration is derived from earlier research on PA and mental health, which usually lasted four to twelve weeks (X. Wang et al., 2022), with most studies including a posttest at the end of six weeks (Herbert et al., 2020; Wei & Liu, 2023). Notably, studies found that a 6-week period is adequate to demonstrate meaningful impacts (Herbert et al., 2020). Based on this, the posttest was set after that period.

The survey was performed online to avoid disrupting the school's internal operations and workflows during the pandemic and to allow students and parents to complete the questionnaires conveniently from their homes. Consequently, initial assessments, such as online surveys on socio-demographic and mental health factors, were sent by email within the first week of the research. Subsequent follow-up surveys were distributed six weeks following the pretest, while PA was consistently monitored utilizing smart devices throughout the study period (see Figure 6). (cf. Kopp, 2021).

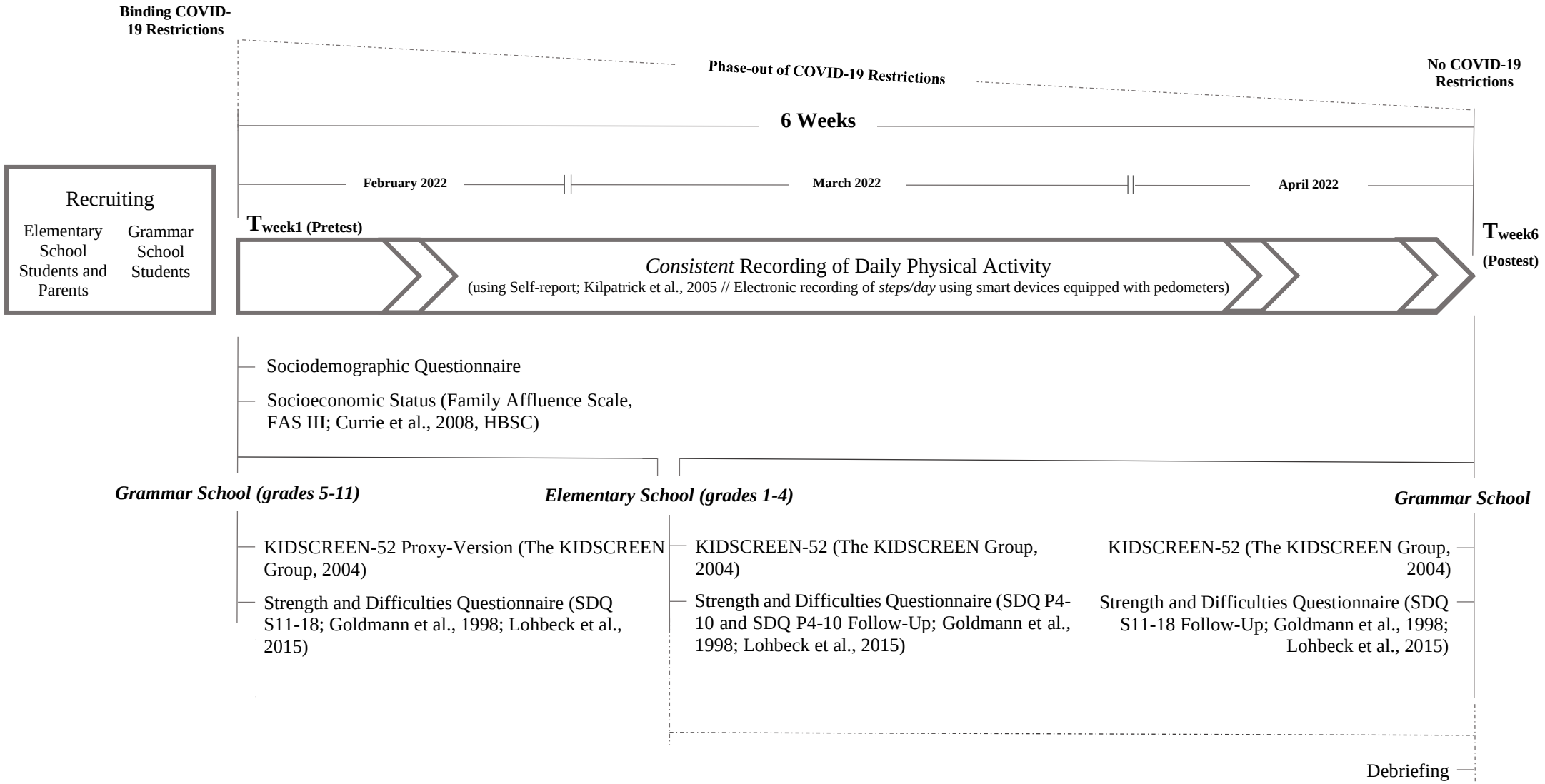

Figure 6 Study design and sequence of measurements. Adapted from Kopp (2021).

3.1.2 Ethical Approval

The study protocol of the present research involving human participants received approval from the ethics committees of the Saarland Medical Association (No. 52/22), Bavarian State Medical Association (No. mb22069), and the Commissioner for Data Protection of the Saarland University (see Chapter 10). So, ethical standards according to the Declaration of Helsinki and its later amendments (World Medical Association, 2013) and institutional review board agreements were met. All legal guardians gave their informed consent, and the children and adolescents provided their informed consent before their inclusion in the study. The students and their legal guardians (for both themselves and their participating children) submitted written informed consent to participate in this study.

3.1.3 Setting and Location for Data Collection - Featured Schools

Data was collected simultaneously in both a private state-approved bilingual elementary school (school number 2052) and a grammar school (school number 0271) in Munich, Germany. Both schools, with a total of 322 students and 11 grades, were part of a comprehensive all-day campus that provided frequent PA in various areas of everyday school life, such as during recess periods, regular courses, active breaks between classes (i.e., short bouts of PA as a break of academic instruction), curriculum-focused active breaks (i.e., short bouts of PA that include curriculum content) and before- and after-school programs. The curriculum specifically incorporated daily physical education classes for all grade levels, with durations of 60 to 80 minutes and 90 to 120 minutes for elementary and grammar school, respectively. Pricing and school contract menus were comparable among both schools. In addition, the campus aims to provide a sustainable and intercultural education. Particular emphasis is placed on promoting internationality, global thinking, and an entrepreneurial spirit. Individual learning and a balanced health concept are essential, with freshly prepared meals, daily sports, and exercise. According to the language immersion principle, children and adolescents are encouraged and challenged on that campus: English and German native-speaking teachers work with children in small groups according to a strongly individualized educational concept. Both schools (with an international scope) frequently admit international families from foreign countries who choose the school campus as a new school for their children during their temporary period in Germany.

The following Figure 7 provides information on the nationalities of approached elementary and grammar school students. In total, 92 (28.57%) children and adolescents from 29 foreign countries were enrolled in both schools.

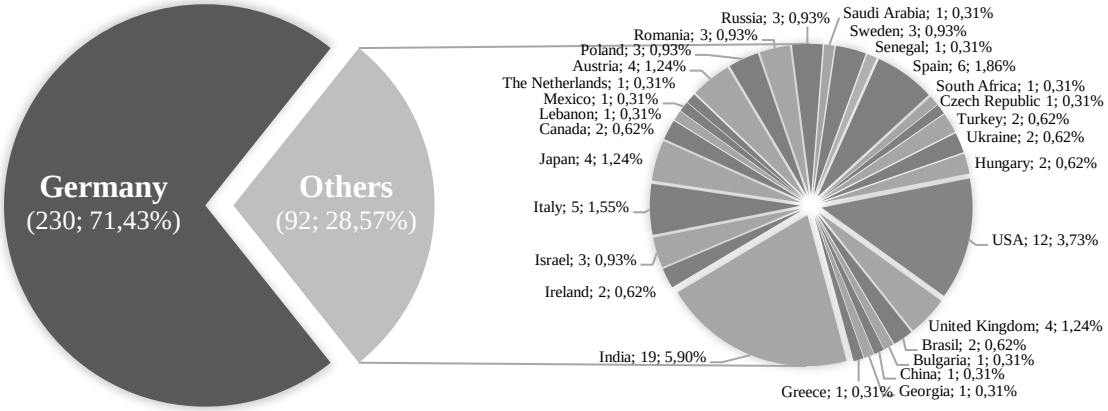

Figure 7 Approached elementary and grammar school students by nationality at the time of data collection.

3.1.4 Inclusion and Exclusion Criteria

This study focused on students enrolled in both an elementary school and a grammar school. The eligibility requirements were as follows:

- age between 6-18,
- fluency in either German or English,
- possession/use of a smartphone or a smartwatch equipped with a built-in pedometer,
- voluntary participation, and
- obtaining written informed consent from both legal guardians and students themselves.

For elementary school kids to participate in the study, their legal guardians were also requested to assist in filling out both online surveys, mainly due to the assessment instruments' validity, the cognitive capacity of young participants, and children's ability to read at this stage. No exclusion criteria were applied. *Note.* Developmentally delayed students were also invited to participate. Their eligibility to participate remained unaffected by this circumstance, as they usually participate in physical education lessons.

3.1.5 Sampling Procedures – Data Collection

The current study featured a longitudinal aspect involving two phases of online data assessment, spanning a total of 6 weeks for each student between February and March 2022. During this period of loosening COVID-19 regulations, students responded to questionnaires about their sociodemographic and mental health status, and PA levels. Following the study's conclusion, participants participated in a post-study session and received a debriefing. Measurement occasions varied slightly for each participant

due to temporally distinct participation in the study. Some students worked on the questionnaires immediately, while others were delayed. Figure 8 displays the procedures and the time sequence of all measures taken during the study period.

Teachers as Executives. Despite possessing the qualifications to guide students during the data collection phases, campus teachers were obligated to participate in a thorough briefing before the study to establish a solid understanding of this research from the outset, thus being prepared for supervision. This strategy aimed to ensure consistent data collection and student treatment across all grades to mitigate any bias from unevenly disseminated knowledge. Consequently, the investigator gave talks to guarantee that teachers were adequately and equally skilled in psychological variables and PA to supervise students and parents effectively if needed. Specifically, teachers were directed to refrain from using retention strategies if it seemed likely that students would withdraw from the study. In order to reduce study dropout (cf. Graham, 2009) and ensure adherence to the research protocols, teachers were instructed to contact students and parents repeatedly via email or in person to gather the follow-up survey data without delay (*Note*. A one-week delay was tolerated). As the study used objective PA data, teachers had to remind the participants to record their PA behavior using their smart devices. At the end of the study, participants were to be debriefed, and if they wished, they could withdraw their initial consent to analyze their data. Employing this approach legally secures using and processing data following the regulations of Saarland University. To relieve the burden on teachers, the investigator compiled all necessary documents and measures utilized in the web-based survey. Documents presented included a written handout about the study content for both students and their parents and an Excel spreadsheet to keep a written record of students' PA during the study period. The online link to the web-based survey was provided centrally to guarantee unified data collection for every student. (cf. Kopp, 2021).

Recruiting of students in both schools. Once the criteria were defined, class teachers in grammar school personally addressed their students (and their parents) and gave them details of the study. Teachers in elementary school (with kids aged 6 to 10) directly contacted the students' parents.

Incentive Schemes. In order to foster the intrinsic drive of children and adolescents towards PA and avoid the influence of external rewards, no compensation was provided for their participation in the study. However, students could register for a voucher raffle upon study completion.

Comprehensive Briefing of Students and Parents. Children, adolescents, and parents interested in participating were given a comprehensive explanation of the study protocols. They were also provided handouts and subscriber information outlining the present research and their obligations over six weeks. Students were notified that 1) their data would be handled securely following the General Data Protection Regulation (2016/679), and 2) this research complied with the German Research Foundation and Saarland University guidelines. Additionally, they were notified that the Ethics Committee has granted approval for the study, which does not entail any intrusive or possibly hazardous techniques.

Due to their voluntary participation, students could withdraw from the study at any point without facing any repercussions. Existing data records would be deleted upon withdrawal. (cf. Kopp, 2021).

Consent for participation. Legal guardians and adolescents who consented to participate provided written informed consent (World Medical Association, 2013).

PA recording during the study period. Between both measurement occasions (T_{week1}-T_{week6}), students adhered to their usual PA regimens and attended physical education lessons at school without interference (cf. Kopp, 2021). However, youths were instructed to consistently wear their smartwatch or carry their smartphone equipped with a built-in pedometer throughout the day, except when sleeping, to keep track of their daily steps. At the end of the day, the students or their parents were required to enter the electronic PA data into a pre-made Excel spreadsheet. Once the study was completed, the data set was sent to the investigator for statistical analysis.

Computerized Survey. The web-based data collection commenced upon students (and parents) agreed to participate. Children (or their parents) and adolescents were scheduled to complete baseline measures within several days of attending the research. As part of pretest data collection, a hyperlink to an online questionnaire measuring demographic variables (e.g., age, gender, current grade, and prior involvement in sports and exercise), mental health problems, HRQoL, and self-reported PA was sent by email in the initial days after consenting to participate in the research. During this session, psychological variables were determined at an early stage in the gradual loosening of COVID-19 regulations. In order to mitigate attrition, the surveys followed a warm-up approach suggested by prior research. Main measures, such as the KIDSCREEN-52 questionnaire and the Strength and Difficulties Questionnaire (SDQ), were positioned several pages into the survey. Hence, students had already responded to questionnaires on socio-demographic details and PA behavior before completing more challenging questionnaires (cf. Bernecker & Job, 2011; Musch & Klauer, 2003). After finishing the pretest, the students were notified about the date for the retesting survey (T_{week6}). In general, the follow-up questionnaire (posttest) on mental health problems, HRQoL, and self-reported PA was distributed six weeks after the pretest in order to asses maintenance or change in psychological variables and PA behavior. The two surveys were almost identical in content, so the main questionnaires on mental health and HRQoL were re-administered, and students had to repeat them. Students or parents entered the surveys using a unique code, facilitating dataset merging for each student across both measurement occasions. The time needed to complete the pre- and posttest surveys varied. The pretest (T_{week1}) required approximately 30 minutes, whereas the posttest (T_{week6}) could be completed in about 25 minutes. In order to mitigate any comprehension challenges faced by elementary school students, parents were asked to assist their children in completing the pretest and posttest questionnaires. However, if children filled in the questionnaires at school (e.g., PC lab), they could also ask their teacher to assist. (cf. Kopp, 2021).

Follow-ups. To ensure that participants completed the surveys promptly, campus teachers provided occasional email or in-person reminders informing students and parents that a new online

survey (e.g., posttest) would be available soon. A processing delay of several days was accepted to accommodate the unavailability of participants during holidays, during which online surveys were also made available. Furthermore, students and parents were instructed to refrain from simultaneously completing chronologically distinct questionnaires (e.g., T_{week1} simultaneously with T_{week6}).

Post-study session and voucher raffle. During debriefing, students had the option to retract their data from any additional analyses. Nevertheless, no student revoked his or her agreement to use their data. Furthermore, students and parents were given explicit information on the study's specific objective and why it was essential to withhold the exact specifics from the outset. Finally, teachers thanked students and parents for their eagerness to participate in the research. This was followed by a voucher raffle.

The flow chart presented in Figure 8 succinctly outlines all pertinent procedures.

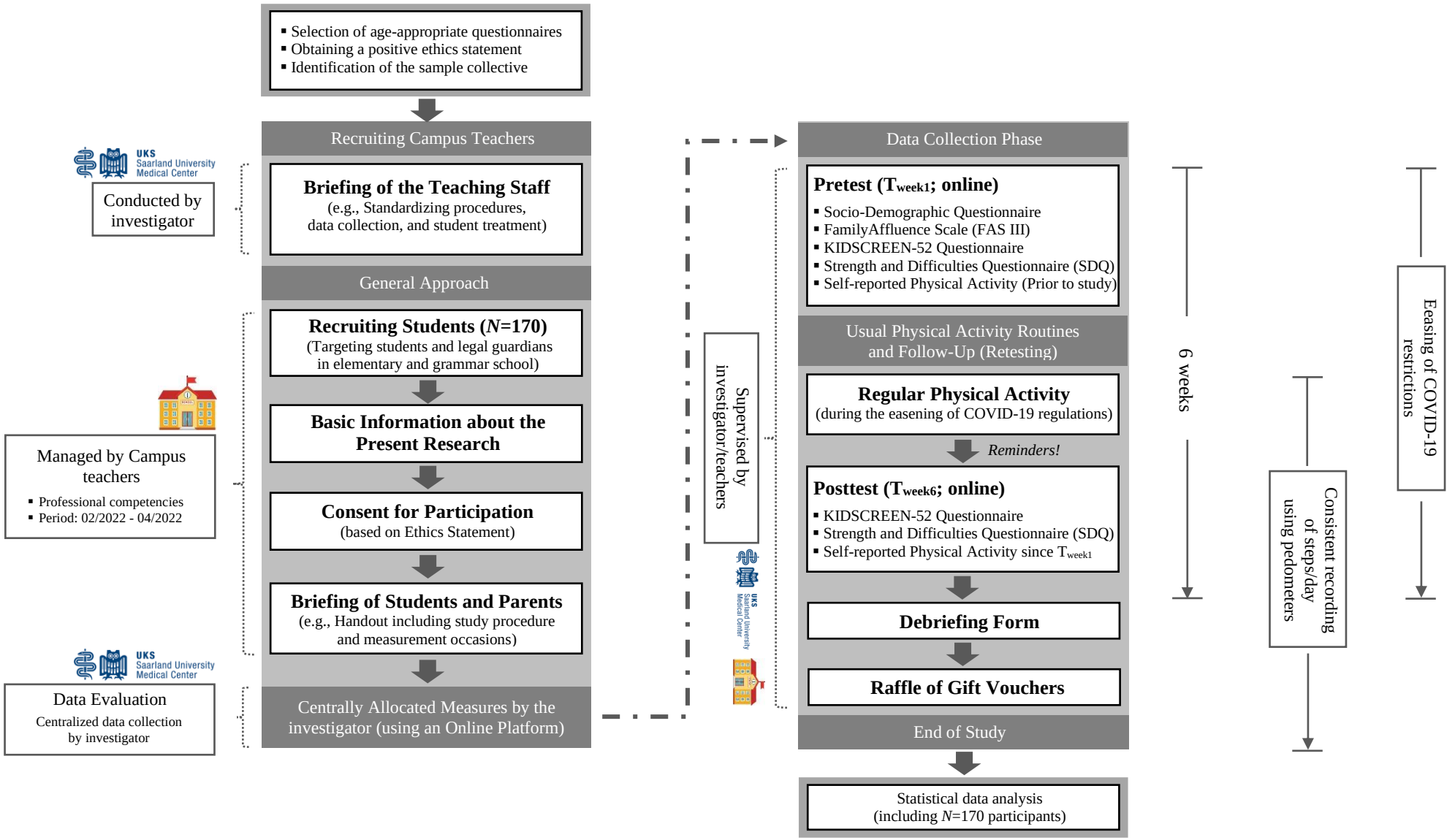

Figure 8 School campus study flow chart, including the sequence of measurements. *Note*. PA was used for statistical computations during the easing of COVID-19 restrictions. Adapted from Kopp (2021).

3.1.6 Determination of Sample Size

An a priori sample size calculation (Power Analysis) for linear regression with two tested predictor variables (pretest and time) was performed using the G*Power software (Faul et al., 2007). The calculation based on a middle effect size ($f^2 = 0.15$), a power of 0.80, and a significance level of 0.05 resulted in a minimal sample size of 89 participants to show significant effects (Field, 2014). The medium effect size was based on previous research investigating the impact of exercise on mental health in children and adolescents (Wegner et al., 2020). For the multilevel growth models (see statistical analyses), prior research has shown that a sample of 50 or more participants is needed at Level 2 to avoid biased estimates (Barr et al., 2013). In this research, the sample size at Level 2 included 170 participants (see Figure 9).

3.1.7 Intended and Achieved Sample Size

Participants were elementary and grammar school students aged 6 to 18. During the present research, 322 campus students and their legal guardians for lower-graded youths were initially approached and asked to participate in the study. Of them, 170 agreed to participate and signed informed consent, including 71 elementary school students from grades 1 to 4 and 99 grammar school students from grades 5 to 11. Those participants followed the online links to complete the baseline (T_{week1}) and retesting (T_{week6}) questionnaires. Figure 9 shows the intended and achieved sample size throughout the study.

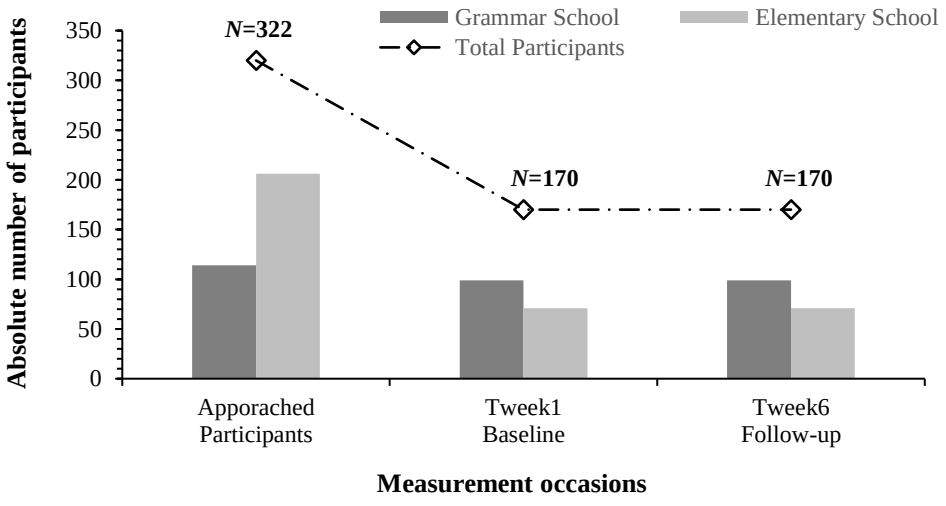

Figure 9 Intended and achieved sample size over six consecutive weeks.

In addition, Figure 10 shows the number of participating and approached students separately for each grade level in elementary school and grammar school.

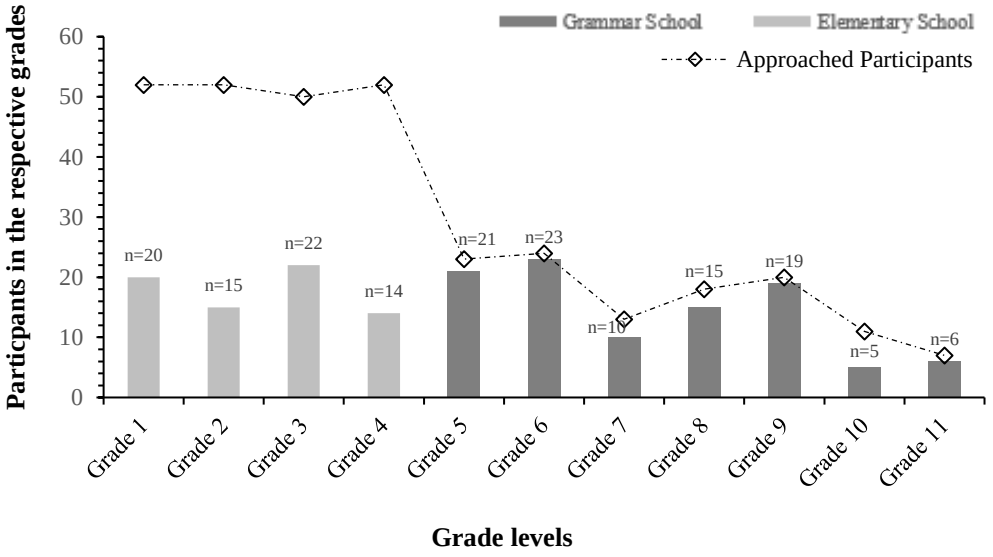

Figure 10 Approached and achieved participants per grade level.

Finally, Figure 11 summarizes the recruiting flow chart for participants at both schools.

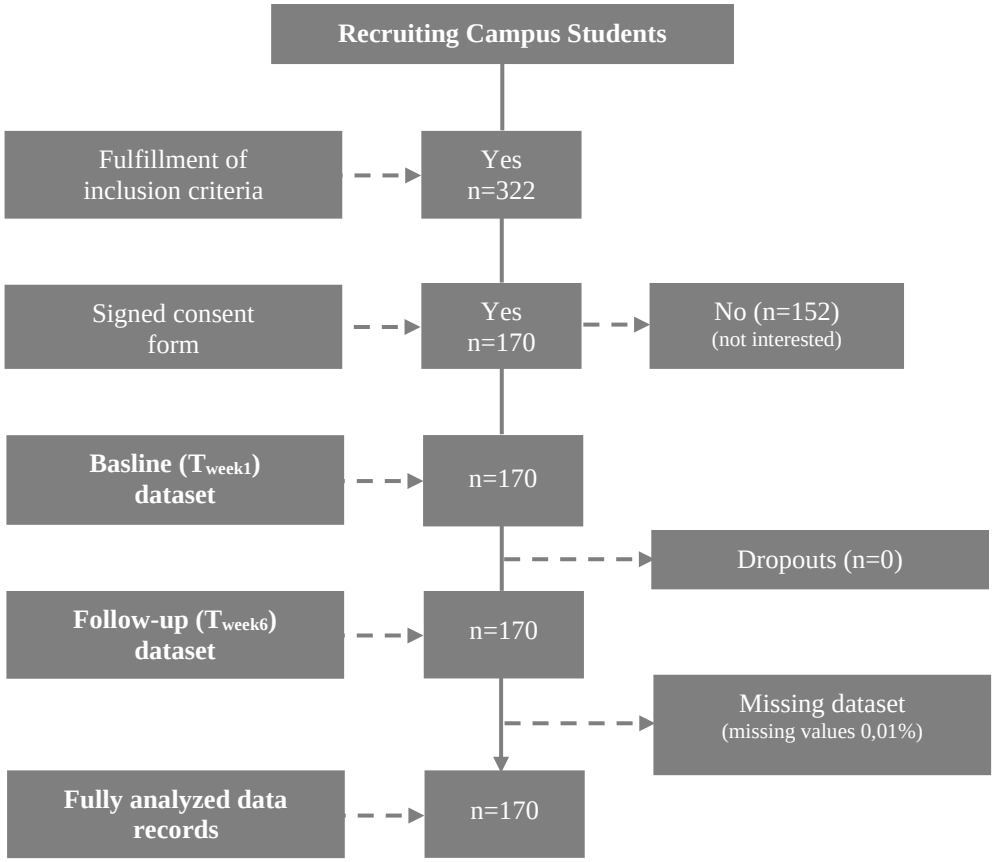

Figure 11 Study recruitment flow chart. *Note*. Missing values were statistically predicted by mixed effects models

3.2 Data Collection - Measures and Covariates

This section defines all primary and secondary outcome measures and covariates to address the research objectives. *Note.* Following the recommendations of the International Consortium for Health Outcomes Measurement (Krause et al., 2021), internationally established, standardized, and validated questionnaires were used to collect data on health-related quality of life (KIDSCREEN-52 index) and mental health problems (Strengths and Difficulties Questionnaire [SDQ]). According to the WHO (1993) guidelines, both instruments are child-centered, age-appropriate, cross-culturally comparable, and rely on self-report, supplemented by proxy judgments if the student is too young to provide a self-report (cf. Silva et al., 2019). Objective tools, such as smart devices (e.g., smartphones or smartwatches), assessed actual PA behavior during the easing of the COVID-19 regulations.

Note. The questionnaires' administration mode can generally affect the participation rate, the number of missing responses, psychometric properties, and scores. Because of this particular target group, especially when looking for children and adolescents, measuring psychological variables is particularly challenging as they may lose interest in filling out a questionnaire or feel that specific measures are too burdensome (Devine et al., 2015). Therefore, this research used online data entry instead of a paper format to reduce the number of missing responses and guarantee intimacy (Haverman et al., 2011). In particular, research confirmed only minor differences between computer and paper versions of the same questionnaires (Mangunkusumo et al., 2006; Turner et al., 1998). Consequently, digital versions of the questionnaires, specifically designed for children, adolescents, and parents, were employed. Due to the large number of international families and students, all questionnaires were provided in validated English and German versions. So, students (and their parents) could select based on their language proficiency. This research utilized the SoSci Survey software (Leiner, 2019) to program and administer the questionnaires online.

3.2.1 Demographic and Socio-economic Status *(control variables)*. At baseline, students provided information on their age, gender, socio-economic status (SES), international background, and prior experience in sports and exercise. SES and international background were checked as children and adolescents from low socio-economic and migrant backgrounds are more susceptible to experiencing mental health problems (Arroyo-Borrell et al., 2017) and were significantly more affected by the COVID-19 pandemic (Ravens-Sieberer et al., 2021a). In addition, SES is a crucial determinant of children's and adolescent's mental health and well-being (Kiernan & Mensah, 2009). SES was assessed using the Family Affluence Scale (FAS III; Boyce et al., 2006) as used in the National Health Studies by the HBSC in 2000/2001. The FAS III uses material markers to assess the family's status. In particular, the scale consists of six items that measure household wealth. These questions include the number of cars (0, 1, 2 or more), the number of bathrooms (0, 1, 2, 3 or more), the number of computers (0, 1, 2, 3 or more), non-shared bedroom (yes/no), dishwasher (yes/no), and the number of holidays abroad taken in the last 12 months (0, 1, 2, 3 or more). The total score is the sum of the answers to the six questions

and can range from 0 to 13. A higher score indicates that the participants' families have a higher socio-economic wealth (Boyce et al., 2006). In order to assess prior experience in exercise and sports, students were asked whether they had participated in any organized exercise courses or played any organized sports prior to the COVID-19 pandemic.

3.2.2 Health-related Quality of Life. The (age-appropriate) KIDSCREEN-52 questionnaire (Ravens-Sieberer et al., 2008; THE KIDSCREEN GROUP EUROPE, 2004) assessed health-related quality of life in children and adolescents. Since it can be challenging to obtain a reliable quality-of-life assessment from children under the age of 8 in elementary school through self-reporting, parents were asked for an external proxy assessment to rate their child's quality of life from the child's perspective. Consequently, for elementary school kids, the (German and English) KIDSCREEN proxy version for parents was used; however, for grammar school students, the standard self-report version was administered instead. The KIDSCREEN has good internal consistency (Cronbach's $\alpha = 0.82$), good retest reliability (ICC = 0.70), and good validity, as shown in several studies (Moore et al., 2020; Rhodes et al., 2019; Schmidt et al., 2020). The questionnaire includes 52 items related to ten dimensions: (1) physical well-being, (2) psychological well-being, (3) moods and emotions, (4) self-perception, (5) autonomy, (6) the quality of parent relation and home life, (7) social support and peers, (8) the quality of school environment, (9) social acceptance, and (10) the satisfaction with financial resources. The items were presented with 5-point Likert-type scales to assess frequency (1 = never, 2 = seldom, 3 = quite often, 4 = very often, 5 = always) or intensity (1 = not at all, 2 = slightly, 3 = moderately, 4 = very, 5 = excessively). Item scores for each dimension were summed up for analysis. Higher scores indicated a better quality of life. Scores for each dimension are calculated using Rasch analysis and then transformed into T-values. The KIDSCREEN questionnaire was designed to be easily understood across different cultures, age groups, and genders, which was essential due to the range of addressed participants and their international backgrounds.

3.2.3 Mental Health. On both measurement occasions, children and adolescents' mental health problems were assessed using the German and English self-report and parents' versions of the Strengths and Difficulties Questionnaire (SDQ) (Goodman et al., 1998). The SDQ is a well-established, reliable, and valid behavioral screening measure of mental health for baseline assessment. At the post-test, however, the respective follow-up questionnaire was employed, which assessed the mental health in the past month. The questionnaires were completed by either the children, adolescents, or their parents. For elementary school students (aged 6 to 10 years), the parent SDQ (i.e., SDQ P 4-10) was used to determine the students' mental health problems. The self-report SDQ (i.e., SDQ S 11-18) was employed for grammar school students. The SDQ assesses mental health problems using 20 items and four subscales: emotional problems, conduct problems, hyperactivity, and peer problems. Each subscale consists of five items with three response options ranging from 0 (not true) to 2 (certainly true). The

SDQ Total Difficulties Score is calculated by adding the scores for each item in every subscale. A higher score indicates that the student is facing more difficulties.

The SDQ usually includes a prosocial behavior subscale, but it wasn't used in the study as the main focus was on mental health problems (Ravens-Sieberer et al., 2021a; Ravens-Sieberer et al., 2021b). The self-reported and parent-reported versions of the SDQ have both been found to be reliable and valid measures of mental health problems in children and adolescents. The SDQ questionnaire is widely used and established, with satisfactory reliability (Cronbach's $\alpha = 0.73$), cross-informant correlation (mean: 0.34), retest reliability (0.62), and validity (Goodman et al., 1998).

3.2.4 Objective and Self-reported Physical Activity. (Actual) PA was operationalized as the *number of daily steps* and measured electronically using smart devices with a built-in pedometer, such as smartwatches and smartphones. However, the primary PA variable used for analysis was the *mean number of daily steps per week*, calculated for each six weeks. Due to the abundance of brands and fitness applications on the market, all smart devices or wearables with pedometers that can be worn continuously were accepted for use during the study period. Participants were asked to wear their smart device all day except for sleeping. The students kept track of their daily PA data using their smartphones. They maintained a separate Excel spreadsheet for this purpose. At the end of the study, they submitted the spreadsheet containing their accurate PA data for the entire study period to the experimenter. The students also indicated their self-reported PA data online during both measurement occasions.

In both measurements, an additional self-report-item, "Please indicate the number of days you participated in sports or exercise in the last week" (Kilpatrick et al., 2005), was used to assess the changes in PA levels from the pretest to the posttest.

3.3 Statistical Analyses

The study sample was described using descriptive analysis. Additionally, linear multilevel growth models were utilized to examine if there was a change in PA (the number of daily steps) over time. The growth modeling was utilized due to the hierarchical nature of the data (Level 1 = weeks, Level 2 = students). However, a Level 3 variable (i.e., elementary vs. grammar school) was not included in the growth modeling because the preliminary intercept-only model revealed that school affiliation did not significantly explain the variation in PA (cf., Field, 2014; Kopp et al., 2024). Growth models are multilevel models in which changes in an outcome over time are modeled using potential growth patterns. The hierarchy in the data is that time points are nested within participants. As such, it is a way of analyzing repeated-measures data with a hierarchical structure (Field, 2014). Initially, intercept-only models were calculated to investigate the extent to which the variation in PA might be attributed to the between- and within-person levels. Next, an unconditional linear growth model was calculated for

physical activity (PA), using merely a "time" variable as an indicator, in order to analyze its temporal changes. Then, conditional growth models were employed to examine the impact of demographic variables on PA. The fixed predictor variables included intercept, time (i.e., week 1 to 6), and the five demographic variables (gender, age, international background, economic status, and prior experience in exercise and sports). The random effects encompassed a random intercept and a random slope for "time". Given a setting of repeated measurements in this study, the variance type "unstructured" was chosen. This selection accommodates all variances and covariances among the random effects (cf. Kopp et al., 2024). In particular, this covariance structure to estimate the model parameters is general and assumed to be completely unpredictable, so it does not confirm a systematic pattern. The chi-square likelihood ratio test is used to evaluate the overall fit of a multilevel model. The deviance between different models is reported as minus twice the log-likelihood (-2LL). The smaller the log-likelihood value, the better the model fits and the less unexplained variance left (Field, 2014). Ultimately, to examine the impact of mental health issues and HRQoL on the development of PA, separate conditional growth models were constructed. These models incorporated the pretest SDQ and KIDSCREEN variables and their interactions with "time" as predictors. Given that students' PA levels were considerably influenced by their international (i.e., migration) background and socio-economic status, conditional growth models controlled for both variables. The participant's PA data had a meager percentage of missing values (0.01%), whereas the SDQ and KIDSCREEN variables and covariates had none. The analyses, however, included these cases despite the missing data since mixed-effects models accurately predict results even with partly missing data. In order to assess any changes in mental health and HRQoL between the pretest and posttest, paired t-tests were conducted for the SDQ and KIDSCREEN variables (cf. Kopp et al., 2024). Hierarchical multiple regression analyses were then conducted on posttest SDQ and KIDSCREEN scores to test whether PA could predict mental health changes. The respective pretest SDQ or KIDSCREEN score was entered as the first blocking variable, and PA (the mean number of daily steps) was added on the second step (*Note*. Hierarchical regression is a method of multiple regression and involves entering known predictors by previous research first, followed by new ones (Field, 2014)). Normality, linearity, and homoscedasticity were assessed by generating normal probability plots of the standardized residual and scatterplots of residuals. The non-autocorrelation assumption was fulfilled, as shown by the Durbin-Watson test (Durbin-Watson-test; $1.5 < d < 2.5$ for all regression models). Furthermore, there were no significant issues of multicollinearity seen among the predictor variables, as shown by the variance inflation factor statistics being less than 4.0. (cf. Kopp et al., 2024).

All analyses were performed with SPSS 27.0 (IBM Corp.; Armonk, NY). The level of significance was set at $p < 0.05$ (two-tailed). To graphically display the results, participants were dichotomized into low and high in a given SDQ and KIDSCREEN variable based on the German norm values. (cf. Kopp et al., 2024).

4. Results

This section presents the results of all inferential statistic tests conducted, including the analytical strategy and descriptions of each primary and secondary outcome. Additionally, major demographic participant characteristics are reported.

4.1 Participant Characteristics

Table 1 displays the socio-demographic baseline characteristics of the *N*=170 consenting elementary and grammar school participants. Most students self-identified their current gender as female (42%) or male (55%). 60 students (35%) reported having an international background. The household wealth of participants ranged from 4 to 13 (M = 9.84, SD = 2.13), indicating an average-to-high economic status of the participants' families. In particular, most participants (90%) reported past sport or exercise behavior. Students from 11 different classes were included in the sample; the inter-class distribution was approximately the same (15 – 20 students from each class/grade) except for the two highest grades, from which only 5 and 6 students participated.

Table 1 Characteristics of the study sample (*N*=170)

	Elementary School (*n*=71)		**Grammar School (*n*=99)**	
	***n* (%)**	***M (SD)***	***n* (%)**	***M (SD)***
Gender				
Men	32 (45)		62 (63)	
Women	38 (54)		33 (33)	
Divers	1 (1)		4 (4)	
Age (years)		8.04 (1.20)		13.10 (2.10)
International background				
Yes	18 (25)		42 (42)	
No	53 (75)		57 (58)	
Economic status		9.34 (2.26)		10.20 (1.97)
Past sport/exercise behavior				
Yes	61 (86)		92 (93)	
No	10 (14)		7 (7)	

Note. Economic status can range from 0 to 13, with higher values representing higher status.

Figure 12 displays the nationalities of participating students during data collection. In total, 35.29% of international (i.e., with migration background) students from 19 countries participated in the study.

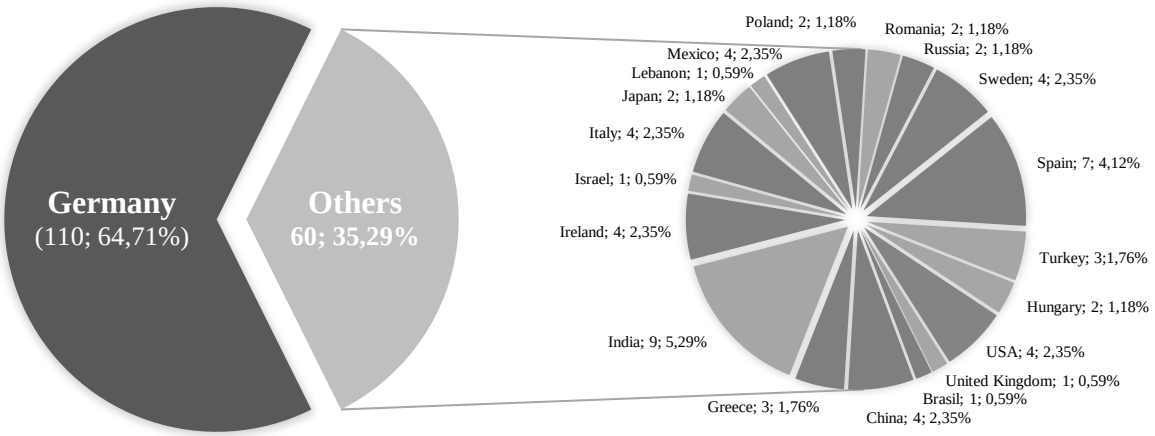

Figure 12 Participating elementary and grammar school students by nationality at the time of data collection

4.2 Inferential Statistical Analyses

4.2.1 Evolution of Physical Activity

The computed growth models showed a substantial linear effect of time, $F(1, 169) = 21.94$, $p < .001$, indicating an increase in PA with each consecutive week of the study period (see mean daily steps and *SD*s in Table 2), $b = 100.00$, $t(169) = 4.68$, $p < .001$, 95% CI [57.85, 142.15]. Furthermore, the study found notable impacts of international background, as shown by $F(1, 163) = 7.90$, $p = .006$, and socio-economic level, $F(1, 163) = 5.59$, $p = .019$. Participants with international backgrounds exhibited lower PA levels compared to their peers, $b = -607.90$, $t(163) = -2.81$, $p = .006$, 95% CI [-1,035.08, -180.02], while economic status positively predicted PA, $b = 117.15$, $t(163) = 2.37$, $p = .019$, 95% CI [19.32, 214.98]. The analysis further revealed significant variance in intercepts across students, $\text{Var}(u_{0j}) = 1{,}493{,}960$, $Z = 18.44$, $p < .001$, and in the slopes across students, $\text{Var}(u_{1j}) = 27{,}022$, $Z = 3.05$, $p = .002$. However, the covariance between intercept and slope was not significant, indicating no between-student variation in how physically active they became over time. The age, gender, or prior sport or exercise habits of the students did not predict PA. The number of self-reported days of sport or exercise behavior showed an increase from the pretest ($M = 4.54$, $SD = 1.52$) to the posttest ($M = 5.54$, $SD = 1.26$), $t(169) = -7.96$, $p < .001$, Cohen's $d_z = 0.61$. These findings match the growth model results discussed earlier, indicating that students improved their PA levels during the 6-week study period. (cf. Kopp et al., 2024).

Table 2 Means (and *SD*s) of daily steps during six weeks

	Elementary school (n=71)	**Grammar school (n=99)**	**Total sample (*N*=170)**
Week 1	6701 (593)	7454 (1557)	7139 (1230)
Week 2	7295 (711)	7506 (1931)	7417 (1544)
Week 3	7386 (841)	7483 (1861)	7443 (1518)
Week 4	7411 (790)	7682 (1900)	7569 (1539)
Week 5	7500 (660)	7805 (2286)	7678 (1798)
Week 6	7367 (674)	7866 (2177)	7658 (1731)

Note. The period between week 1 and week 6 reflects the easing of the Covid-19 restrictions. Adapted from Kopp et al., 2024.

4.2.2 The Impact of Mental Health Issues on Physical Activity

The parameter estimates for the SDQ variables are summarized in Table 3. Mental health problems at the pretest were unrelated to PA over the 6-week period. Similarly, mental health problems did not predict how participants changed their PA over time, except for the emotional symptoms variable, which revealed a significant interaction with Time, $b = 18.44$, $t(168) = 2.06$, $p = .041$, 95% CI [0.76, 36.11]. Students exhibiting higher levels of emotional symptoms showed a sharper increase in PA towards the end of the 6-week period compared with students with lower levels of emotional symptoms (see Figure 13). (cf. Kopp et al., 2024).

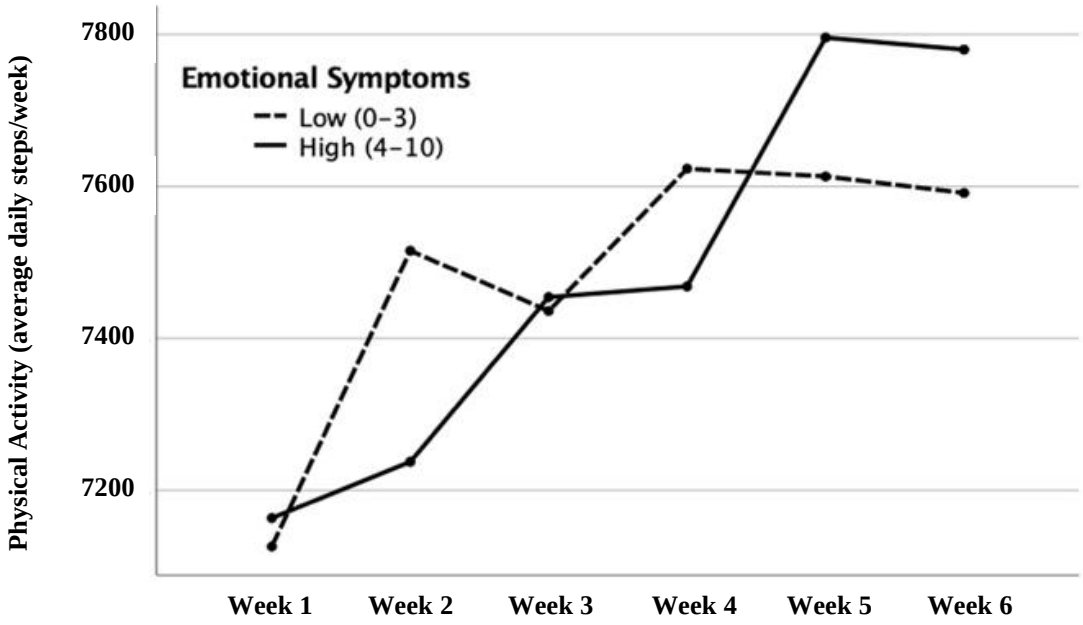

Figure 13 Physical activity among students with high and low levels of emotional symptoms (cf. Kopp et al., 2024).

Table 3 Unstandardized parameter estimates for the growth models examining the relationship between mental health issues and physical activity during the COVID-19 pandemic

	Mental health problems (total)	Emotional symptoms	Conduct problems	Hyperactivity	Peer problems
Model 1					
Fixed effects					
Intercept	6,166.86**	6,176.69**	5,832.06**	6,225.47**	6,113.98**
International background	-650.81**	-668.41**	-645.25**	-645.51**	-648.25**
Economic status	124.72**	125.49**	127.96**	125.78**	124.74**
Time	100.00**	100.00**	100.00**	100.00**	100.00**
Variable	-10.23	-40.48	82.58	-49.64	-29.20
Random effects					
Residual	883,275**	883,275**	883,275**	883,275**	883,275**
Intercept	1,467,317**	1,447,572**	1,452,924**	1,467,620**	1,472,110**
Slope	27,022**	27,022**	27,022**	27,022**	27,022**
Cov (Intercept, Slope)	-40,330	-38,985	-40,848	-42,784	-41,195
Deviance (-2LL)	17,282	17,280	17,278	17,279	17,280
Model 2					
Fixed effects					
Intercept	6,204.32**	6,293.37**	5,838.16**	6,161.62**	6,091.51**
International background	-650.81**	-668.41**	-645.25**	-645.51**	-648.25**
Economic status	124.72**	125.49**	127.96**	125.77**	124.74**
Time	82.57	44.59	97.17**	129.29**	110.40**
Variable	-13.61	-79.28	79.72	-32.86	-18.68
Time × Variable	1.57	**18.44***	1.33	-7.69	-4.87
Random effects					
Residual	883,275**	883,275**	883,275**	883,275**	883,275**
Intercept	1,469,071**	1,441,107**	1,455,043**	1,468,251**	1,473,954**
Slope	27,402**	25,564**	27,479**	27,155**	27,418**
Cov (Intercept, Slope)	-41,146	-33,914	-41,831	-43,073	-42,048
Deviance (-2LL)	17,277	17,269	17,271	17,272	17,273

Note. Cov = covariance; -2LL = -2 log likelihood. The dependent variable was physical activity (number of daily steps) during the six weeks. Within Model 1, the impact of the corresponding SDQ variable was assessed to determine its effect on PA during the course of the six weeks. Model 2 was modified to include the interaction between the SDQ variable and time to investigate the impact of the SDQ variable on the progression of PA over the six weeks. International background: 0 = no, 1 = yes. Significant relationships between mental health problems and physical activity are shown in bold. Adapted from Kopp et al. (2024).

*$p < .05$; **$p < .01$

Note. Model 1 and Model 2 are nested models and, thus, must be presented separately. Model 1 tests the effect of the respective SDQ variable on PA during the six weeks in general, yet not on the evolution of PA over the six weeks. In Model 2, the interaction between the variable and time is added to test how PA changes over the six weeks depending on the variable. This also explains why the time effect is equal across the subscales in Model 1. PA is a time-varying variable, and although its value can change across time, the parameter value estimating the "Time" (or slope) effect is assumed to be constant (Model 1). One can ease this assumption by including an interaction between time and the subscale, which allows for different rates of change for participants with different scores in the subscale (Model 2; Singer & Willett, 2003). Regarding the deviance, the –2 log likelihood (–2LL) was used to indicate model fit. This is a standard procedure when models are nested (i.e., models that have been fit using the same data and where one model is a subset of the other). The change in –2LL thus reflects the change between models; lower –2LL values are better.

4.2.3 The Impact of Health-related Quality of Life on Physical Activity

Parameter estimates for the KIDSCREEN variables are shown in Table 4. HRQoL at the pretest was largely unrelated to PA over the 6-week period. The analysis revealed that only the level of physical well-being had a significant impact on PA, $b = 85.52$, $t(166) = 2.97$, $p = .003$, 95% CI [28.61, 142.44]. This indicates that students with greater physical well-being tended to be more active. None of the HRQoL variables were shown to be significant predictors of students‘ changes in PA over time, as confirmed by the lack of significant interactions between the HRQoL variable and time (i.e., Variable × Time interactions). *Note*. In this data analysis, Model 1 examines the impact of the respective KIDSCREEN variable on overall PA during the six weeks in general rather than on the evolution of PA over the course of the six weeks. Model 2 incorporates the interaction between the variable and time to examine the fluctuations in PA over the six weeks depending on the variable. (cf. Kopp et al., 2024).

Table 4 Unstandardized parameter estimates for the growth models examining the relationship between health-related quality of life and physical activity during the COVID-19 pandemic

	Physical well-being	Psychological well-being	Moods and emotion	Self-perception	Autonomy	Parent relation	Financial resources	Social support	School environment	Social acceptance
Model 1										
Fixed effects										
Intercept	4,652.57**	5,794.51**	6,028.56**	6,022.78**	6,162.14**	5,879.48**	6,489.02**	5,222.48**	6,666.23**	5,356.23**
International background	-712.19**	-663.84**	-643.09**	-642.22**	-632.56**	-645.18**	-616.43**	-635.78**	-585.00**	-631.94**
Economic status	121.73**	127.40**	124.70**	124.90**	123.93**	124.90**	132.49**	127.59**	115.83*	121.32*
Time	100.00**	100.00**	100.00**	100.00**	100.00**	100.00**	100.00**	100.00**	100.00**	100.00**
Variable	**85.52****	10.04	0.74	1.16	-5.93	6.96	-43.84	34.53	-23.75	55.83
Random effects										
Residual	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**
Intercept	1,412,076**	1,474,754**	1,472,368**	1,471,959**	1,468,919**	1,468,184**	1,473,809**	1,451,585**	1,445,564**	1,448,079**
Slope	27,022**	27,022**	27,022**	27,022**	27,022**	27,022**	27,022**	27,022**	27,022**	27,022**
Cov (Intercept, Slope)	-45,013	-41,879	-40,705	-40,611	-39,999	-39,917	-43,663	-41,653	-37,187	-38,733
Deviance (-2LL)	17,273	17,310	17,282	17,281	17,281	17,282	17,279	17,279	17,281	17,279
Model 2										
Fixed effects										
Intercept	4,763.05**	5,961.54**	6,050.51**	5,929.09**	6,440.30**	5,524.23**	6,076.54**	5,312.46**	6,926.77**	5,163.92**
International background	-712.19**	-663.84**	-643.09**	-642.22**	-632.56**	-645.18**	-616.43**	-635.78**	-585.00**	-631.94**
Economic status	121.73**	127.40**	124.70**	124.90**	123.93**	124.90**	132.49**	127.59**	115.83*	121.32*
Time	50.00	22.98	89.81	143.53	-29.71	265.75*	288.20*	58.46	-23.57	190.37
Variable	**79.14***	2.84	-0.06	5.90	-20.88	21.66	-11.41	30.57	-35.18	70.56
Time × Variable	2.89	3.32	0.37	-2.20	6.97	-6.86	-14.80	1.83	5.42	-6.92
Random effects										
Residual	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**	883,275**
Intercept	1,413,883**	1,475,482**	1,474,484**	1,473,635**	1,468,187**	1,466,621**	1,469,447**	1,453,424**	1,444,695**	1,449,069**
Slope	27,393**	27,177**	27,479**	27,384**	26,863**	26,682**	26,114**	27,415**	26,827**	27,242**
Cov (Intercept, Slope)	-45,832	-42,214	-41,687	-41,390	-39,658	-39,189	-41,673	-42,503	-36,774	-39,199
Deviance (-2LL)	17,267	17,277	17,278	17,277	17,275	17,275	17,270	17,274	17,274	17,272

Note. Cov = covariance; -2LL = -2 log likelihood. The dependent variable was physical activity (number of daily steps) during the six weeks. In Model 1, the effect of the respective KIDSCREEN variable was assessed to determine its impact on PA during the course of the six weeks. Model 2 was modified to include the interaction between the KIDSCREEN variable and time was added to investigate the impact of the KIDSCREEN variable on the evolution of PA over the six weeks. International background: 0 = no, 1 = yes. Significant relationships between health-related quality of life and physical activity are shown in bold. Adapted from Kopp et al. (2024).

*$p < .05$; **$p < .01$

4.2.4 Evolution of Mental Health Problems and Health-related Quality of Life

The prevalence of mental health issues experienced a modest decline from the pretest to the posttest. However, it is important to note that this reduction did not reach statistical significance (p = .062). (*p* = .062). Regarding single subscales, the hyperactivity subscale showed a significant reduction at the posttest, $t(169) = 2.90$, $p = .004$, Cohen's $d_z = 0.22$. HRQoL showed no significant changes, except for physical well-being, $t(169) = -2.92$, $p = .004$, Cohen's $d_z = 0.22$, autonomy, $t(169) = -5.83$, $p < .000$, Cohen's $d_z = 0.48$, and the quality of school environment, $t(169) = -2.69$, $p = .008$, Cohen's $d_z = 0.21$. These factors improved considerably during the posttest, as indicated in Table 5. (cf. Kopp et al., 2024).

Table 5 Psychometric properties: Mental health problems and HRQoL at the pretest and the posttest

	Pretest	**Posttest**	***t*-test (*df* = 169)**	***p*-value**	**Cohen's d_z**
Mental health problems					
Mental health problems (total)	11.08 ± 5.72	10.48 ± 6.55	1.88	.062	0.14
Emotional symptoms	3.01 ± 2.37	2.90 ± 2.64	0.78	.436	0.06
Conduct problems	2.14 ± 1.70	1.96 ± 1.74	1.65	.100	0.13
Hyperactivity	3.81 ± 2.35	3.47 ± 2.31	2.90	**.004**	0.22
Peer problems	2.14 ± 1.66	2.15 ± 1.83	-0.11	.916	0.01
Health-related quality of life					
Physical well-being	17.29 ± 3.29	17.86 ± 3.40	-2.92	**.004**	0.22
Psychological well-being	23.21 ± 5.26	23.69 ± 4.76	-1.77	.079	0.14
Moods and emotion	27.53 ± 6.01	27.61 ± 6.20	-0.24	.814	0.02
Self-perception	19.76 ± 4.51	19.82 ± 4.95	-0.28	.778	0.02
Autonomy	18.61 ± 3.56	19.94 ± 3.43	-5.83	**.000**	0.48
Parent relation	24.16 ± 4.11	24.15 ± 4.37	0.21	.983	0.00
Financial resources	12.72 ± 2.49	12.71 ± 2.57	0.04	.972	0.00
Social support	22.72 ± 4.54	22.73 ± 4.36	-0.04	.969	0.00
School environment	22.79 ± 4.71	23.59 ± 4.76	-2.69	**.008**	0.21
Social acceptance	13.05 ± 2.24	13.03 ± 2.48	0.14	.891	0.01

Note: The data are reported as mean ± SD. Significant *p*-values are indicated in bold. Cohen's d_z represents the measure of effect size. By convention, effect sizes of 0.20, 0.50, and 0.80 are classified as small, medium, and large, respectively. (cf. Kopp et al., 2024).

4.2.5 The Impact of Physical Activity on Mental Health Problems

The multiple regression analyses indicated that PA did not have a significant impact on the decrease of mental health issues from the pretest to the posttest (see Table 6) (cf. Kopp et al., 2024).

4.2.6 The Impact of Physical Activity on Health-related Quality of Life

The multiple regression analyses revealed that PA had no impact on the alteration in HRQoL (see Table 7) (cf. Kopp et al., 2024).

Table 6 Multiple regressions analysis of physical activity on the reduction of mental health problems (posttest)

	Mental health problems (total)		**Emotional symptoms**		**Conduct problems**		**Hyperactivity**		**Peer problems**	
	ß	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***
Step 1										
Pretest variable	.78	16.07**	.76	14.98**	.70	12.54**	.79	16.73**	.66	11.22**
Step 2										
Pretest variable	.78	16.16**	.76	14.98**	.69	12.38**	.79	16.67**	.66	11.28**
Physical activity	.07	1.47	.04	0.72	.09	1.68	.03	0.52	.08	1.38

Note. The posttest SDQ variables were the dependent variables, while controlling for the respective pretest SDQ variable. The standardized regression weights (ß) and the respective *t*-tests are presented (cf. Kopp et al., 2024).

*$p < .05$; **$p < .01$

Table 7 Multiple regressions analysis of physical activity on the change in health-related quality of life (posttest)

	Physical well-being		**Psychological well-being**		**Moods and emotion**		**Self-perception**		**Autonomy**		**Parent relation**		**Financial resources**		**Social support**		**School environment**		**Social acceptance**	
	ß	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***	**ß**	***t***
Step 1																				
Pretest variable	.71	13.07**	.76	15.06**	.76	15.23**	.80	17.52**	.64	10.78**	.65	11.04**	.62	10.24**	.62	10.21**	.66	11.35**	.56	8.64**
Step 2																				
Pretest variable	.72	12.92**	.76	15.12**	.77	15.37**	.81	17.57**	.64	10.71**	.65	11.01**	.61	10.10**	.63	10.39**	.67	11.40**	.56	8.69**
Physical activity	-.04	-0.65	.07	1.43	.08	1.68	.05	1.17	-.03	-0.50	-.03	-0.57	-.08	-1.26	-.10	-1.67	.07	1.11	-.06	-0.95

Note. The posttest KIDSCREEN variables were the dependent variables while controlling for the respective pretest KIDSCREEN variable**.** The standardized regression weights (ß) and the respective *t*-tests are presented (cf. Kopp et al., 2024).

*$p < .05$; **$p < .01$

5. Discussion

5.1 Summary

This dissertation investigated the reciprocal relationship between PA and (the change in) mental health in German children and adolescents during the gradual loosening of COVID-19 regulations. The scientific contribution is derived from a longitudinal study conducted under real-life conditions in a German elementary and grammar school ranging from grades 1-11, targeting students (*N*=170) aged 6-18. The study included repeated measures in two waves (T_{week1} and T_{week6}) over a period of six weeks. Pretest data was collected in February 2022, just before the German authorities gradually withdrew the Covid-19 restrictions. The posttest data collection was placed six weeks later, in April 2022, with continuous measurement of PA (steps/day) utilizing smart devices equipped with a built-in pedometer during the whole research period. This work extends previous research by identifying the bilateral association between psychological variables (i.e., mental health and HRQoL) and PA behavior during the easing of the COVID-19 regulations.

5.2 Critical Analysis and Reflections

Consistent with the hypothesis, the PA levels steadily increased after gradually loosening the COVID-19 regulations. However, this rise was unrelated to pretest mental health issues and HRQoL, with the exception of emotional symptoms. Students suffering from greater emotional problems showed reduced PA levels straight after the easing of constraints but increased their PA levels towards the end of the study. Moreover, hyperactivity decreased, and physical well-being, perceived autonomy, and perceived quality of the school environment improved after the easing of COVID-19 restrictions. Nevertheless, the students' level of PA did not serve as a predictor for any of these changes. The fact that PA levels improved after the COVID-19 restrictions were lifted aligns with similar findings from research examining the PA of youth upon their return to school (Benzing et al., 2022; Hurter et al., 2022). Notably, this trend was expected since COVID-19 regulations limited or eliminated several possibilities for youths to engage in PA, such as active commuting to school, active breaks during school hours, and sports activities both inside and outside the school campus (McKenzie, 2019; Schlund et al., 2021). Moreover, this research demonstrated no covariance between intercept and slope in the rate of change in PA levels, indicating that students increased their PA engagement after the pandemic, irrespective of their activity levels during the COVID-19 measures. The results were further confirmed by students' self-reported PA levels. The negative impact of COVID-19 containment measures on children‘s and adolescents‘ PA levels appears to have decreased with the resumption of school attendance and their renewed participation in recreational sports activities. Considering the evidence

that mental health prior to the COVID-19 crisis predicted PA during the pandemic (cf. Wunsch et al., 2021), this research postulated that mental health issues and HRQoL during the pandemic would affect the pace of increase in students' PA levels after the COVID-19 measures were gradually withdrawn. However, empirical analyses revealed no evidence confirming this assumption. Notably, the intensity of emotional symptoms was the only factor showing a substantial interaction effect, while pretest conduct problems, hyperactivity, peer problems, and overall mental health problems were not related to how PA evolved throughout the course of the six weeks. In terms of HRQoL, none of the KIDSCREEN variables substantially predicted the increase in PA levels that occurred after loosening the security measures. These findings suggest that the factors for the gradual rise in PA were mainly unrelated to students' mental health. Instead, it is likely that school and sports clubs reopening probably had a more substantial impact on the gradual increase in PA during this specific period. Consequently, the impact of mental health on students' participation in PA was diminished. (cf. Kopp et al., 2024).

Regarding the interaction effect of emotional symptoms, this research revealed that those students who had higher levels of anxiety and concern showed lower PA levels immediately after the security measures were lifted. However, they did catch up and increased their PA levels towards the end of the six weeks. However, it is essential to note that this result might potentially be a spurious finding resulting from the administration of multiple tests since the observed impact was gone after the Bonferroni adjustment was included. Bonferroni correction is applied to the α-level to control the overall Type 1 error rate when multiple significance tests are carried out (cf. Field, 2014). Conversely, as shown in previous studies, the result may also be explained by greater initial concerns about and longer adaptations to the gradually loosening security measures among apprehensive students (Fineberg et al., 2021). While there were only little variations (ranging from 20 to about 200 daily steps per week) seen across groups at each measurement occasion, this finding remains important as it emphasizes the positive impact of even a tiny shift towards a more active lifestyle on the emotional well-being of children and adolescents. The result has clinical and therapeutic significance since little modifications in behavior are often more attainable than substantial adjustments in lifestyle. (cf. Kopp et al., 2024).

Moreover, this research sought to examine whether the lifting of COVID-19 regulations had any impact on students' mental health status and if increased PA levels anticipate this change. The findings indicated a reduction in participants' hyperactivity levels with gradually loosening restrictions, along with improvements in their physical well-being, perceived autonomy, and the quality of the school environment. However, students’ PA did not predict any of these alterations, so contradicting prior research that has shown evident advantages of PA for the mental well-being of children and adolescents (Biddle et al., 2019, García-Hermoso et al., 2020; Marker et al., 2018; Wegner et al., 2020). The disparities in outcomes might be attributed to variations in the study's structure and physical activity assessment. Prior research mostly used a PA intervention, but this research employed an observational methodology. Intervention studies have shown moderate impacts, although observational data indicate

weak or nonexistent relationships (Biddle et al., 2019; Marker et al., 2018). Furthermore, most observational studies measure PA using self-reported data, which can result in overestimation (Kopp et al., 2020) and common method variance (Field, 2014) potentially inflating the magnitude of the relationship seen in prior research. Notably, this study used a more objective behavioral assessment by using smart devices equipped with a built-in pedometer, such as smartphones or smartwatches. Another plausible explanation is that the resumption of typical behaviors (such as PA) following the lifting of COVID-19 restrictions coincided with multiple positive changes that collectively had a significant influence on enhancing students' mental health and well-being. As a result, the usual positive impact of PA became less prominent and less obvious. Indeed, literature shows that children who engaged in PA experienced improved HRQoL compared to their sedentary peers throughout the COVID-19 lockdown. However, these disparities were gone soon after the gradual easing of the emergency measures. Furthermore, the post-lockdown PA alteration did not correlate with any HRQoL modifications (Benzing et al., 2022). Consequently, while removing COVID-19 regulations had a positive impact on students' mental health, these effects were not directly associated with the rise in PA. This increase in PA might instead be attributed to several other favorable changes that co-occurred alongside the lifting of restrictions, which collectively had a considerably more significant effect. (cf. Kopp et al., 2024).

Prior studies have shown that boys exhibit higher PA levels compared to girls, and PA tends to decline as individuals age (Andersen et al., 2006; Whitt-Glover et al., 2009). Nevertheless, the latest findings indicate these disparities may attenuate during the COVID-19 crisis. Several studies have shown that lockdown measures had a greater effect on PA among girls compared to boys, particularly among older children (e.g., Dunton et al., 2020). Interestingly, additional research have reported that the disparity in PA levels between sexes decreased during the pandemic (Hurter et al., 2022; Velde et al., 2021). However, these were re-established upon their return to school (Benzing et al., 2022; Hurter et al., 2022). Prior studies have also shown that psychological resilience, which is associated with mental well-being, augments as individuals age as a result of cognitive maturation and increased social engagement (Masten & Motti-Stefanidi, 2020; Twum-Antwi et al., 2020). This observation could have influenced the study outcome concerning the association between PA and mental health in elementary school students. Unlike adolescents in grammar school, children in this age group may have lower levels of resilience and, therefore, be more susceptible to the impact of external factors, including PA. Nevertheless, this investigation did not find evidence that age played a moderating role. This phenomenon may instead be attributed to the adverse impact of lockdown regulations on social relationships. Despite the fact that cognitive development, which contributes to resilience, is more developed in adolescents, those students were significantly more affected by social distancing and self-isolation during the crisis. Unlike younger children, this is because they have stronger connections with friends outside their family (Masten & Motti-Stefanidi, 2020). Consequently, it is plausible that the

beneficial impact of cognitive development and the detrimental impact of social isolation nullified each other, resulting in no moderating influence of age in this research. (cf. Kopp et al., 2024).

Considering sample characteristics, this research observed no notable disparity in PA levels between boys and girls, and age did not impact this outcome. The observed findings cannot be ascribed to differing variances across subgroups of students, given that the sample size was sufficiently large and balanced across sex and age. This study specifically included a substantial sample size of both males and females, with a comparable number of students from each class in the sample. Therefore, the findings do not provide sufficient evidence for conclusions based on sex and age. Nevertheless, this research identified substantial impacts of students' foreign background and socioeconomic level on PA. Participants with international (migration) backgrounds had lower PA levels compared to their peers, while those from higher economic status showed higher PA levels (cf. Bhogal et al., 2021; Reger et al., 2020). These results are consistent with previous research conducted in Germany, which revealed that children from low socioeconomic households and with foreign origins were substantially impacted by the crisis (Ravens-Sieberer et al., 2021a). Consequently, these groups may benefit from targeted COVID-recovery interventions. (cf. Kopp et al., 2024).

5.3 Strengths, Limitations, and Future Directions

The present study has multiple strengths, including a sizable school-based sample and a wide age range of participants (6 to 18 years old). Smart devices equipped with built-in pedometers were used to objectively measure PA during the study course, which evidence suggests is an accurate, reliable, and valid way of assessing PA (Degroote et al., 2018; Fuller et al., 2020; Kopp et al., 2024). Moreover, a prospective research design was employed, so participants were followed over six consecutive weeks. PA and psychological data about them were collected in two waves as their psychological characteristics or circumstances might have changed. A multiple-perspective approach was used to assess mental health (problems), encompassing self-reports from children and adolescents and proxy reports from parents. Standardized instruments (i.e., KIDSCREEN and SDQ) widely used in previous epidemiological studies (e.g., Ravens-Sieberer et al., 2021a) and proven age-appropriate, valid, and reliable were employed. Advanced statistical techniques, such as hierarchical multiple regression and conditional growth modeling, were applied to analyze the longitudinal data. Specifically, this study indicates high statistical power (Faul et al., 2007) to detect predicted effects. Overall, this was the first longitudinal study design that tested the reciprocal relationship between mental health, health-related quality of life, and PA simultaneously in a single set-up under naturalistic conditions during the easing of COVID-19 regulations, significantly contributing to the field and extending past research.

However, this research also has several limitations that warrant caution in interpreting the results. First, the study sample was recruited from a large private school campus in Bavaria, Germany,

requiring tuition fees, so the participants were from higher-income households. Adolescents from higher-wealth households typically engage more often in physical exercise outside school (e.g., due to greater access to sports and clubs and raising awareness among parents about the importance of PA), which might affect the participants' PA motivation and, in turn, the study findings (cf. Altermann & Gröpel, 2023; Bann et al., 2019). In particular, the population need not be representative of the general population of German students and, therefore, children and adolescents. Low-income families are particularly vulnerable due to the economic, educational, and social divides (Bhogal et al., 2021; W. Li et al., 2021; Reger et al., 2020). Consequently, it is still unclear whether the results of the current study also apply to children and adolescents with a lower socio-economic status. Thus, future research during a crisis should sample participants (and families) with different socio-economic statuses and also from state schools to enlarge the generalizability of the results.

Second, although (1) internationally established, standardized, and validated questionnaires recommended by the ICHOM (Krause et al., 2021) were used to collect data on psychological variables and (2) slightly different questionnaire versions (i.e., proxy versions) suitable for parents with their children (<10 years) in elementary school were employed to account for varying levels of understanding and literacy interpreting or answering questions on mental health and HRQoL might have been challenging. In particular, parent reports are considered the standard method for assessing general characteristics or symptoms of mental disorders in children and adolescents in clinical and research settings. However, even though this approach enabled the inclusion of a larger sample in elementary schools, relying exclusively on parent-reported (proxy) questionnaires increased the risk of method bias so that associations might be over-reported or underestimated. For instance, elementary school parents' feelings about mental health aspects or HRQoL during the easing of the COVID-19 restrictions may affect how parents perceive their children, increasing the risk of exaggerating or understating child mental health problems and HRQoL, respectively (T. C. Chi & Hinshaw, 2002; Krijnen et al., 2023). Furthermore, mental health issues were evaluated by questionnaires rather than by clinical professionals (Hussong et al., 2022). So, only psychological symptoms were indicated, which may not always match clinical diagnoses (Low et al., 2020). The symptoms of mental health problems identified in this research may be somewhat part of routine developmental transitions.

Third, although students submitted a thorough dataset (99.9%) on their daily PA for analyses, confirming whether they had really worn the pedometers throughout their active periods of the day was not feasible (cf. Kopp et al., 2024).

Fourth, this study allowed free choice of PA (programs) and used steps per day to operationalize the level of PA in general; however, future studies should also focus on different indicators and differentiate between endurance and resistance exercise activities (Chovanec & Gröpel, 2020) and their effect on mental health. It is crucial to determine whether all types of exercise have equal benefits (i.e.,

individuals should choose their favorite) or if some forms of exercise are more advantageous (Chekroud et al., 2018).

Fifth, even though smart devices offer a unique and often used opportunity in research to measure PA longitudinally and in various real-life contexts, this ecological benefit comes at the cost of a potentially compromised measurement fidelity (Dudarev et al., 2023). In particular, a wearable sensor's fidelity - reliability and validity - depends on the sensor's accuracy and likely varies across different contexts and conditions under which the measure was taken. This finding aligns with prior research (e.g., Bent et al., 2020), which indicated higher reliability for low-intensity PA measurements (e.g., walking) and reduced reliability with increased PA levels (e.g., running) (e.g., Dudarev et al., 2022). Moreover, some pedometer models may not accurately capture certain types of PA, leading to underestimation or missed data (Griffiths et al., 2016). Therefore, the present objective PA (daily steps) data derived from different (wrist-worn) smart device sensors (i.e., pedometers) across brands in the conditions of everyday life may differ slightly from actual PA. Future studies should use smart devices from the same brand to guarantee at least between-participant fidelity.

Sixth, the Hawthorne effect could compromise the internal validity of this research since students (and parents) were conscious of being observed and may have, therefore, elevated their PA levels in order to align with the anticipated norms (cf. Kopp et al., 2024; Paradis & Sutkin, 2017). In general, the Hawthorne effect occurs when a participant's behavior changes due to being observed rather than as a result of an intervention. In this context, social desirability may have caused method bias, compromising data validity and affecting the relationships between the data gathered (Grossbard et al., 2007). Therefore, the students may have responded to the questionnaires and the single-frequency item on PA influenced by social desirability, as they wanted to present themselves positively and appear consistent with the objective PA data (Jordalen et al., 2018). Because of this, the study's results may be biased, especially among youths in grammar school who may have answered questions to gain social approval or avoid negative attributes. Moreover, recall bias in self-reported PA may have occurred when participants were asked to recall information about their PA levels over a certain period.

Seventh, seasonal factors may have influenced the findings, such as the gradual loosening of COVID-19 regulations. Notably, this research was initiated towards the end of winter, and gathering data lasted until the beginning of spring. Hence, the results should be interpreted with caution. However, given comparable findings from studies that tested PA after the re-opening of schools at various times (Benzing et al., 2022; Hurter et al., 2022; Velde et al., 2021), the seasonal effect seems unlikely to alone account for the study results. (cf. Kopp et al., 2024).

Eighth, participants reported their prior experience in PA since past behavior is a reliable indicator of continued exercise participation (McEachan et al., 2011). However, they reported an excessive number of diverse fitness and sports disciplines in which they had previously engaged. The significant diversity in previous sport and exercise backgrounds, along with the limited number of

students in each specific sport or exercise discipline, hindered the possibility of conducting relevant studies on how this experience affected their PA behavior. In future research, it may be beneficial to account for children and adolescents who have comparable activity histories (cf. Kopp, 2021).

Finally, this work studied the reciprocal effect of PA and psychological variables over six weeks during the easing of the COVID-19 regulations. So, the observation period was relatively short; however, it represents the average study period of previous research (e.g., Herbert et al., 2020). Nevertheless, the question arises whether longer-term PA exceeding the study period would interact differently with children's and adolescents' mental health and HRQoL. In particular, longitudinal studies should include three or more waves to capture long-term reciprocal patterns reliably (Stenling et al., 2017). This remains an avenue for future research.

5.4 Conclusion

In conclusion, this dissertation aimed to highlight the reciprocal relationship between psychological variables and PA in a naturalistic setting during the easing of the COVID-19 restrictions in Germany in a sample of school students in both an elementary and grammar school. This work demonstrates that children's and adolescents' PA increased, and their mental health improved as the German government gradually withdrew COVID-19 regulations. However, there was no significant relationship between these effects. The mental health condition of students before the lifting of the restrictions did not predict how fast or slow they resumed PA after the restrictions were lifted. Similarly, contrary to the hypothesis, engagement in PA after the restrictions were less strict did not significantly contribute to improving mental health and HRQoL among these participants during the relatively short observational period of six weeks. Therefore, further research is needed to understand the interrelations between PA and mental health in children and adolescents.

This dissertation presents a unique and innovative approach to understanding the psychological factors (i.e., mental health and HRQoL) of children and adolescents that affect or are affected by regular PA. This research is particularly relevant given that the burden on children and adolescents, specifically those already suffering from mental health problems, is expected to endure long after the pandemic is over. However, PA could help alleviate psychological complaints and mitigate the negative impact of COVID-19 containment measures. As such, PA programs linked to schools should be included as part of the recovery process for children and adolescents affected by the pandemic.

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7. Publication/Acknowledgements

This chapter briefly overviews basic information about the organ of the publication and the author's contributions to the original publication. In addition, this chapter acknowledges some of the main individuals who have supported this research.

7.1 Original Publication

The dissertation has been pre-published as a scientific journal article and is now open to the research community. The published paper discusses the scientific contribution outlined in this study. The article was published as follows:

Authors: Philipp Moritz **Kopp**, Eva Möhler, Peter Gröpel
Title: Physical Activity and Mental Health in School-Aged Children: A Prospective Two-Wave Study during the Easing of the COVID-19 Restrictions
Journal: Child and Adolescent Psychiatry and Mental Health (CAPMH)
Doi: https://doi.org/10.1186/s13034-023-00695-8

7.2 Authors‘ Contribution

Doctoral candidate Philipp Moritz Kopp served as the leading investigator and was the first author of the approved manuscript. He conceived the longitudinal design at both schools, selected the measures employed, and finally conducted the study at both participating schools in Munich, Germany. Specifically, he performed statistical analyses, composed the first draft, reviewed and revised the manuscript, accepted and published in the *Child and Adolescent Psychiatry and Mental Health* journal. Eva Möhler and Peter Gröpel assisted with statistical methods and interpretation of the data set.

7.3 Organ of Publication

The original manuscript was submitted in June 2023, accepted in December 2023, and published in January 2024 in the special section *Child and Adolescent Mental Health during the Covid-19 pandemic* of the *Child and Adolescent Psychiatry and Mental Health (CAPMH)* quartile 1 (Q1) journal edited by Springer Nature & BMC. CAPMH, the official journal of the International Association for Child and Adolescent Psychiatry and Allied Professions, is an open-access online journal that provides an international platform for rapid and comprehensive scientific communication on child and adolescent

mental health across different cultural backgrounds. CAPMH is a scientifically rigorous and broadly open forum for interdisciplinary and cross-cultural research information exchange involving psychiatrists, pediatricians, psychologists, neuroscientists, and allied disciplines. The journal focuses on improving the knowledge base for the diagnosis, prognosis, and treatment of mental health conditions in children and adolescents. It aims to integrate basic science, clinical research, and the practical implementation of research findings. The special issue sought submissions about children‘s and adolescents' mental health related to the COVID-19 pandemic and was interested in empirical work and, thus, submissions of a quantitative nature (cf. Child and Adolescent Psychaitry and Mental Health [CAPMH], 2024). The current 2-year Impact Facor (IF) of CAPMH is 5.6, whereas the 5-Year Impact Factor is 5,0 (cf. Springer Nature & BMC). CAPMH is listed as a Q1 journal in all categories/sections (SCImago Journal & Country Ranking [SJR], 2023)

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Munich, February 2024

8. Curriculum Vitae

For data protection reasons, the curriculum vitae (CV) is not published in the electronic version of this dissertation. // Aus datenschutzrechtlichen Gründen wird der Lebenslauf in der elektronischen Fassung der Dissertation nicht veröffentlicht.

9. Ethics Statement

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Sehr geehrte Frau Professorin Möhler,

wir bestätigen den Erhalt des Schreibens per E-Mail vom 03.07.2022 von Herrn Philipp Kopp mit dem überarbeiteten Studienantrag.

Nachdem nun die noch offenen Fragen beantwortet/eingearbeitet wurden, erhält unser am 01.07.2022 erteiltes Votum eine uneingeschränkte Gültigkeit.

Mit freundlichen Grüßen

Prof. Dr. U. Grundmann
Vorsitzender

Der Bewertung liegen die nachfolgend aufgeführten Unterlagen zugrunde:

- eMail-Anschreiben vom 03.07.2022
- 2022-07-03_Procedure Scheme_pko.pdf
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Seite **1** von **1**

Die Ethik-Kommission bei der Ärztekammer des Saarlandes ist unter Beachtung der internationalen Richtlinien der ICH, GCP sowie des AMG und der MDR tätig, nach Landesrecht (Saarländisches Heilberufekammergesetz, § 5 Abs. 1) anerkannt und beim Bundesinstitut für Arzneimittel und Medizinprodukte (§ 41a AMG) sowie beim Bundesamt für Strahlenschutz nach § 36 Abs. 1 Strahlenschutzgesetz registriert.

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