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Exploring Physical Activity in the Interplay of Health Behaviors and Health

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Summary

Non-communicable and chronic diseases are a major health threat due to severe health effects, high prevalence rates and enormous costs. The role of health behaviors is essential, as they are relevant for individual as well as for public health. Moreover, a link between health behaviors and several diseases has been scientifically demonstrated. Physical activity is one important health behavior that is associated with numerous health benefits such as reduced overall mortality, preventive factor for chronic diseases and improved health-related quality of life. Bouchard's model describes the association between physical activity and health and considers further important interrelated factors like personal attributes, other health behaviors and the social or physical environment.

This doctoral thesis comprises four published studies located in the interplay of physical activity and health described in Bouchard's model. Study 1 examines and describes health behavior patterns based on physical activity and other relevant health behaviors like smoking, alcohol and nutrition. By using latent class analysis – a model-based clustering method – different subgroups showing their own distinct health behavior pattern were identified. Study 2 examines whether people change their physical activity behavior after a doctoral diagnosis. Study 1 and Study 2 represent the two main studies of this thesis. Study 3 and Study 4 serve as additional studies. Study 3 investigates trends in important motor performance parameters monitored over a timespan of ten years. Study 4 investigates whether school programs (full-day versus half-day) are associated with sports-club engagement. Study 1 and Study 2 investigate adults, whereas Study 3 and Study 4 focus on primary school children.

The four included studies complement each other by exploring physical activity and associations with health considering different life phases. All four studies provide import knowledge for health promotion and prevention programs. They underline the relevance of physical activity and point out its significant role in tackling current health challenges due to non-communicable and chronic diseases.

1. Introduction

1.1. General introduction

The interplay of health behaviors and health is a complex domain. Health behaviors have been identified as major (risk) factors regarding non-communicable and chronic diseases. Health behaviors comprise various behaviors affecting health, e.g. smoking, taking part in medical screenings or dental care. The rising threat of non-communicable or chronic diseases such as heart diseases, cancer or diabetes imply a huge burden on public health. Physical activity has been identified as an important preventive health behavior for multiple chronic conditions (Warburton, Charlesworth, Ivey, Nettlefold, & Bredin, 2010). However, despite considerable evidence for the benefits of regular physical activity, more than one fourth of the global population show insufficient physical activity rates (Guthold, Stevens, Riley, & Bull, 2018). 42.2% of the German population (males: 40.2%, females: 44.1%) exhibit insufficient physical activity rates not fulfilling the minimum requirement of 150 minutes of moderate or 75 minutes of vigorous physical activity per week. Germany's physical inactivity numbers are the least favorable among all European countries (Guthold et al., 2018).

The presented research work is settled within the complex interplay of health behavior, health promotion and health prevention. Both – the promotion of health as well as the prevention of diseases – are relevant and effective tools regarding public health problems (Kumar & Preetha, 2012). Physical activity – a very common and important health behavior – plays a central role in this discourse. This dissertation presents studies following a public health approach to investigate the relationship between physical activity and health, as well as further associations that are relevant within this context. The dissertation includes four peer-reviewed, published studies that are located in the interplay of physical activity and health, focusing on prevention and health promotion:

Study 1: Rabel, M., Laxy, M., Thorand, B., Peters, A., Schwettmann, L., & Mess, F. (2019). Clustering of Health-Related Behavior Patterns and Demographics. Results From the Population-Based KORA S4/F4 Cohort Study. *Front Public Health, 6*(387).

Study 2: Rabel, M., Mess, F., Karl, F. M., Pedron, S., Schwettmann, L., Peters, A., . . . Laxy, M. (2019). Change in Physical Activity after Diagnosis of Diabetes or Hypertension: Results from an Observational Population-Based Cohort Study. *International Journal of Environmental Research and Public Health, 16*(21), 4247.

Study 3: Spengler, S., Rabel, M., Kuritz, A. M., & Mess, F. (2017). Trends in Motor Performance of First Graders: A Comparison of Cohorts from 2006 to 2015. *Front Pediatr, 5*, 206.

Study 4: Spengler, S., Kuritz, A., Rabel, M., & Mess, F. (2019). Are primary school children attending full-day school still engaged in sports clubs? *PLOS ONE, 14*(11).

The focus of this dissertation is on Study 1 and Study 2. These two studies represent the main part of the presented research work. Study 3 and Study 4 are add-ons complementing Study 1 and 2. They fit within the theoretical context of this dissertation and supplement the topic by focusing on a younger target group.

The modern scientific field is segregated into the major scientific branches of the natural sciences, social sciences and formal sciences. Health sciences combine disciplines of natural sciences and social sciences (Hurrelmann & Razum, 2012). In the spectrum of research from fundamental research to applied research, the presented work is located in the middle, comprising characteristics of both fundamental and applied research. In health sciences, the combination of basic research with more applied population-based and patient-oriented research is referred to as translational research (Rubio et al., 2010). Translational research aims to ensure that scientific insights are transferred to the general population (Woolf, 2008). Further, the research work comprised in this dissertation bases on observational studies.

This dissertation is allocated to the research domain of health sciences, public health. According to the OECD's (Organization for Economic Co-operation and Development) research and development classification, health sciences are a second-level classification of the broader field of medical and health sciences (OECD, 2015). Public health is a discipline that focuses on health promotion and can be described as what society does collectively to assure the conditions for people to be healthy (Institute of Medicine (US) Committee on Assuring the Health of the Public in the 21st Century, 2002). Wanless defines public health comprehensively as “the science and art of preventing disease, prolonging life and promoting health through the organized efforts and informed choices of society, organisations, public and private communities and individuals” (Wanless, 2004 as cited in Schwartz et al., 2012, p. 4).

Following a public health approach, the overall aim of this dissertation is to investigate health behaviors – especially physical activity – as major determinants of health. More precisely, this dissertation aims to describe physical activity’s relevance for public health and to extend the existing literature by examining associations between physical activity and health while also considering individual characteristics and environmental factors. Further, this dissertation emphasizes the discussion of resulting insights and its public health implications.

1.2. Theoretical background: health and health behavior

Health is a broad, complex and multidisciplinary concept. There are numerous definitions and theoretical models trying to explain health and its determinants. In 1948 the World Health Organization defined health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (World Health Organization, 2014, p. 1). Former Canadian Minister of National Health and Welfare Marc Lalonde (1974) defined health within his *health field concept* as a composition of the four interrelated fields: Human biology, environment, lifestyle and health care organization. Evans and Stoddart (1990) provided a theoretical framework that builds on Lalonde’s *health field concept* and intends to imply the complex interplay of behavioral and biological responses within a social and physical environment. Figure 1 illustrates this framework.

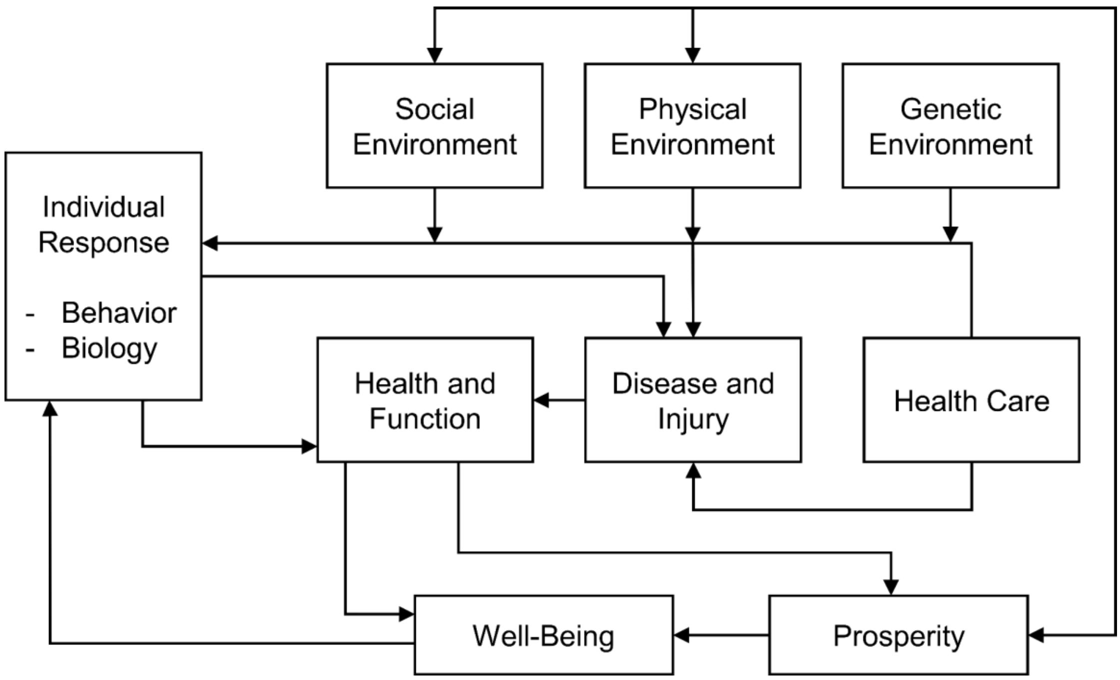

Figure 1. Determinants of health framework by Evans & Stoddart

Dahlgren and Whitehead (1991) follow a further common heuristic definition of health and its determinants. Dahlgren and Whitehead's model depicts health-affecting factors as layers. The layer including age, sex and constitutional factors and the layer including individual lifestyle factors account as proximal influences. The layers social community networks, living and working conditions and the layer general socio-economic, cultural, and environmental conditions represent more distal determinants of health. Figure 2 shows Dahlgren and Whitehead's model.

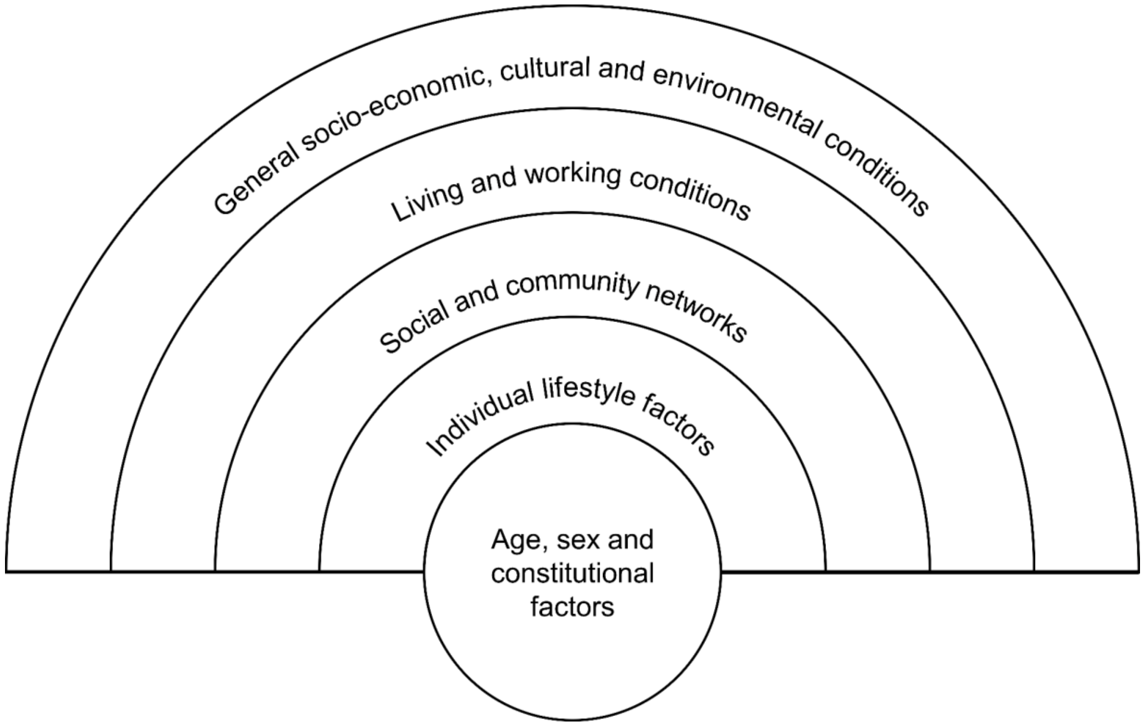

Figure 2. Determinants of health by Dahlgren & Whitehead

Living and working conditions can further be categorized into: agriculture and food production, education, work environment, unemployment, water and sanitation, health care services and housing.

Both models declare behavior as significant determinants of health. According to Kasl and Cobb (1966), health behavior can be described by health behavior, illness behavior and sick role behavior for which they provide the following definition:

> Health behavior is any activity undertaken by a person believing himself to be healthy, for the purpose of preventing disease or detecting it in an asymptomatic stage. Illness behavior is any activity, undertaken by a person who feels ill, to define the state of his health and to discover a suitable remedy. The principal activities here are complaining and seeking consultation from relatives, friends, and from those trained in matters of health. Sick role behavior is the activity undertaken by those who consider themselves ill, for the purpose of getting well. It includes receiving treatment from appropriate therapists, generally involves a whole range of dependent behaviors, and leads to some degree of neglect of one's usual duties. (Kasl & Cobb, 1966, p. 246)

Build on Kasl and Cobbs' definition, Cockerham (2014) defined health behavior as "the activity undertaken by people for the purpose of maintaining or enhancing their health, preventing health problems, or achieving a positive body image" (p. 764). The close link between health behaviors and health is not only indicated in the context of theoretical models. Furthermore, health behaviors are considered as key contributors to chronic diseases, which are the greatest cause of death (Glanz, Rimer, & Viswanath, 2015). Medical conditions including heart disease, cancer, lung diseases and diabetes are mainly driven by key risk factors such as smoking, alcohol consumption, poor diet and physical inactivity (Bauer, Briss, Goodman, & Bowman, 2014). The relationship between health behaviors and health has also been shown empirically (Cheon et al., 2014). Many different theoretical models center on health behaviors and their influences. In line with numerous reviews, the most applied models in the context of health behavior are the following (Glanz et al., 2015): *Health Belief Model* (Rosenstock, 1974), *Social Cognitive Theory* (Bandura, 2004), and *Theory of Planned Behavior* (Ajzen, 1991). A further popular model that aims to explain health behavior is Schwarzer's (1992) *Health Action Process Approach*. Frequently investigated health behaviors are smoking, alcohol consumption, nutrition and physical activity (Meader et al., 2016).

1.3. Physical activity and health

Physical activity is closely linked to health. Physical inactivity is listed among the top risk factors for causes of death (WHO, 2009). Meta-analyses in the last ten years provide evidence for physical activities' positive effects on overall mortality (Kelly et al., 2014; Lollgen, Bockenhoff, & Knapp, 2009). Physical activity can be defined as "any bodily movement produced by skeletal muscles that results in energy expenditure" (Caspersen, Powell, & Christenson, 1985, p. 126). In relation to this broad theoretical concept, one has to distinguish between other related concepts such as *exercise*, *sport* and *sedentary behavior*. Thivel et al. (2018) provided an overview of the definitions of these terms which can be seen in Table 1.

Table 1. Definition of physical activity and related concepts

Terms	**Definitions**
Physical activity	Any body movement generated by the contraction of skeletal muscles that raises energy expenditure above resting metabolic rate. It is characterized by its modality, frequency, intensity, duration, and context of practice

Terms	Definitions
Physical inactivity	Represents the non-achievement of physical activity guidelines
Exercise	Subcategory of physical activity that is planned, structured, repetitive, and that favors physical fitness maintenance or development
Sport	Sport is part of the physical activity spectrum and corresponds to any institutionalized and organized practice, reined over specific rules
Sedentary behaviors	Any waking behaviors characterized by an energy expenditure ≤1.5 METs, while in a sitting, reclining, or lying posture

Note: Reprinted from (Thivel et al., 2018).

The benefits of regular physical activity and its effectiveness in primary and secondary prevention regarding chronic or non-communicable diseases like cardiovascular diseases, diabetes, cancer, hypertension, obesity, depression and osteoporosis are well established (Warburton, Nicol, & Bredin, 2006). Furthermore, increased levels of physical activity are associated with better health-related quality of life – another very relevant health parameter (Bize, Johnson, & Plotnikoff, 2007; Pucci, Rech, Fermino, & Reis, 2012). Longitudinal studies show a positive correlation of physical activity and physical components but also mental components of health-related quality of life (Rabel, Meisinger, Peters, Holle, & Laxy, 2017). Additionally, sufficient levels of physical activity contribute to successful ageing (Gopinath, Kifley, Flood, & Mitchell, 2018). In terms of costs, physical inactivity is associated with substantially higher health care costs (Pratt, Macera, & Wang, 2000; Yates et al., 2016).

Bouchard’s model (2012) is a flexible and generalizable model that describes the relationship between physical activity and health as well as interrelations with other important parameters. Apart from physical activity, it especially considers the influence of other health behaviors and describes their relations within the associations of physical activity and health.

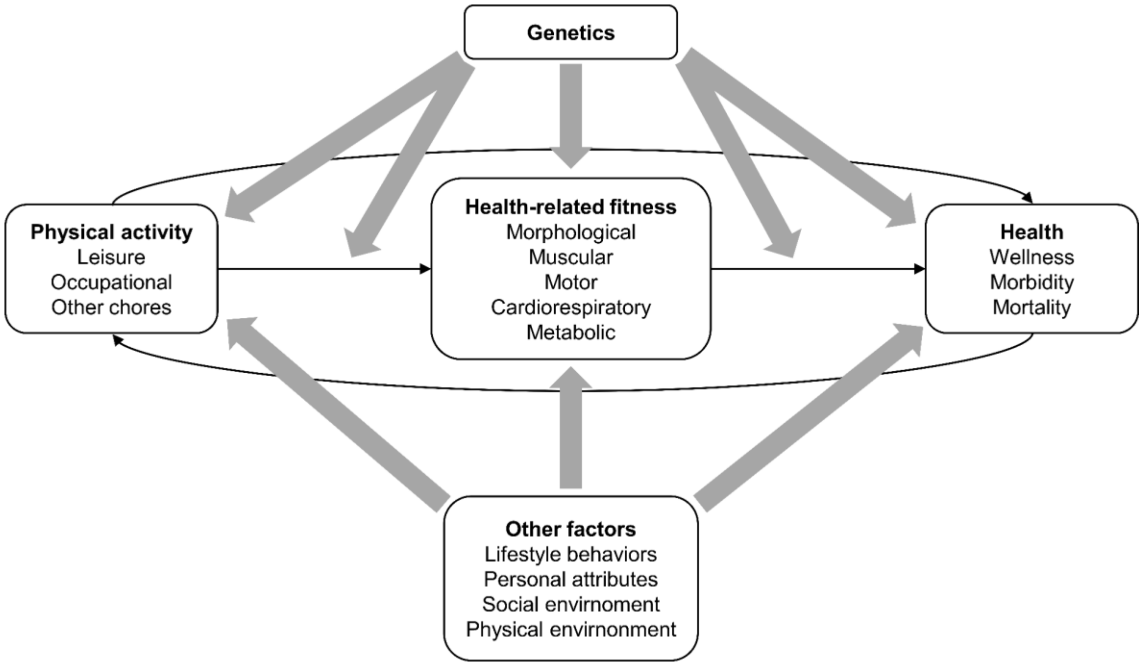

Figure 3. Relationship between physical activity and health

Note: Reprinted from (Bouchard et al., 2012).

As illustrated in Figure 3, genetics, health-related fitness and other factors influence the relationship between physical activity and health. Physical activity covers leisure-time physical activity, work-related physical activity as well as chore-related physical activity. The model's health concept understands health as a continuum with positive and negative poles including wellness, morbidity and mortality. Health-related fitness covers physiological parameters that adapt through physical activity and have an effect on health. The interplay of physical activity, health-related fitness and health is further affected by genetics and other factors such as other health behaviors, individual characteristics and environmental factors. Bouchard's model depicts a reciprocal relationship between physical activity and health. Besides a direct pathway between physical activity and health, in most cases the effects are due to changes in the intermediate factor health-related fitness (Bouchard et al., 2012).

1.4. Conducted studies

All four studies that are subject of this dissertation are rooted in the context of Bouchard's theoretical model. Figure 4 shows how the particular studies are located in Bouchard's model. The colored arrows do not represent the verification of a causal path between the individual constructs of the model. Rather, they clarify which components of the model were considered in the individual studies. Apart from the model's central constructs *Physical activity* and *Health*, each of the four studies addressed the construct *Other factors*. This includes in particular the consideration of other lifestyle behaviors besides physical activity (Study 1) or different environments (Study 4). In addition, however, personal attributes such as age, gender or educational level were also taken into account. Considering these factors is particularly relevant for health promotion. Including other factors is particularly important in order to develop effective and tailor-made interventions and health programs.

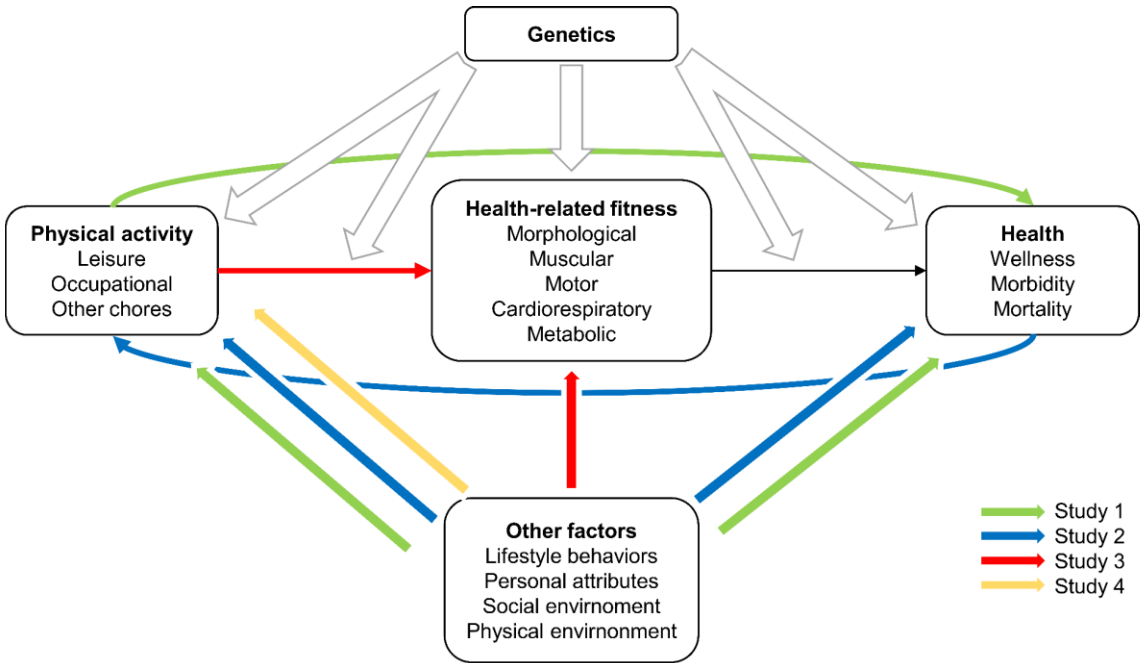

Figure 4. The studies of this dissertation in the context of Bouchard's model

Study 1: Rabel, M., Laxy, M., Thorand, B., Peters, A., Schwettmann, L., & Mess, F. (2019). Clustering of Health-Related Behavior Patterns and Demographics. Results From the Population-Based KORA S4/F4 Cohort Study. Front Public Health, 6(387).

Study 2: Rabel, M., Mess, F., Karl, F. M., Pedron, S., Schwettmann, L., Peters, A., . . . Laxy, M. (2019). Change in Physical Activity after Diagnosis of Diabetes or Hypertension: Results from an Observational Population-Based Cohort Study. International Journal of Environmental Research and Public Health, 16(21), 4247.

Study 3: Spengler, S., Rabel, M., Kuritz, A. M., & Mess, F. (2017). Trends in Motor Performance of First Graders: A Comparison of Cohorts from 2006 to 2015. Front Pediatr, 5, 206.

Study 4: Spengler, S., Kuritz, A., Rabel, M., & Mess, F. (2019). Are primary school children attending full-day school still engaged in sports clubs? PLOS ONE, 14(11).

Study 1 (Rabel, Laxy, et al., 2019) identifies and describes subgroups that share a similar health behavior pattern. In addition, the identified subgroups are described in terms of change in physical and mental health-related quality of life. Following Bouchard's model, this study covers physical activity as one health behavior that is considered for clustering multiple health behaviors. The other considered health behaviors – smoking behavior, alcohol consumption and dietary behavior – fall under the category *Lifestyle behaviors*. Further, socio-demographic factors like sex, age, education and body mass index can be summarized as *Personal attributes.* Physical and mental health-related quality of life are health parameters. Therefore – as shown in Figure 4 – Study 1 covers the dimensions *Physical activity*, *Other factors* and *Health*.

Study 2 (Rabel, Mess, et al., 2019) examines possible associations between a diabetes diagnosis or a hypertension diagnosis and change in physical activity. Within Bouchard's model, this study includes information on *Physical activity* and *Health* by using data on diabetes mellitus and hypertension. *Other factors* are represented by including information on participants' *Personal attributes* like sex, age, education and family status.

The first of two add-on studies for this dissertation, Study 3 (S. Spengler, Rabel, Kuritz, & Mess, 2017) investigates trends in dimensions of motor performance. Therefore, in the context of Bouchard's model, this study incorporates information on *Physical activity* and *Health-related fitness* via motoric tests examining the motor dimensions aerobic fitness, strength, speed and balance. Furthermore, information on *Other factors* includes the *Personal attributes* sex and anthropometrics.

The second add-on study, Study 4 (Sarah Spengler, Kuritz, Rabel, & Mess, 2019) examines whether sports club participation rates are affected by the school program (half-day school or full-day school). Classing this study with Bouchard's model, it focuses on *Physical activity* and *Other factors.* Leisure time physical activity is represented by habitual sports club membership. Information on school program and personal attributes fall under the category *Other factors*.

Although all studies are rooted within Bouchard's theoretical framework, they can clearly be distinguished regarding their target population. While the two main studies – Study 1 and Study 2 – focus on an adult population, Study 3 and Study 4 set the focus on primary school children. Hence, this dissertation approaches the field of health behaviors, especially physical activity and health based on four studies covering an age range from first grade school children to a general adult population. Physical activity is an important health-related factor already in childhood but extending through adulthood (Sarah Spengler et al., 2019). It is therefore advisable to consider the whole lifespan regarding the interplay of physical activity and health.

2. Methods

The applied methods are explained in detail in the individual studies. Only a few selected points are described again in this part. As the two main studies both use KORA data, this chapter contains some background information on the KORA studies. Further, this dissertation includes studies that applied diverse statistical analyses. In order to emphasize the range of statistical analyses, the concepts of the applied statistical methods of the two main studies and the two add-on studies are also presented in this chapter.

2.1. KORA studies

The acronym KORA stands for „Kooperative Gesundheitsforschung in der Region Augsburg“. KORA is a research platform that conducts population-based, longitudinal, epidemiological studies. The research platform aims to investigate associations between health, diseases and circumstances of life in a population. With its information from large population-based studies and its follow-ups, KORA offers a suitable set of data for the investigation of health behavior and health in the context of this dissertation. The KORA studies are a sequel to the MONICA project (“monitoring trends and determinants in cardiovascular disease”) and within this research platform, four major health surveys with follow-ups and additional smaller surveys have been undertaken since 1984 (Holle, Happich, Löwel, Wichmann, & for the, 2005). The research presented in Study 1 and Study 2 bases on the KORA-S4 study and its two follow-up studies F4 and FF4. The S4 study was performed from 1999 to 2001 and included 4261 participants with an age range from 25 to 74 years. The first follow-up, the F4 study, ran from 2006 until 2008 and included 3080 participants. The second and latest follow-up, the FF4 study, was conducted from 2013 until 2014 and included 2279 participants. For these three studies data were collected via standardized medical examinations and standardized face-to-face interviews by trained personnel. Of the 4261 participants at S4, 51% were female and mean age was 49.2 years. Within the S4 cohort, 54% received a lower level of secondary education, 23% an intermediate and 23% a high level of secondary education (responding to German Hauptschule, Realschule, Gymnasium).

In the KORA S4/F4/FF4 studies, physical activity is assessed self-reportedly, via two items. The items cover the amount of physical activity people do during summer and winter. These two items combined represent physical activity within the KORA studies.

There is no clear optimal way to assess physical activity and although there are more valid ways than questionnaires, questionnaires remain the most common method (Sylvia, Bernstein, Hubbard, Keating, & Anderson, 2014). Furthermore, methods like doubly labeled water or accelerometry are very expensive, provide a considerable patient burden and are thus not feasible for large population-based studies.

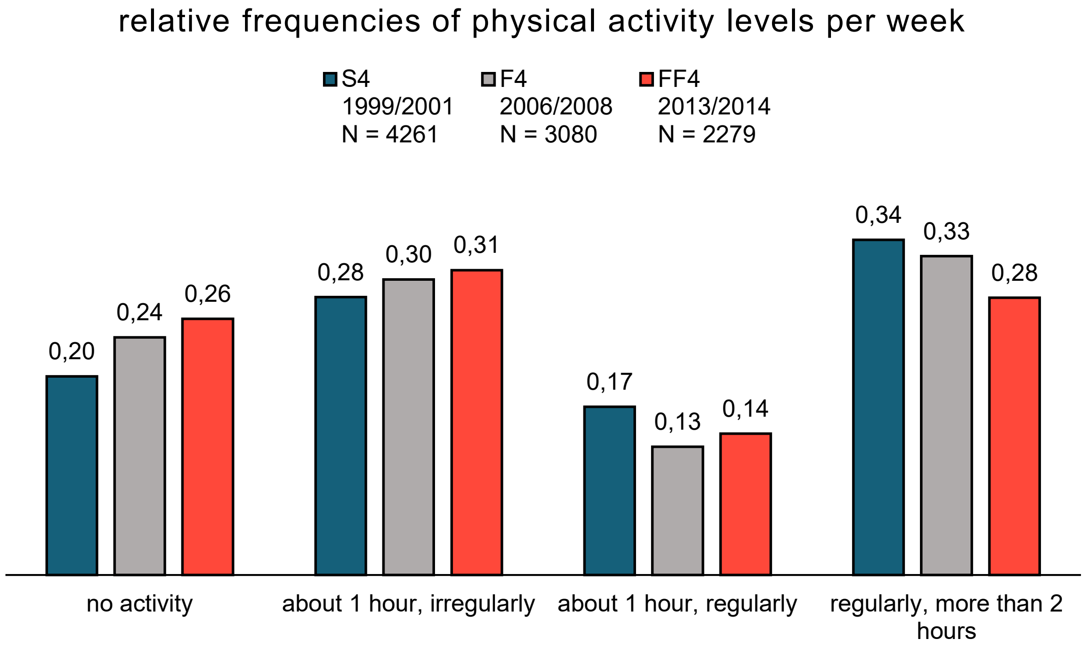

Figure 5. Overview of the relative frequencies of physical activity in the KORA S4/F4/FF4 studies

2.2. Statistical methods

2.2.1. Latent class analysis

The main aim of Study 1 was to identify subgroups within a population, based on the health behaviors smoking, alcohol consumption, nutrition and physical activity. The identified subgroups represent clusters of people that share a similar pattern of their health behaviors. Figure 6 illustrates a graphical example of this idea.

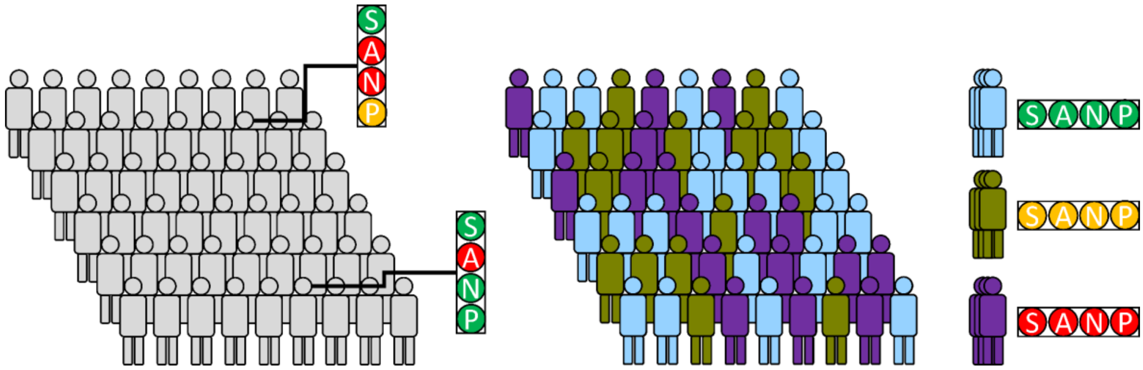

Figure 6. The idea of grouping people of a population based on shared health behavior patterns

Annotations: S = smoking behavior, A = alcohol consumption, N = nutrition, P = physical activity.

Latent class analysis is an approach to detect these latent, underlying, unobserved groups named classes. Collins and Lanza (2010) describe latent class analysis as a method "to look for subtypes of individuals that exhibit similar patterns of individual characteristics" (Collins & Lanza, 2010, p. 8). Latent class analysis uses categorical information on measured variables to describe an underlying, latent, categorical class (Masyn, 2013). In case of Study 1, this underlying, latent class represents the different identified subgroups. Figure 7 illustrates a generic path diagram with health behavior classes in the context of latent class modelling. According to path diagram conventions, an oval object denotes the latent variable. The measured indicator variables are denoted by boxes. Arrows symbolize direct (causal) relationships between objects (Masyn, 2013).

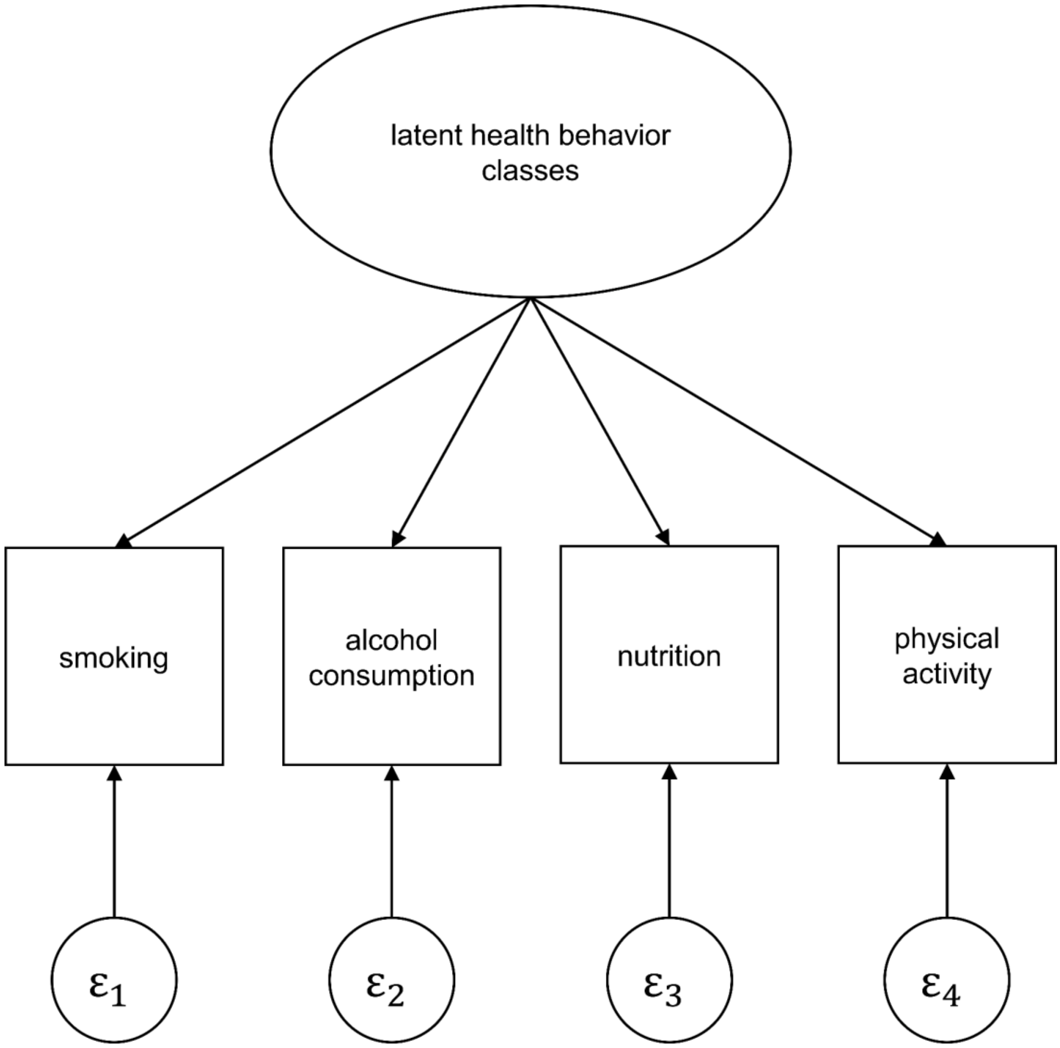

Figure 7. Health behavior as a latent variable

As already mentioned, in latent class analysis observed categorical indicator variables (here: smoking, alcohol consumption, nutrition and physical activity) are a function of a categorical latent variable (here: health behavior classes) and measurement error. A similar latent variable approach that is common in the social sciences is factor analysis. The major difference between latent class analysis and factor analysis is the distribution of the latent variable, as factor analysis treats the latent variable as continuous variable (Collins & Lanza, 2010). A further difference between the two methods is that traditional factor analysis is considered to be a variable-oriented approach and latent class analysis a person-oriented approach. Variable-oriented approaches assume that associations between variables are true for all people. In contrast, “[p]erson-centered approaches describe similarities and differences among individuals with respect to how variables relate to each other and are predicated on the assumption that the population is heterogeneous with respect to the relationships between variables” (Laursen & Hoff, 2006, p. 379, as cited in Masyn, 2013, pp. 552-553). Latent class analysis has become increasingly popular to cluster health behaviors (McAloney, Graham, Law, & Platt, 2013). Compared to more traditional clustering techniques like k-means or hierarchical clustering, latent class analysis has the advantage that it is a model-based approach. Due to its model-based nature, latent class analysis is more flexible and provides better information on cluster criteria (Hagenaars & McCutcheon, 2002).

The latent class analysis in Study 1 was conducted by using the poLCA R-package (Linzer & Lewis, 2011). Technically, a basic unconditional latent class model uses cross-tabulation tables of the measured variables. The latent class model probabilistically groups latent classes based on the cross-tabulation tables by estimating latent class prevalence and item-response probabilities. The item-response probabilities are conditional, based on latent class membership. The basic unconditional model can be extended by including covariates to estimate latent class membership. In the unconditional model, the probability for latent class membership is equal for all observations prior to the responses in the observed indicator variables. By including covariates, prior probabilities vary for each observation based on a function of the covariates (Linzer & Lewis, 2011). Latent class analysis assumes that the measured variables are conditionally independent and all dependencies are explained by latent class membership. This assumption however might also be partially relaxed (Masyn, 2013).

2.2.2. Logistic regression

Study 2 investigates whether a doctoral diagnosis might be associated with a change in health behavior. Specifically, the aim was to investigate possible associations between a diabetes or a hypertension diagnosis and a change in physical activity. Figure 8 shows a graphical representation of this research idea.

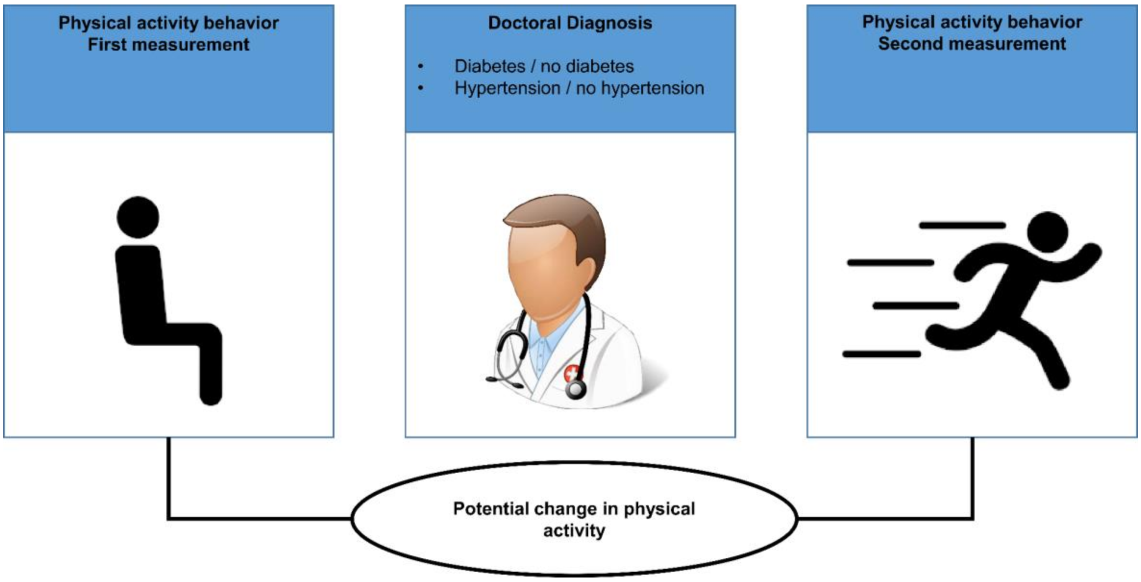

Figure 8. Graphical outline of the research aim of Study 2

The outcome of this study was change in physical activity, which was coded binary, indicating a change between two measurement points. The main independent variable was information on a doctoral diagnosis concerning diabetes or hypertension. Both types of diagnoses were binary coded as well, indicating whether there has been a diabetes or hypertension diagnosis or not. Logistic regression models were used to analyze this research idea.

Logistic regression is a specialized type of generalized linear model. It is a suitable methodological approach to build models that have a categorical, two-level outcome. Logistic regression probabilistically estimates a binary outcome based on a linear combination of independent variables. To align the ranges of possible values for the outcome and the independent variables, logistic regression uses a logit transformation (Diez, Barr, & Cetinkaya-Rundel, 2016). A logistic regression model with logit transformation can be formulated as

$$logit(p_i) = ln\frac{p_i}{1-p_i} = \beta_0 + \beta_1 x_{1,i} + \beta_2 x_{2,i} + \cdots + \beta_k x_{k,i}$$

p_i and $1 - p_i$ are the probability and complementary probability of the outcome, k represents the number of the independent variables x_i and β stands for the (logistic) regression coefficients. The regression coefficients β_1 represent the expected change in the logarithmic probability, if the independent variable $x_{1,i}$ increases by one unit. β_0 stands for the logarithmic probability that the outcome becomes equal 1 while all independent variables become 0. As expressed in the equation, the logistic regression model can be written as logarithmic odds. Via an exponential transformation, the logarithmic odds can be written as odds ratios. An exponentiated regression coefficient $e^{\beta_1} = 1$ means that the independent variable x_1 is not associated with the odds ratio. Hence, there is no association between the outcome and the independent predictor variable. If $e^{\beta_1} > 1$ there is a positive correlation between the independent predictor and the outcome. If $e^{\beta_1} < 1$, then the correlation is negative (Eid, Gollwitzer, & Schmitt, 2015). Logistic regression is considered a fairly robust method with only a small number of assumptions. Logistic regression assumes a linear relationship between continuous independent variables and the logit-transformed outcome. It assumes independence of errors, meaning that the data should not contain related cases. A further assumption would be that there is no multicollinearity which implies that the independent predictor variables should not be highly correlated (Field, 2009).

2.2.3. Statistical methods in Study 3 and Study 4

Study 3 uses (multiple) linear regression models to analyze whether assessment year is a significant predictor of annual measured motor performance dimensions. Linear regression is a very common statistical approach to investigate an outcome variable of interest dependent on covariates. The outcome variable is commonly the dependent variable and the covariates are the independent variables. A common feature of linear regression models is that the association between dependent and independent variables is affected by random noise or error. The outcome variable is therefore a random variable and its distribution depends on the independent explanatory variables. A simple linear regression model can be formulated as follows (Fahrmeir, Kneib, & Lang, 2009):

$$y = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k + \varepsilon$$

y represents the dependent outcome, β_0 is the intercept, β is the regression coefficient and x is the independent covariate. k reflects the number of covariates and ε depicts the residuals or the error term of the model. Linear regression relies on the assumption of a linear relationship between y and x, no collinearity between the covariates, independent residuals and homoscedasticity.

In Study 4, the statistical methods of Chi^2-test and Mann-Whitney-U-test are used. A Chi^2-test of independence can be used to investigate whether two categorical variables are associated with each other. With this test, observed cross-tabulated frequencies are compared to expected frequencies. The Chi^2-test requires that none of the observed, cross-tabulated frequencies is zero and all of these frequencies should be at least five (Weiß, 2013).

The Mann-Whitney-U-test is a non-parametric alternative to the very common t-test. In contrast to the t-test, the Mann-Whitney-U-test requires no symmetric distribution or normal distribution. The test is based on ranks and compares the medians of two samples to assess differences between the two samples (Weiß, 2013).

3. Results

This section contains reprints of the abstracts of the four conducted studies that are part of this dissertation. Reprints of the complete studies can be seen in the Appendix 6.2. All studies have been published under the Open Access Creative Commons Attribution License (CC-BY), which permits the use, distribution and reproduction of material from published articles, provided the original authors and sources are credited. Besides the abstracts, this section contains information on the individual contribution of the author of this doctoral thesis to the specific studies.

3.1. Study 1

Rabel, M., Laxy, M., Thorand, B., Peters, A., Schwettmann, L., & Mess, F. (2019). Clustering of Health-Related Behavior Patterns and Demographics. Results From the Population-Based KORA S4/F4 Cohort Study. *Front Public Health, 6*(387).

3.1.1. Abstract Study 1

Background: Health behaviors are of great importance for public health. Previous research shows that health behaviors are clustered and do not occur by chance. The main objective of this study was to investigate and describe the clustering of alcohol consumption, nutrition, physical activity and smoking while also considering the influence of sex, age and education.

Methods: Using data from the population-based KORA S4/F4 cohort study, latent class regression analysis was undertaken to identify different clusters of health behavior patterns. The clusters were described according to demographics. Furthermore, the clusters were described regarding health-related quality of life at baseline and at a 7-year follow-up.

Results: Based on a sample of 4,238 participants, three distinct classes were identified. One overall healthy class and two heterogeneous classes. Classes varied especially according to sex, indicating a healthier behavior pattern for females. No clear association between healthier classes and age, education or physical and mental health-related quality of life was found.

Discussion: This study strengthens the literature on the clustering of health behaviors and additionally describes the identified clusters in association with health-related quality of life. More research on associations between clustering of health behaviors and important clinical outcomes is needed.

3.1.2. Contribution to Study 1

Matthias Rabel is first and corresponding author of Study 1 and was mainly involved in all steps of the manuscript production. Matthias Rabel together with Filip Mess and Michael Laxy conceptualized the study. He is responsible for the formal analysis and the applied methods. He further wrote the original draft and was mainly involved in the editing and review process of the manuscript. Michael Laxy, Barbara Thorand, Annette Peters, Lars Schwettmann and Filip Mess provided supervision for Study 1 throughout the whole process. All authors approved the manuscript for publication.

3.2. Study 2

Rabel, M., Mess, F., Karl, F. M., Pedron, S., Schwettmann, L., Peters, A., . . . Laxy, M. (2019). Change in Physical Activity after Diagnosis of Diabetes or Hypertension: Results from an Observational Population-Based Cohort Study. *International Journal of Environmental Research and Public Health, 16*(21), 4247.

3.2.1. Abstract Study 2

Background: Chronic diseases like diabetes mellitus or hypertension are a major public health challenge. Irregular physical activity (PA) is one of the most important modifiable risk factors for chronic conditions and their complications. However, engaging in regular PA is a challenge for many individuals. The literature suggests that a diagnosis of a disease might serve as a promising point in time to change health behavior. This study investigates whether a diagnosis of diabetes or hypertension is associated with changes in PA.

Methods: Analyses are based on 4261 participants of the population-based KORA S4 study (1999–2001) and its subsequent 7-and 14-year follow-ups. Information on PA and incident diagnoses of diabetes or hypertension was assessed via standardized interviews. Change in PA was regressed upon diagnosis with diabetes or hypertension, using logistic regression models. Models were stratified into active and inactive individuals at baseline to avoid ceiling and floor effects or regression to the mean.

Results: Active participants at baseline showed higher odds (OR = 2.16 [1.20;3.89]) for becoming inactive after a diabetes diagnosis than those without a diabetes diagnosis. No other significant association was observed.

Discussion: As PA is important for the management of diabetes or hypertension, ways to increase or maintain PA levels in newly-diagnosed patients are important. Communication strategies might be crucial, and practitioners and health insurance companies could play a key role in raising awareness.

3.2.2. Contribution to Study 2

Matthias Rabel is first and corresponding author of Study 2 and was mainly involved in all steps of the manuscript production. Matthias Rabel contributed to the conceptualization of the manuscript, decided on the methodological approach, was in charge of the formal analysis, wrote the original draft, was primary responsible for the review and editing process. Filip Mess and Michael Laxy were involved in the conceptualization of Study 2 as well. Filip Mess, Florian M. Karl, Sara Pedron, Lars Schwettmann, Annette Peters, Margit Heier and Michael Laxy provided supervision during all steps of the creation and publication of the manuscript. All authors approved the manuscript for publication.

3.3. Study 3

Spengler, S., Rabel, M., Kuritz, A. M., & Mess, F. (2017). Trends in Motor Performance of First Graders: A Comparison of Cohorts from 2006 to 2015. *Front Pediatr, 5*, 206.

3.3.1. Abstract Study 3

Background: Motor performance is an important factor for health. Already in childhood, motor performance is associated with, e.g., obesity and risk factors for cardiovascular diseases. It is widely believed that the motor performance of children has declined over recent years. However, this belief is lacking clear evidence. The objective of this study was to examine trends in motor performance of first grade students during a period of 10 years (2006–2015). We examined trends in (a) aerobic fitness, (b) strength, (c) speed, and (d) balance for boys and girls separately and considered body mass index (BMI) as a potential confounder.

Methods: From 2006 to 2015, we tested 5,001 first graders [50.8% boys; mean age 6.76 (0.56) years] of 18 primary schools in Germany. Each year between 441 and 552 students of the same schools were surveyed. Performance tests were taken from the Motorik-Module Study and the "German Motor Ability Test": "6-min run," "push-ups," "20-m sprint," and "static stand." Linear regression models were conducted for statistical analysis.

Results: A slightly negative trend in aerobic fitness performance was revealed in boys ($\beta = -0.050$; $p = 0.012$) but not in girls. In the strength performance test no trend over time was detected. Performance in speed (boys: $\beta = -0.094$; girls: $\beta = -0.143$; $p \leq 0.001$) and balance tests (boys: $\beta = -0.142$; girls: $\beta = -0.232$; $p \leq 0.001$) increased over time for both boys and girls. These findings held true when BMI was considered.

Conclusion: This study only partly supported the assumption that motor performance of children has declined: in our study, aerobic fitness declined (only in boys), while strength remained stable and speed and balance even increased in both sexes. Moreover, it seems as if BMI can explain changes in performance only to a small extent. Changed lifestyles might be a substantial cause. Further research on recent trends of motor performance and interacting variables is needed to support the results of our study and to provide more knowledge on causes of these trends.

3.3.2. Contribution to Study 3

Sarah Spengler is first and corresponding author of Study 3. Matthias Rabel is coauthor of Study 3. He contributed to Study 3 as follows. Matthias Rabel was substantially involved in the conceptualization and design of the study. He executed the analysis, critically revised the draft and approved the final manuscript. Furthermore, he was involved in the review process of the manuscript.

3.4. Study 4

Spengler, S., Kuritz, A., Rabel, M., & Mess, F. (2019). Are primary school children attending full-day school still engaged in sports clubs? *PLOS ONE, 14*(11).

3.4.1. Abstract Study 4

Purpose: Schools and organized sports both offer great chances to promote physical activity among children. Full-day schools particularly allow for extensive participation in extra-curricular physical activities. However, due to time reasons, full-day schools may

also prevent children from engagement in organized sports outside school. There is only little national and international research addressing the possible competition of full-day schools and providers of organized sports outside school and the potential effects on children's physical activity behavior. In Germany's educational system, a transformation towards more full-day schools is currently taking place. The existence of both, half-day and full-day schools, gave occasion to the following research question: Do students attending half-day and full-day school differ with respect to a) sports club membership rate and b) weekly amount of sports club training?

Methods: Data were collected in eleven German primary schools. Selected schools offered both half-day and full-day (minimum three days/week with at least seven hours) care. 372 students' data (grades 1–4; N = 153 half-day, N = 219 full-day; 47.4% male, 8.8±1.2y) were eligible for analyses. We assessed sports club membership and weekly training duration via questionnaire. Statistical analyses included Chi-square and Mann-Whitney-U-Tests.

Results: 83% of half-day school students and 67% of full-day school students were sports club members ($\chi 2(1) = 12.31$, $p<.001$). Weekly duration of training in sports clubs among sports club members (N = 266) also differed between the groups (mdn = 150 min in half-day, mdn = 120 min in full-day school students; $z = -2.37$, $p = .018$). Additional analyses stratified for age and gender showed similar results.

Conclusion: Primary school students attending full-day schools engage less in organized sports outside school than half-day school students, regardless of age and gender. Future studies should examine if the detected lower engagement in sports club physical activity is compensated by physical activities in other settings such as school or non-organized leisure time.

3.4.2. Contribution to Study 4

Sarah Spengler is first and corresponding author of Study 4. Matthias Rabel is coauthor of Study 4. He contributed to Study 4 as follows. Matthias Rabel was involved in data curation, execution of the formal analysis, decision on methodology, visualization of findings and in the review and editing process of the manuscript for publication.

4. Discussion

This dissertation presents four studies in the context of health behaviors – especially physical activity – and health. The overall aim of this dissertation is to investigate health behaviors – especially physical activity – as major determinants of health. It is intended to describe the public health relevance of physical activity and to extend the existing literature by examining associations between physical activity and health while also considering individual characteristics and environmental factors. Study 1 identified three subgroups within one population, representing distinct health behavior patterns. It further described the characteristics of those subgroups and discussed its value for health promotion interventions. Study 2 showed no indication for improved physical activity levels after a diabetes or hypertension diagnosis. Furthermore, it showed that physically active participants are more likely to become physically inactive after a diabetes diagnosis. These two studies are the core of the presented research work. Next to the two main studies, this dissertation includes two studies that additionally contribute to the outlined research topic. Study 3 reported a decline in aerobic fitness performance in first grade students over a period of ten years for boys exclusively. Other important health-related fitness parameters – strength, speed and balance – remained stable or showed an increase. Study 4 examined the potential conflict between full-day school programs and organized sport clubs. It showed that primary school children who took part in a full-day school program are less engaged in sport clubs.

All four studies provided valuable insights on the interplay of physical activity and health or interrelated concepts that affect this relationship. In addition, the studies yield important findings for planning and implementing health-promotion programs. As already shown in the introduction, Bouchard’s model provides a theoretical basis for examining physical activity and health. The model is suitable as theoretical framework for the allocation of the studies. The following section discusses two major parts of Bouchard’s model by using results and implications of the conducted four studies. Figure 9 provides an outline of how the discussion is structured. Analogous to Bouchard's (2012) description, the results of the studies are first related to the simplest derivation of the model, including only the two central constructs *Physical activity* and *Health*. Afterwards, the two constructs will be supplemented by the *Other factors* construct.

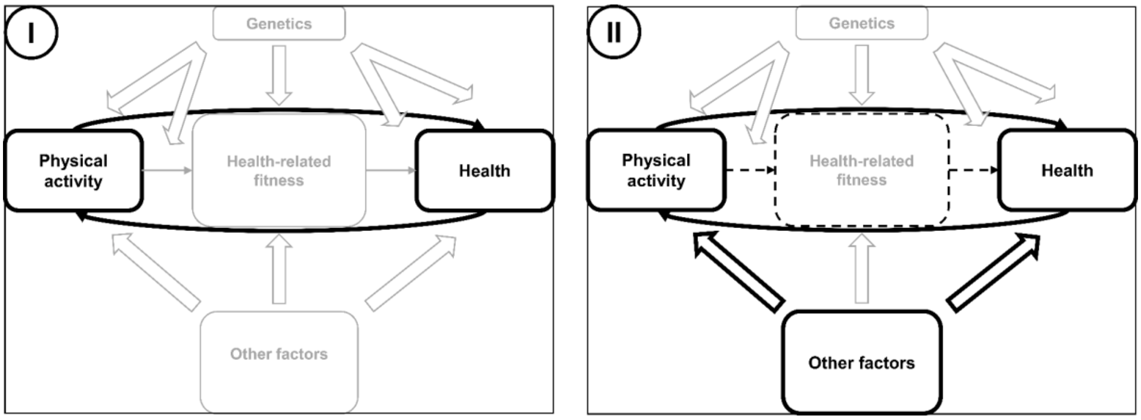

Figure 9. Discussion outline

The results of the study are discussed in the context of the Bouchard Model in two steps

4.1. Physical activity and health

Study 1 is primarily concerned with the identification of different subgroups based on different health behaviors. Physical activity is considered as health behavior, but the focus is set on the pattern of the different health behaviors. Therefore, the results of Study 1 will be discussed in the next section, when different health behaviors are considered by the *Other factors* construct.

Study 2 incorporates the constructs *Physical activity* and *Health*. Diabetes and hypertension are diseases that do not physically impair people to be physically active. Further, treatment guidelines for both diseases demand a regular amount of physical activity. Nevertheless, inactive participants were not more likely to become active after a hypertension diagnosis. In case of a diabetes diagnosis active participants had even higher odds of becoming inactive after a diagnosis compared to participants that did not receive such a diagnosis. Hypothetical explanations for this observation have been discussed within Study 2. Due to high prevalence rates, comparably less physical impairments and good treatment options, diabetes and hypertension might have too little of an impact on constructs like risk perception or threat appraisal that theoretically affect behavior change. Patients might prefer simple medical treatment compared to the effort of a sustainable change in physical activity. Furthermore, people might not be aware of health benefits in the context of diabetes or hypertension. As the benefits of regular physical activity are widespread among scientific researchers (Lavie, Ozemek, & Kachur, 2019), this implicates the urge for a better communication and clarification of these benefits on health. Research indicates that awareness on health benefits through physical activity is associated with the engagement in physical activity (Williamson, 2016). The role of physical activity should be strengthened in both primary and secondary prevention. Therefore, health promotion programs and interventions should emphasize physical activity related health benefits to establish a better perception in the healthy population as well as in patients.

Study 3 describes the change in motor performance over a period of 10 years. The motor performance domains aerobic fitness, strength, speed and balanced were measured by physical activity tasks like “6-minutes run”, “push-ups”, “20-meters sprint” or a “one-legged static stand”. Given the fact that improvements in these *Health-related fitness* domains are associated with favorable effects on health (Bouchard et al., 2012), it is plausible to discuss the results of Study 3 in this section of *Physical activity* and *Health*. In the period from 2006 to 2015 aerobic fitness declined in boys, whereas it remained stable or even improved over the years in the other domains. Because aerobic fitness is an important health-related factor that is closely linked to chronic diseases like cardiovascular diseases (Fernström, Fernberg, Eliason, & Hurtig-Wennlöf, 2017), public health campaigns should stress the importance of regular aerobic exercise especially for boys. It might be fruitful to implement physical exercises that focus on this domain in physical education in primary schools.

4.2. Physical activity and health including other factors

The inclusion of *Other factors* adds a new construct to the relationship between *Physical activity* and *Health*. The new construct incorporates e.g. further health behaviors, personal attributes or social and physical environment that are associated with differences in *Health* or affect *Physical activity* and determine its relationships (Bouchard et al., 2012, p. 17).

Study 1 considers physical activity and covers additional health behaviors like smoking, alcohol consumption and nutrition to describe health-related behavior. Based on these health behaviors, the study identified three classes (subgroups) that represent different health behavior patterns. Class 2 represents a healthy subgroup showing the highest probabilities for favorable health behavior categories. Class 1 and class 3 show an unhealthier profile. Class 1 displays higher probabilities for risky alcohol consumption but also higher probabilities for favorable physical activity. Class 3 shows higher probabilities for unhealthy smoking behavior and alcohol consumption. All three subgroups reveal somehow typical behavior patterns (overall health, unhealthy alcohol plus favorable physical activity, unhealthy alcohol plus unhealthy smoking) that have been identified in other studies as well (Conry et al., 2011; Mawditt, Sacker, Britton, Kelly, & Cable, 2016; Poortinga, 2007). Regarding personal attributes, the subgroups were also identified conditioned on socio-demographics. While the healthy subgroup (class 2) consisted exclusively of women, there were no associations between healthier classes and age or education. The results strengthen the notion of interrelated health behaviors (Prochaska, Spring, & Nigg, 2008). Knowledge on interrelated health behaviors could be of great importance for public health. With a more complete understanding of health behavior patterns of a target group, public interventions could tackle multiple health behaviors at the same time and thus be more cost-effective. Further, due to potential synergistic effects of multiple health behaviors, health promotion programs that focus on more than one health behavior could be more effective. Combining the information on common behavior patterns with additional data of health care providers could lead to a comprehensive health care.

Study 4 investigates differences in sports club engagement between primary school children in half-day and full-day school programs. Children taking part in full-day school programs showed lower sport-club membership rates and less minutes of participation per week. Thus, by including data on the school setting, this study adds information on children's social and physical environment. As sport clubs are a key environment for physical activity and therefore health promotion in children (Rütten & Pfeifer, 2017), the results of Study 4 stress the importance of alternative physical activity environments to compensate for a poor sport club engagement. Hence, full-day school programs should offer (extra-curricular) physical activity programs. A hypothetical fruitful approach would be to promote collaborations between schools and sport clubs to provide opportunities for physical activity across different settings.

4.3. General discussion

Physical activity is an important health behavior and relevant factor for health. A lack of physical activity is considered as one of the most threatening risk factors for a variety of medical conditions. The epidemiologist Jerry Morris acknowledged physical activity's important status by declaring it public health's "best buy" (Morris, 1994 as cited in Das & Horton, 2016). Additionally, Das and Horton (2016) link the seriousness of physical activity related health promotion and prevention to the following relevant points: There recently has been new evidence on the relationship between physical activity and public-health relevant diseases (e.g. dementia) (Sallis et al., 2016). A lack of physical activity is associated with hefty costs for the health care system (Ding et al., 2016). Sedentariness – a concept that is related to physical activity – has become a growing health-threat (Ekelund et al., 2016). Furthermore, although physical activity levels are rising in more and more countries, there is still no improvement in sight (Sallis et al., 2016). Against this backdrop, it becomes obvious that there is a global need for action. This dissertation contains studies that aim to gain knowledge for health promotion and prevention in the field of physical activity and health. Moreover, it recognizes the importance of including further aspects that interrelate with physical activity and health, such as other health behaviors, personal attributes or the social and physical environment. In addition, the included studies represent two different phases of life by taking into account both adulthood and childhood. Whereas Study 1 and Study 2 concentrate on an adult population, Study 3 and Study 4 set the focus on children. Although the benefits of regular physical activity are thoroughly examined and documented, numbers of insufficient physical activity are alarmingly high (Guthold et al., 2018). Consequently, one could deduce the need for better communicating scientific results to the general population. In the meaning of translational research, the presented research work aims to give input to facilitate the transfer of scientific knowledge on health promotion and prevention. For this purpose, it is important to acknowledge the peculiarities of physical activity as a health behavior. On the one hand, models and theories that are often used to explain change in physical activity are mostly derived from other disciplines like psychology or sociology. On the other hand, physical activity stands out as an adoption behavior compared to cessation behaviors (e.g. smoking, alcohol). It is not a necessary behavior like eating and it needs time and regularity (Rhodes & Nigg, 2011). Consequentially, practitioners declare counseling on physical activity as more challenging than counseling on other health behaviors (Dolor et al., 2010). Moreover, well-tailored health promotion or prevention programs should carefully consider their target population. Study 1 pointed out that within a population there might be subgroups that show multiple risky behavior patterns, which might be tackled simultaneously to be more (cost-) effective. Based on Study 2, public awareness of physical activity's role especially in secondary prevention needs to be emphasized. Hence, practitioners need to be collaborate with all protagonists of the health care system when it comes to enlighten patients on physical activity benefits. Following Study 3 and Study 4, primary schools should promote health literacy already by underlining the importance of exercising and providing a social and physical environment in which one can be physically active.

4.4. Outlook

In addition to the findings of the included studies, more research is needed in the field of physical activity and health. The World Health Organization declared its vision of a healthier world by aiming to reduce the global physical inactivity prevalence by 15% (World Health Organization, 2018). To reach this goal, a scientific evidence-based understanding of the relationship between physical activity and health and interrelated parameters is needed. Further, more valid methods than questionnaires to measure physical activity in population-based studies are needed. Although questionnaires are comparatively cheap and easy to implement, self-reported data is prone to multiple biases. Accelerometers or other valid devices that track information on physical activity (e.g. pedometers) could provide better data quality for physical activity related research. Additionally, there is a demand for transferring knowledge of interventions to a population level. Interventions for health behavior change that showed to be effective under small and controlled circumstances need to be scaled up at a population level (Reis et al., 2016). Thus, there is a need for research that focuses on examining health behavior change and associations with health based on interventions that are based in real-world settings. Bauer et al. (2014) state the importance of tackling multiple risk factors for diseases simultaneously. In order to get a more detailed description of overall health behavior, research needs to examine multiple health behaviors. In addition to frequently investigated health behaviors such as smoking, alcohol consumption, nutrition and physical activity, studies should include other health behaviors like sleep, sexual health behavior, vaccination behavior or taking part in medical preventive check-ups. Cluster analysis could be a suitable approach to identify potential risk groups showing unfavorable patterns of health behaviors. The clusters should be examined regarding medical or economic outcomes in order to further investigate the relevance of the identified clusters.

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6. Appendix

6.1. Bibliography

Complete list of all scientific publications by Matthias Rabel.

- **Rabel, M.**, Mess, F., Karl, F. M., Pedron, S., Schwettmann, L., Peters, A., . . . Laxy, M. (2019). Change in Physical Activity after Diagnosis of Diabetes or Hypertension: Results from an Observational Population-Based Cohort Study. *International Journal of Environmental Research and Public Health, 16*(21), 4247. doi:10.3390/ijerph16214247

- **Rabel, M.**, Laxy, M., Thorand, B., Peters, A., Schwettmann, L., & Mess, F. (2019). Clustering of Health-Related Behavior Patterns and Demographics. Results From the Population-Based KORA S4/F4 Cohort Study. *Front Public Health, 6*(387). doi:10.3389/fpubh.2018.00387

- Spengler, S., Kuritz, A., **Rabel, M.**, & Mess, F. (2019). Are primary school children attending full-day school still engaged in sports clubs? *PLoS ONE, 14*(11), e0225220. doi:10.1371/journal.pone.0225220

- **Rabel, M.**, Meisinger, C., Peters, A., Holle, R., & Laxy, M. (2017). The longitudinal association between change in physical activity, weight, and health-related quality of life: Results from the population-based KORA S4/F4/FF4 cohort study. *PLOS ONE, 12*(9), e0185205. doi:10.1371/journal.pone.0185205

- Spengler, S., **Rabel, M.**, Kuritz, A. M., & Mess, F. (2017). Trends in Motor Performance of First Graders: A Comparison of Cohorts from 2006 to 2015. *Front Pediatr, 5*, 206. doi:10.3389/fped.2017.00206

- Mess, F., Gerth, D., Hanke, J., **Rabel, M.**, & Walter, U. N. (2015). Gesundheitsverhalten und Gesundheit bei wissenschaftlichen und nicht-wissenschaftlichen Beschäftigten – ein Vergleich an der Universität Konstanz. In A. Göring & D. Möllenbeck (Eds.), *Bewegungsorientierte Gesundheitsförderung an Hochschulen. Hochschulsport: Bildung Und Wissenschaft*. (Vol. 3, pp. 115-129). Göttingen: Universitätsverlag.

6.2. Reprints of conducted studies

This section contains reprints of the four conducted studies that are part of this dissertation. All studies have been published under the Open Access Creative Commons Attribution License (CC-BY), which permits the use, distribution and reproduction of material from published articles, provided the original authors and sources are credited.

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ORIGINAL RESEARCH
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Clustering of Health-Related Behavior Patterns and Demographics. Results From the Population-Based KORA S4/F4 Cohort Study

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Background: Health behaviors are of great importance for public health. Previous research shows that health behaviors are clustered and do not occur by chance. The main objective of this study was to investigate and describe the clustering of alcohol consumption, nutrition, physical activity and smoking while also considering the influence of sex, age and education.

Methods: Using data from the population-based KORA S4/F4 cohort study, latent class regression analysis was undertaken to identify different clusters of health behavior patterns. The clusters were described according to demographics. Furthermore, the clusters were described regarding health-related quality of life at baseline and at a 7 year follow-up.

Results: Based on a sample of 4,238 participants, three distinct classes were identified. One overall healthy class and two heterogeneous classes. Classes varied especially according to sex, indicating a healthier behavior pattern for females. No clear association between healthier classes and age, education or physical and mental health-related quality of life was found.

Discussion: This study strengthens the literature on the clustering of health behaviors and additionally describes the identified clusters in association with health-related quality of life. More research on associations between clustering of health behaviors and important clinical outcomes is needed.

Keywords: health behavior pattern, latent class analysis, latent class regression, cluster analysis, alcohol, nutrition, physical activity, smoking

INTRODUCTION

Health behaviors are closely linked to a person's general health. This is not only postulated in theoretical models like the determinants of health-model (1), but has also been shown empirically (2). In addition to the individual level, health behaviors also have large public health implications. Particularly, alcohol consumption, nutrition, physical activity (PA) and smoking are well-known and important factors regarding public health. In its report on global health risks, the World Health Organization (WHO) lists health behaviors among the leading risk factors for death in high-income countries (3, 4). Plenty of studies have investigated the association between one of these single risk behaviors and health (5–9). However, health-impairing factors usually do not occur apart, but tend to group in clusters (10, 11). A bundling of different health risks can be identified (12) and certain population strata show common patterns of multiple health behaviors (13–15). As there is evidence that multiple health behaviors have synergistic effects and might be targeted simultaneously by interventions, analyzing patterns of health behaviors can be of great importance for public health (16). First, there is evidence that interventions which tackle multiple behaviors seem to be more cost effective (17). Second, with the already described bundling of behaviors and a common culmination of risk factors for individuals (12), considering more than one health behavior to describe individual health patterns seems to be appropriate. Third, in order to design health promoting interventions it is crucial to identify the characteristics of the target group (18), which requires an understanding of how multiple health behaviors are clustered (19). In-depth knowledge about the characteristics of a population might be helpful to identify vulnerable groups, which could profit most from public health interventions (20).

Multiple studies have investigated the general clustering of health behaviors in adults (11, 15, 20, 21). Yet, due to methodological differences (22) as well as different investigated health behaviors (11), the literature is quite heterogeneous. Furthermore, only few studies have investigated the associations between the general clustering of health behaviors and important physical health outcomes like all-cause mortality (7, 23–25).

Health-related quality of life (HRQOL) is an important patient relevant outcome combining physical and mental aspects of health (26). Due to the rise of chronic diseases the concept of HRQOL is crucial for public health (27). Several studies have investigated associations between single health behaviors and HRQOL (28–31). However, little is known about the relationship between patterns of several health behaviors and HRQOL at the population level. Dumuid et al. (32) identified four distinct clusters based on PA, nutrition and screen time in school-aged children. They report differences in HRQOL scores with highest scores for a mixed cluster (low screen time, healthy eating, and moderate PA) (32). Another study investigated associations between a clustering of healthy behaviors (non-smoking, adequate PA, consumption of at least five portions of fruit or vegetables per day) and HRQOL in US adults with diabetes. According to this study, an increase of healthy behaviors is associated with better HRQOL (33). To the best of our knowledge, only one study investigated the relationship of the clustering of health behaviors and HRQOL in a general population (16). Based on smoking, drinking alcohol, PA and nutrition, six health behavior clusters were identified. The scientists report that healthier clusters tend to be associated with better aspects of HRQOL (16). To the best of our knowledge, no study investigated the association between the clustering of health behaviors and HRQOL, including multiple measurements of HRQOL at different time points. Due to this reason, the present study uses data from a population-based cohort study including information on HRQOL at two time points approximately 7 years apart.

The main objective of this study was the identification of clusters that share a similar pattern based on their health behavior. It is assumed that health behavior patterns are closely linked to demographic factors (34). Therefore, sex, age and education are also included in the clustering process. The considered behaviors are smoking, alcohol consumption, leisure time PA, and nutrition. In order to attain comparability with other clustering solutions and with regard to the public health impact of these four behaviors, the present study considers these behaviors in order to identify health behavioral clusters. In order to receive a profound understanding of the identified clusters and characterize their differences, it is helpful to describe them with additional parameters (35). Therefore, the identified clusters will be described regarding sociodemographic parameters. With respect to the sparse scientific background on the association between the clustering of health behaviors and HRQOL, the clusters will be additionally described regarding longitudinal change in physical and mental HRQOL between baseline and a 7-year follow-up.

METHODS

Data Source

Our analyses are based on data obtained from the population-based KORA (Cooperative Health Research in the Region of Augsburg) S4/F4 cohort study. In total 4,261 non-institutionalized inhabitants of the Augsburg Region in Southern Germany took part in the baseline health survey conducted in 1999-2001 (S4). All S4 participants were invited to participate in a follow-up examination approximately 7 years later (F4; 2006-2008). A total of 3,080 (72%) participants were investigated at follow-up. The reasons for losses at follow-up are as follows: death (176), claim for data deletion (12), no contact possible (174), refusal to participate (395), illness/lack of time (218), no contact information available (206). At baseline and at follow-up a physical examination and standardized interviews were performed. More detailed information on the KORA S4 study concerning sampling methods and data collection has been published elsewhere (36). All study participants gave written informed consent and the KORA S4/F4 studies were approved by the Ethics Committee of the Bavarian Medical Association.

Measures

Alcohol

Alcohol consumption was calculated based on participants' self-reported information on beer, wine and spirits consumption on the previous workday and weekend. The weekday consumption was multiplied by five and added to the weekend consumption. Total alcohol intake per day [g/day] was derived from dividing this number by seven. Details on the calculation and validation process have already been published (37). For the present study alcohol consumption has been grouped into the following three categories: (1) 0 g/day = "no alcohol," (2) <20 g/day = "moderate consumption," (3) ≥20 g/day = "risky consumption" as suggested by published classifications (38).

Nutrition

Dietary intake was collected by using a food-frequency-questionnaire investigating 24 food groups. Based on recommendations of the German Nutrition Society (DGE) an index was built rating the frequency with which each food was consumed by assigning either 2, 1, or 0 points. Higher scores reflect better compliance to DGE recommendations. A resulting sum score was then rated according to DGE guidelines grouped into the following three categories: (1) "favorable," (2) "ordinary," and (3) "adverse." This approach was established in earlier KORA studies and was validated against a detailed seven-days-dietary protocol (39).

Physical Activity

Participants were asked to report their weekly time spent on leisure-time PA (including cycling) in summer and winter. The two responses were combined and categorized into four groups: (1) "(almost) no activity," (2) "about 1 h per week irregularly," (3) "about 1 hour per week regularly," and (4) "regularly more than 2 h per week." Categories (2) and (3) were condensed for all statistical analyses because they were not considered adequately distinct. The questions about leisure-time PA originated from the German Cardiovascular Prevention Study conducted between 1979 and 1995 and were validated in the KORA population, by using a PA diary (40).

Smoking

Smoking behavior was classified considering the actual behavior and the regularity with which the behavior was performed. Therefore, participants were asked whether they currently smoke and whether they have ever smoked. Additionally, regularity was surveyed by inquiring whether someone usually smokes regularly (at least one cigarette per day) or irregularly (usually less than one cigarette per day). According to this information, smoking behavior was grouped into (1) non-smoker, (2) ex-smoker, (3) irregular smoker, and (4) regular smoker.

Health-Related Quality of Life

HRQOL was estimated with the SF-12 health survey. This short version of the SF-36 health survey consists of 12 items distinguishing between physical and mental components of HRQOL. Both components can be summarized in a physical component summary score and a mental component summary score with a mean of 50 points and a standard deviation of ten points. Higher scores imply a better HRQOL. Information about psychometric quality criteria can be found elsewhere (41).

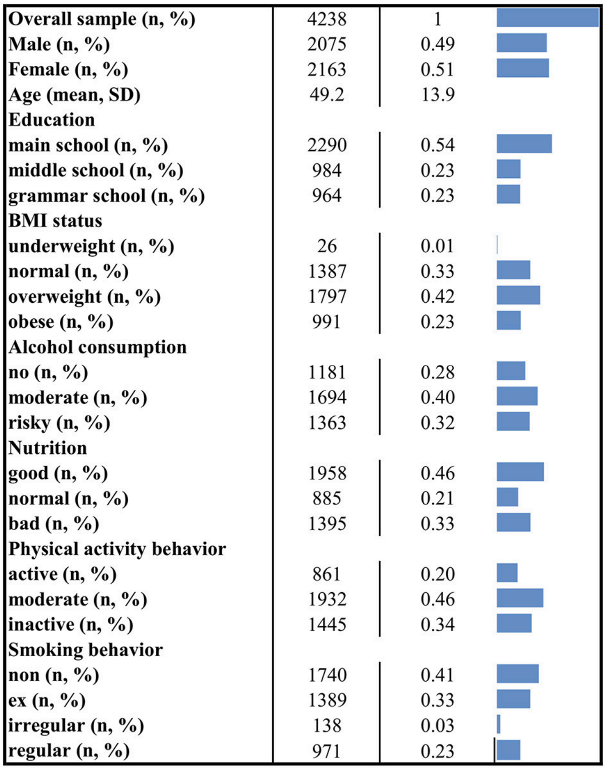
Covariates

Information about sex (male, female), age (continuous) and education (main-, middle- and grammar school corresponding to German "Hauptschule," "Realschule," and "Gymnasium") were also collected during the standardized interviews.

Statistical Analysis

In order to identify homogeneous subgroups based on the samples' health behaviors, a latent class analysis was carried out. This method allows to cluster cases into unobserved classes. An advantage of latent class analysis compared to traditional clustering techniques like hierarchical clustering or k-means is that it is a model-based approach. Therefore, this approach is more flexible and the choice of a cluster criterion is less arbitrary (42). Key assumptions to this approach are that the latent class variable and the observed variables, in this case the health behaviors alcohol consumption, nutrition, PA and smoking, are treated as categorical. Another assumption is that the observed variables are locally independent and that dependencies are conditional on the latent classes' variable (43). In a basic, unconditional model, latent class models analyze cross-classification tables of observed variables to estimate the probability of latent class membership. This unconditional model can be extended with covariates which influence latent class membership, into a latent class regression analysis. While in the unconditional model it is assumed that every individual has the same probability for class membership, this approach allows for varying probabilities depending upon observed covariates (44). In our study, sex, age, and education were added to the analysis as covariates, since their importance in this process has been stressed in past studies (11). Latent class membership is based solely on data from the S4 study (1999-2001). **Figure A1** in the Appendix gives a visual overview of the latent class regression model. Since in this case, the number of latent classes is unknown, multiple models with an increasing number of classes were fit. To identify the most parsimonious model that represents the data best, several model fit criteria including Akaike information criterion (AIC) and (sample-sized-adjusted) Bayesian Information Criterion (BIC) were deployed. In this study we prioritized BIC as it is the most commonly used criterion which is supposed to be very accurate (45). In addition, model selection should also consider the practical meaning of identified classes (46) and therefore a complex model that cannot provide a new meaningful class is seen as inferior to a simpler model with a marginally worse model fit. Cluster analysis is an analysis to identify groups/clusters. In latent class analysis the term for these groups is class. Therefore, the terms will be used synonymously in this paper.

Descriptive statistics were used to describe and interpret the different latent classes. To investigate differences in HRQOL at baseline (S4) and the follow-up (F4) and to investigate the change in HRQOL between the measurement points a mixed model with a random intercept was fit. In this model HRQOL is the dependent variable and latent class membership, and an interaction between latent class membership and measurement time point are independent



Overall sample (n, %)	4238	1	
Male (n, %)	2075	0.49	
Female (n, %)	2163	0.51	
Age (mean, SD)	49.2	13.9	
Education			
main school (n, %)	2290	0.54	
middle school (n, %)	984	0.23	
grammar school (n, %)	964	0.23	
BMI status			
underweight (n, %)	26	0.01	
normal (n, %)	1387	0.33	
overweight (n, %)	1797	0.42	
obese (n, %)	991	0.23	
Alcohol consumption			
no (n, %)	1181	0.28	
moderate (n, %)	1694	0.40	
risky (n, %)	1363	0.32	
Nutrition			
good (n, %)	1958	0.46	
normal (n, %)	885	0.21	
bad (n, %)	1395	0.33	
Physical activity behavior			
active (n, %)	861	0.20	
moderate (n, %)	1932	0.46	
inactive (n, %)	1445	0.34	
Smoking behavior			
non (n, %)	1740	0.41	
ex (n, %)	1389	0.33	
irregular (n, %)	138	0.03	
regular (n, %)	971	0.23	

FIGURE 1 | Socio-demographic characteristics and distribution of health behaviors. The figure displays descriptive information for the overall applicable sample. N, number of observations; %, column percent (except for the first row); SD, standard deviation.

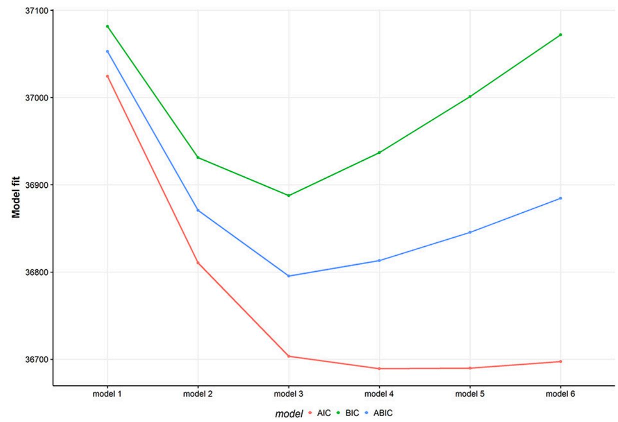


FIGURE 2 | Model fit for multiple models. The figure displays three different model fit criteria for different models. Smaller values indicate a better model fit. The model number represents the number of latent classes. AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; ABIC, sample size adjusted BIC.

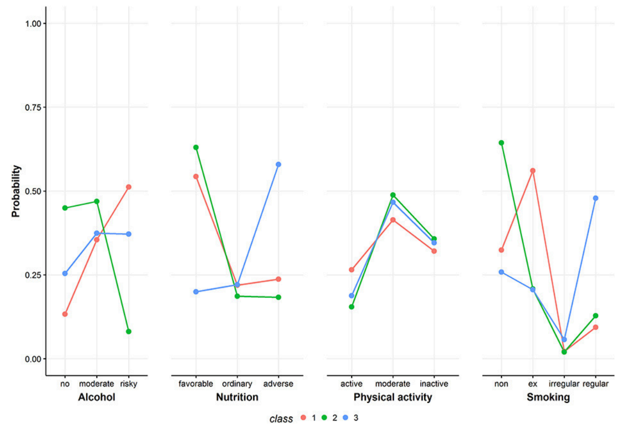


FIGURE 3 | Class-conditional item probabilities. The figure shows the probabilities of each health behavior category conditional on latent class membership.

variables. Sex, age, and education were introduced as covariates in the model. Altogether two mixed models were fit to differentiate between physical and mental HRQOL.

All data related processes and statistical analyses were conducted using R (Version 3.4.3) (47). Latent class regression analysis was carried out using the "poLCA" package (Version 1.4.1) (44).

RESULTS

Participants

Twenty three participants (0.5%) of the baseline S4 study were excluded from the latent class regression analysis due to missing data in the behavioral variables or the covariates. The remaining sample of 4,238 had a mean age of 49.2 (±13.9) years ranging from 24 to 75 years. 49% of the sample were male, 54% graduated from main school, 23.2% from middle school and 22.7% from grammar school. One third of the population had a normal BMI ($\geq$18.5–<25 kg/m^2). Nearly two third of the participants were overweight (BMI$\geq$25–<30 kg/m^2) or obese (BMI$\geq$30 kg/m^2). Only 0.6% was underweight (BMI<18.5 kg/m^2). **Figure 1** shows more socio-demographic details and the distribution of the health behavior categories for the overall sample.

Class Selection

Figure 2 shows model fit criteria for the different models. Smaller y-values indicate a better model fit. Multiple models with an increasing number of classes from one to six were fit. The two-class (BIC = 36931.16), three-class (BIC = 36887.63) and four-class (BIC = 36936.96) solutions showed the best model fit regarding the BIC criteria. After a substantial comparison of all solutions, the four-class solution did not reveal any new unique behavioral pattern. Therefore, the three-class solution was chosen as the most appropriate model. For comparison, see **Figure 3** and **Figures A2, A3** in the Appendix showing the class-conditional item probabilities.

Description of the Identified Groups

Figure 3 shows the class-conditional item probabilities. This plot displays the probability of an item response given latent class

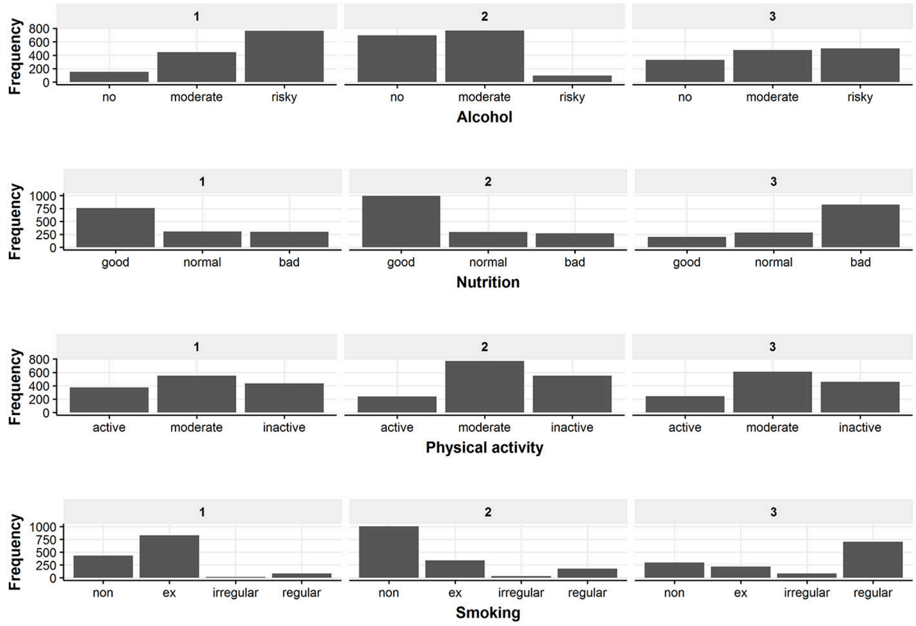


FIGURE 4 | Overview of the behavior distribution in the three latent classes. The figure displays the frequency of every health behavior category for the three classes.

membership. The specific values are presented in **Table A1** in the Appendix.

In the following, the three classes from the selected three-class model solution are described regarding their health behavior patterns and socio-demographic characteristics. **Figure 4** gives a detailed overview of the health behaviors of the identified classes. Information on the distribution of the three covariates included in the latent class regression can be found in **Figure 5**. Exact numbers on the distribution of the health behaviors and the covariates can be seen in **Table A2** in the Appendix.

Class 1

Class 1 has 1,366 members of which 84% are male. Mean age is 56.1 (±11.9) years, 45% are main school attendees and it is the class with the most grammar school graduates (35%). 0.1% are underweight, 26% are of normal weight, 50% are overweight and 24% are obese. Conditional on class 1 membership, class members have the highest probability for risky drinking (51%), a favorable diet (54%), moderate PA (41%) and ex-smoking (56%).

Class 2

Class 2 is the biggest class. Class 2 consists of 1,562 participants and is exclusively female. The biggest share are main school attendees (60%) and the mean age is 52.4 (± 13.0) years. 0.5% are underweight, 34% have a normal weight, 37% are overweight and 29% are obese. Regarding health behavior, class 2 membership has the highest probability for drinking no (45%) or moderately (47%) alcohol, having a favorable diet (63%), being moderately physically active (49%), and being non-smoking (64%).

Class 3

Class 3 is composed of 1,310 participants, 71% thereof are male. Most participants of class 3 received a main school educational degree (56%). Class 3 is the youngest class with a mean age of 38.1 (± 9.8) years. Most participants have normal weight (40%) or are overweight (43%). 1.3% are underweight and 16% are obese. Concerning health behavior, class 3 membership implies highest probabilities for moderate (37%) or risky (38%) alcohol consumption, adverse dietary behavior (58%), moderate PA (47%) and regular smoking (48%).

Associations Between Latent Classes and Health-Related Quality of Life

Based on the mixed model, class 1 (mean = 48.88; 95%-CI = 48.36–49.41) and 2 (mean = 48.47, 95%-CI = 47.89–49.06) have the highest physical HRQOL at baseline. Class 3 has a mean score of 46.96 (95%-CI = 46.28–47.55) concerning physical HRQOL. At follow-up, mean values for physical HRQOL are 47.64 (95%-CI = 47.07–48.21) for class 1, 47.62 (95%-CI = 47.00–48.25) for class 2 and 47.17 (95%-CI = 46.51–47.82) for class 3.

Regarding mental HRQOL, class 1 had a mean score of 51.06 (95%-CI = 51.37–52.17), class 2 had a mean score of 50.77 (95%-CI = 50.14–51.40) and class 3 had a mean score of 50.39 (95%-CI = 49.76–51.02). Follow-up values for mental HRQOL were 51.32 (95%-CI = 50.70–51.95) for class 1, 50.95 (95%-CI = 50.27–51.63) for class 2 and 51.18 (95%-CI = 50.47–51.89) for class 3.

Figure 6 provides a visual overview of the mean physical and mental HRQOL of the three classes.

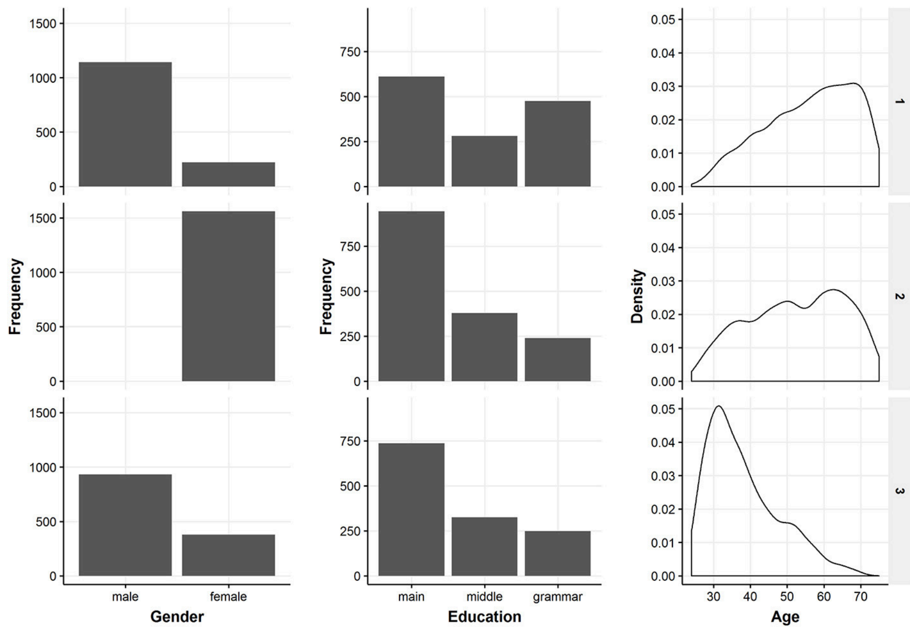


FIGURE 5 | Overview of the included covariates in the three latent classes. The figure shows descriptive information on gender, education and age which were included in the latent class regression.

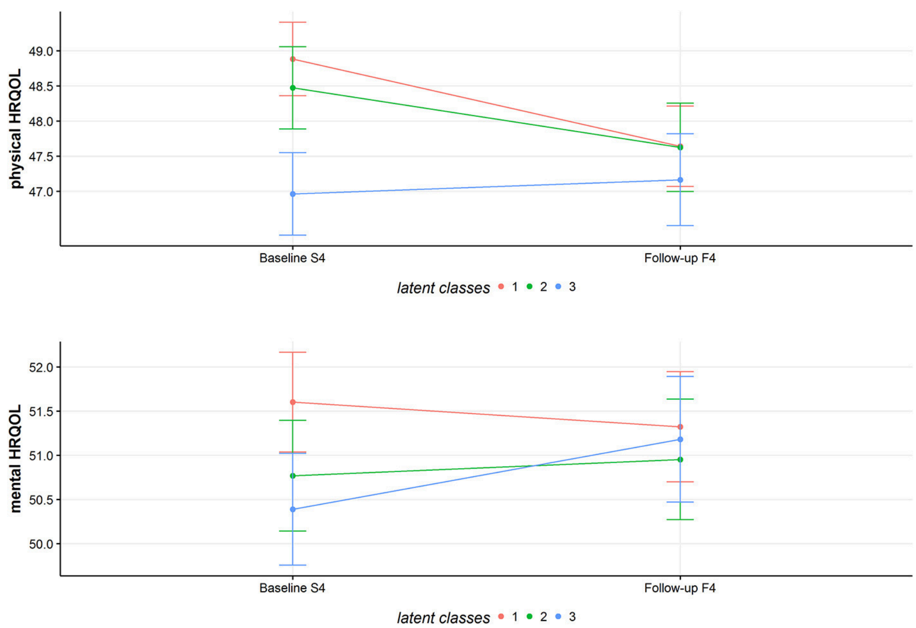


FIGURE 6 | Predicted mean values of physical and mental HRQOL for the latent classes. The figure shows the estimated marginal means for physical and mental HRQOL for the three classes at baseline and follow-up.

DISCUSSION

This study aimed at identifying different subgroups of a population based on the health behaviors alcohol consumption, nutrition, PA and smoking, while also taking the influence of the parameters sex, age and education into account. Three distinct classes were identified. All three classes show a unique pattern regarding the health behaviors. Class 2 represents a healthy cluster, showing a very healthy pattern and the highest item probabilities for healthy behavior categories. Class 1 and class 3 on the other hand show more unhealthy profiles. Class 1 shows highest item probabilities for a risky alcohol consumption. In addition, class 1 has the highest probability for former smoking which has been associated with higher odds for hospital treatments and higher numbers in physician visits (48).

Cluster analysis is very exploratory and although comparisons with other studies are difficult because of different investigated health behaviors and methodological approaches, our results are in line with similar investigations. In line with previous studies, we identified an overall healthy cluster with class 2 (13, 14, 16, 20, 21, 49, 50). Similar to previous studies, we observed a clustering of unhealthy smoking behavior and unhealthy alcohol consumption (11, 15, 16, 20). This clustering becomes very evident for class 3 and partially for class 1 considering the high number of ex-smokers in this class. Some studies report a combination of excessive alcohol consumption and higher PA rates (14, 16, 49). A tendency of this combination could be observed in class 1, which has highest item probabilities for drinking and the highest probability for active PA amongst the three classes.

Regarding socio-demographic characteristics of the identified clusters, the present results are in line with previous studies. Previous research reported a higher male prevalence in more unhealthy clusters (14, 20). Our findings support this result, showing the highest female prevalence rates for the healthy class 2. In our study, age and education were not a good indicator for distinguishing between healthy and unhealthy clusters, as younger and older clusters or more and less educated clusters can be found on both ends of the spectrum. A similar result is also mentioned in the systematic review of Meader et al. (11).

Scientific evidence on associations between clustering of health behaviors and HRQOL is sparse. Conry et al. (16) report a tendency for healthier clusters having a better quality of life. This result could not be replicated by our study. We found no clear association between a healthier behavior pattern and better physical or mental HRQOL. The different latent classes show different adjusted means in physical and mental HRQOL. The classes are also different in their change of physical or mental HRQOL over the years. However, the different changes in physical/mental HRQOL might be due to regression to the mean. Furthermore, the differences in physical/mental HRQOL are too small to be considered as clinically relevant. For the SF-12 questionnaire a difference from three to five points can be seen as the minimal clinically relevant threshold (51).

Our study has several limitations. One problem lies in the way the health behaviors are measured and operationalized. All information on health behaviors is self-reported and thus prone to information bias like recall-bias or social desirability-bias. Furthermore, taking average scores for PA by combining information on winter and summer can be considered as another weakness. However, especially in large cohort studies with many variables, one has to balance the tradeoff between accuracy and feasibility. Another limitation lies in the cross-sectional design of this study. The clustering of the health behaviors is based on the baseline-study and therefore can only be seen as a snapshot. Nevertheless, the questions in the KORA-study are conceptualized to gather information on an established behavior. A further drawback is the assumption that the health behavior pattern which was identified at baseline, remains stable over time. Even though, this assumption might be very bold, this is an adult population and there is evidence, that health behavior patterns are quite stable over time (52, 53). Another limitation of this study concerns the longitudinal description of HRQOL for the established clusters at baseline. The reduced sample size of the KORA-study might result in a biased depiction of HRQOL as healthier people with better HRQOL are more likely to remain in the study. Taking this into account, the observed changes in physical and mental HRQOL might not necessarily reveal a true change on a population level. Although we adjusted our analyses for several variables, chances are high that HRQOL might have been influenced by a factor we did not adjust for, e.g., socio-economic status. Therefore, residual confounding cannot be ruled out.

Besides the aforementioned limitations, this study has several noticeable strengths. The data are collected in a large population-based cohort study. The clustering is based on a latent class model. This approach offers a clustering based on a statistical model instead of more arbitrary cluster criteria and thus might be more sophisticated than traditional clustering approaches (54). Moreover, this methodological approach allows introducing covariates to factor in their influence on health behavior patterns. Another strength of this study is that the clustering is not only based on dichotomous variables like the absence or presence of a risk factor but also on polytomous variables. Despite its limitations and the therefore limited level of inference, addressing the relevance of health behavior clusters by linking them to HRQOL—a clinically important outcome—adds value to this study.

In conclusion, this study identified distinct patterns of health behaviors within a large population-based sample. The observed health behavior patterns and the socio-demographic characteristics of the identified clusters are in line with the few other existing international studies. Knowledge on specific clusters which are common in an adult population are an important step for comprehensive health promoting public health policies. The clustering of lifestyle factors like health behaviors can give valuable information on characteristics of target groups for primary preventions. Combining these findings with further information on big data by health care providers or individual risk probabilities might result in even more effective and comprehensive health care. Further research on health behavior patterns should focus on linking identified clusters to important medical outcomes in order to identify vulnerable groups and to allow for individualized patient-centered primary prevention programs.

AUTHOR CONTRIBUTIONS

MR, FM, and ML: Conceptualization. MR: Formal analysis, investigation, methodology, and writing-original draft. BT, AP, LS, ML, and FM: Supervision. MR, BT, AP, LS, ML, and FM: Writing–review and editing.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2018.00387/full#supplementary-material

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix

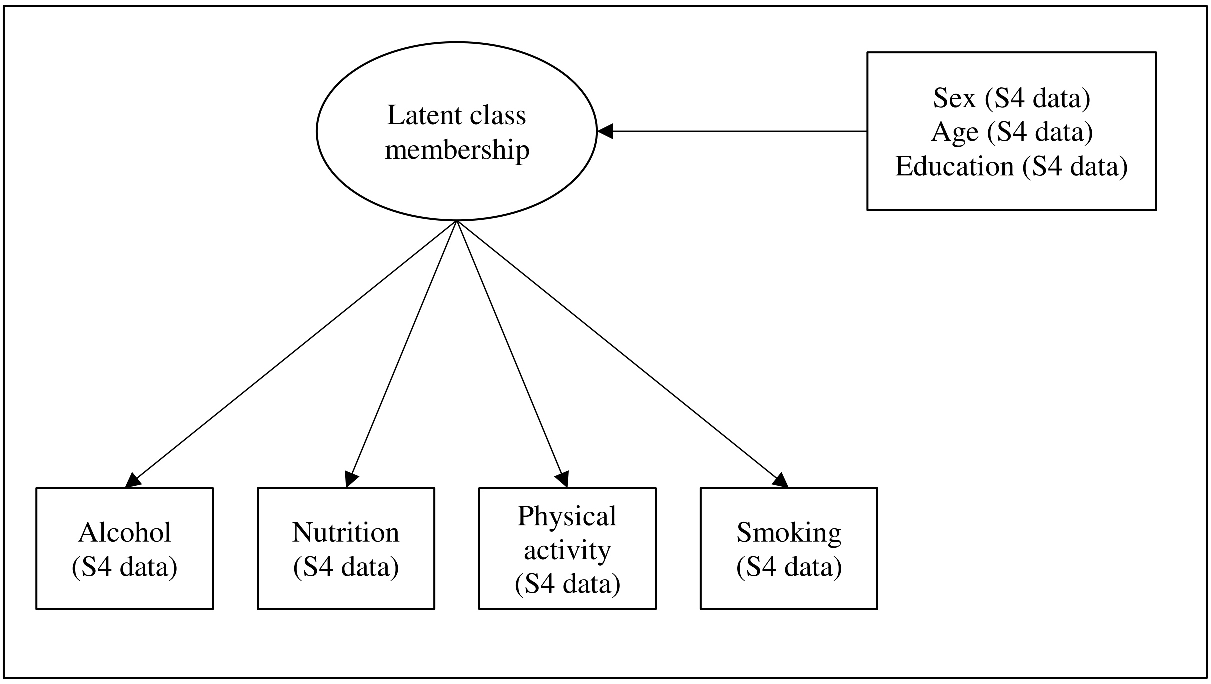

Figure A1. The latent class regression model.
A graphical description of the latent class regression model based on baseline (S4) data.

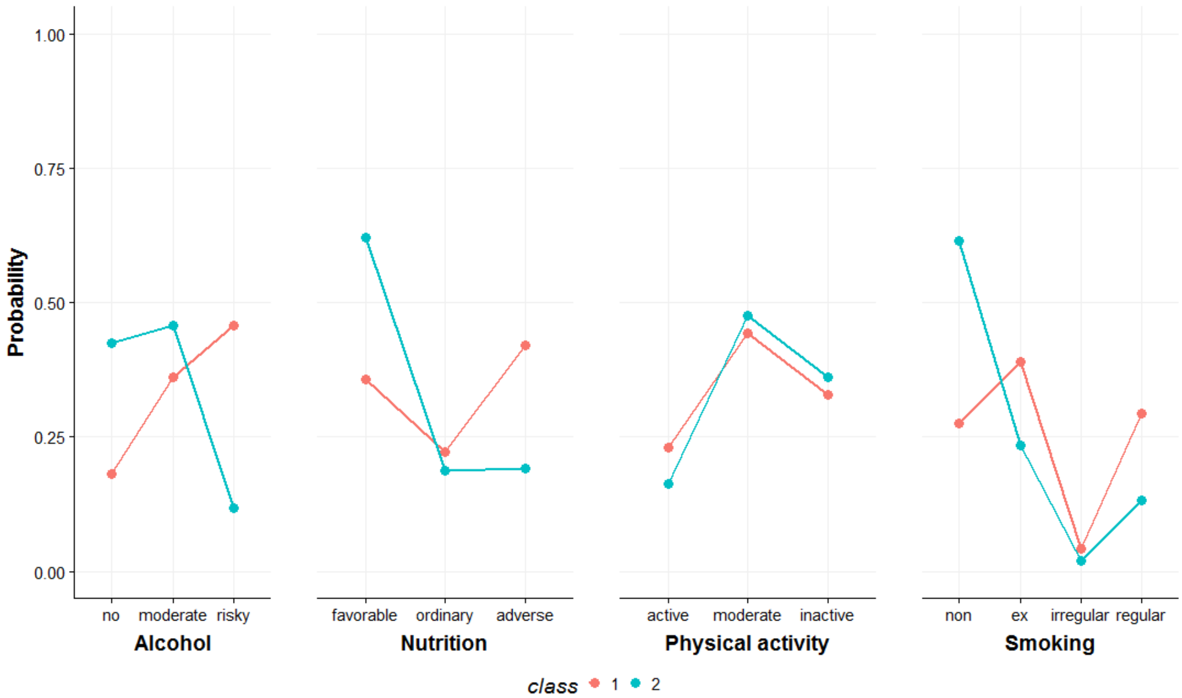

Figure A2. Two-class-conditional item probabilities.
The figure shows the probabilities of each health behavior category conditional on latent class membership for a two-class model.

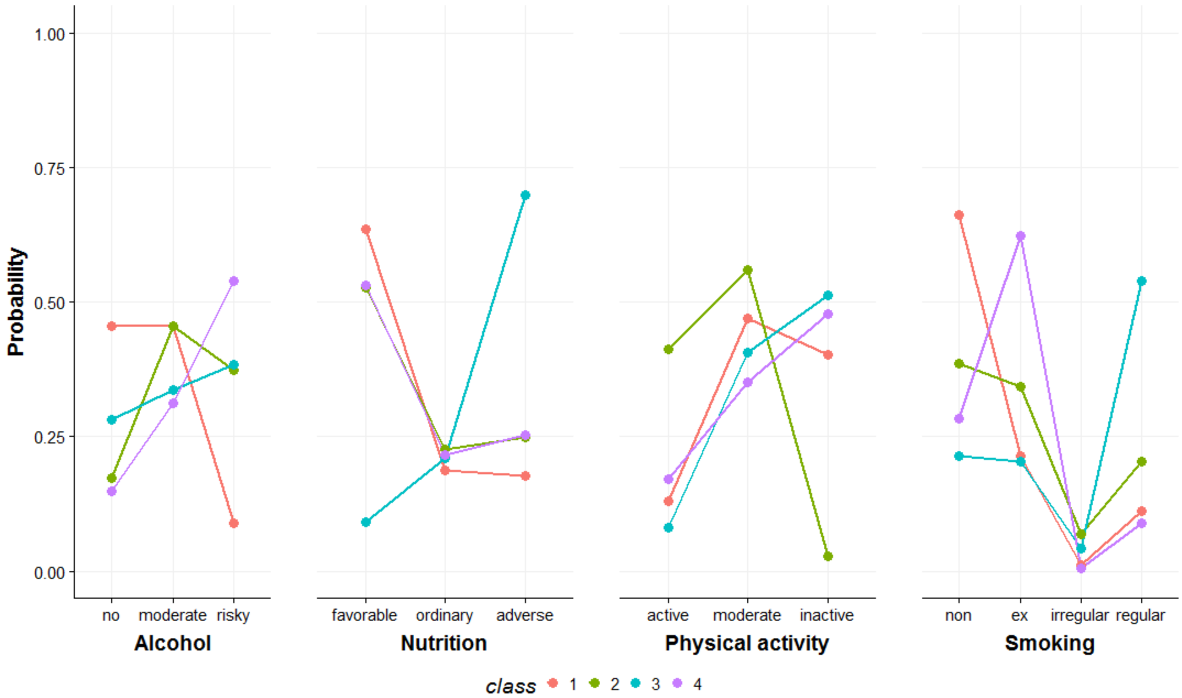

Figure A3. Four-class-conditional item probabilities.
The figure shows the probabilities of each health behavior category conditional on latent class membership for a three-class model.

Table A1. Three-class-conditional item probabilities exact values
Referring to Figure 3 in the manuscript, this table shows the exact numerical values of the class-conditional item probabilities.

		Class 1	Class 2	Class 3
Alcohol	**no**	0.133	0.450	0.254
	moderate	0.355	0.469	0.374
	risky	0.512	0.081	0.372
Nutrition	**favorable**	0.543	0.630	0.200
	ordinary	0.219	0.187	0.221
	adverse	0.237	0.183	0.579
Physical activity	**active**	0.265	0.155	0.188
	moderate	0.414	0.488	0.466
	inactive	0.321	0.357	0.346
Smoking	**non**	0.324	0.644	0.258
	ex	0.561	0.208	0.206
	irregular	0.022	0.020	0.057
	regular	0.094	0.128	0.479

Table A2. Further descriptive statistics on latent classes.
In addition to the reported information in the manuscript, this table shows further descriptive information concerning the three latent classes.

	Latent Classes		
	I	**II**	**III**
Overall sample (n, %)	1366 (32.2)	1562 (36.9)	1310 (30.9)
Male (n, %)	1143 (83.7)	0 (0.0)	932 (71.1)
Female (n, %)	223 (16.3)	1562 (100.0)	378 (28.9)
Age (mean, SD)	56.1 (11.9)	52.4 (13.0)	38.1 (9.8)
Education			
main school (n, %)	610 (44.7)	944 (60.4)	736 (56.2)
middle school (n, %)	281 (20.6)	378 (24.2)	325 (24.8)
grammar school (n, %)	475 (34.8)	240 (15.4)	249 (19.0)
Alcohol consumption			
no (n, %)	153 (11.2)	697 (44.6)	331 (25.3)
moderate (n, %)	447 (32.7)	769 (49.2)	478 (36.5)
risky (n, %)	766 (56.1)	96 (6.1)	501 (38.2)
Nutrition			
good (n, %)	761 (55.7)	997 (63.8)	200 (15.3)
normal (n, %)	306 (22.4)	297 (19.0)	282 (21.5)
bad (n, %)	299 (21.9)	268 (17.2)	828 (63.2)
Physical activity behavior			
active (n, %)	377 (27.6)	241 (15.4)	243 (18.5)

moderate (n, %)	552 (40.4)	771 (49.4)	609 (46.5)
inactive (n, %)	437 (32.0)	550 (35.2)	458 (35.0)
Smoking behavior			
non (n, %)	432 (31.6)	1009 (64.6)	299 (22.8)
ex (n, %)	830 (60.8)	339 (21.7)	220 (16.8)
irregular (n, %)	18 (1.3)	34 (2.2)	86 (6.6)
regular (n, %)	86 (6.3)	180 (11.5)	705 (53.8)

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Change in Physical Activity after Diagnosis of Diabetes or Hypertension: Results from an Observational Population-Based Cohort Study

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Abstract: *Background:* Chronic diseases like diabetes mellitus or hypertension are a major public health challenge. Irregular physical activity (PA) is one of the most important modifiable risk factors for chronic conditions and their complications. However, engaging in regular PA is a challenge for many individuals. The literature suggests that a diagnosis of a disease might serve as a promising point in time to change health behavior. This study investigates whether a diagnosis of diabetes or hypertension is associated with changes in PA. *Methods:* Analyses are based on 4261 participants of the population-based KORA S4 study (1999–2001) and its subsequent 7-and 14-year follow-ups. Information on PA and incident diagnoses of diabetes or hypertension was assessed via standardized interviews. Change in PA was regressed upon diagnosis with diabetes or hypertension, using logistic regression models. Models were stratified into active and inactive individuals at baseline to avoid ceiling and floor effects or regression to the mean. *Results:* Active participants at baseline showed higher odds (OR = 2.16 [1.20;3.89]) for becoming inactive after a diabetes diagnosis than those without a diabetes diagnosis. No other significant association was observed. *Discussion:* As PA is important for the management of diabetes or hypertension, ways to increase or maintain PA levels in newly-diagnosed patients are important. Communication strategies might be crucial, and practitioners and health insurance companies could play a key role in raising awareness.

Keywords: physical activity; diagnosis; diabetes; hypertension; health behavior; chronic disease

1. Introduction

Chronic diseases like cancer, diabetes mellitus, or cardiovascular conditions are considered to be among the most important challenges to public health. Further, chronic diseases are the main driver for impaired quality of life, and account globally for more than 70% of deaths [1]. Nonetheless, they are preventable. The key risk factors for chronic diseases include poor diet, alcohol consumption, smoking, and physical inactivity [2]. Furthermore, even though the benefits of positive health behavior changes are well known [3], people often have difficulties initiating a change in their health behavior for several reasons [4].

The literature suggests that so-called "health shocks" might serve as a "natural nudge" [5], "wake-up call" [6], "window of opportunity" [7] or "teachable moment" [8] to initiate a health behavior change. A health shock in this context is considered to be an unpredicted illness that lowers a person's health status [9]. Other sources define health shocks as an outbreak of a disease [5] or as a negative effect on someone's health [10]. Further studies expand the term and describe a health shock as a change in self-assessed health [10] or a decline in grip strength [11]. Finally, according to Agüero and Beleche [5], the diagnosis of an illness like diabetes or hypertension can also be interpreted as a health shock [5]. Within this study, we follow Agüero and Beleche's [5] definition. Therefore, a medical diagnosis might be a promising point in time to initiate health behavior changes, as physicians occupy a central role when it comes to health behavior [12].

There are several theoretical health behavior theories supporting the hypothesis that a diagnosis might lead to a health behavior change. One very popular theoretical model to describe behavior changes is the Health Action Process Approach Model by Schwarzer. This psychological approach suggests that risk perception is an important factor when it comes to building an intention to change a health behavior [13]. The Protection Motivation Theory by Rogers is a further theory proclaiming threat appraisals as a fundamental component of behavior change [14]. Both the Health Action Process Approach and the Protection Motivation Theory offer a theoretical foundation for the event of a diagnosis to be viewed as an important factor explaining health behavior and health behavior changes.

Empirically, a few studies have investigated possible associations between a diagnosis of several kinds of diseases and a change in different kinds of health behaviors. Whereas the effects of different types of diagnoses, for example a decline in self-assessed health status, cancer diagnosis, cardiovascular conditions, stroke, and diabetes, on smoking cessation have been documented by multiple studies [6,7,10,15–18], the body of evidence for other behaviors is smaller, and study results are more heterogeneous. For example, it was reported that alcohol consumption decreased slightly after the diagnosis of one of multiple chronic diseases [6] or after a cancer diagnosis [19]. Regarding dietary behavior, it was shown that people eat a healthier diet after a cancer [15] or a diabetes diagnosis [20].

In terms of physical activity (PA), studies reported decreasing levels of PA after a cancer diagnosis [15,19], or no change after experiencing a diabetes diagnosis [20,21] or any multiple chronic disease diagnosis [6]. In contrast, one other study reported significant increases in women's PA after a diabetes diagnosis [22].

Relative to the few studies on associations between changes in PA after a diabetes diagnosis, the number of studies examining PA changes after a hypertension diagnosis is even smaller; only two studies have dealt with the latter relationship. Hernandez et al. described that only 25% of inactive participants increased their PA after a hypertension diagnosis [23]. Neutel and Campell reported small but non-lasting improvements in PA behavior after a hypertension diagnosis [24].

For both, i.e., diabetes and hypertension, the benefits of PA are well known [25,26], and regular PA is recommended in treatment guidelines [27,28]. Hence, knowledge about a possible health behavior change after a diabetes or hypertension diagnosis is crucial for a couple of reasons concerning public health. First, it yields important information on designing public health interventions. It might strengthen the claim that for the whole process of behavior change, the moment of receiving information about health consequences could be even more important than the knowledge itself of the harmful consequences [5]. Second, as evidence suggests that physicians play an important role when it comes to promoting behavioral changes [12], behavioral interventions promoted by physicians could be designed more effectively in the context of the diagnosis. Third, a positive health behavior change could lower the risk of disease reoccurrence, increase health-related quality of life, and positively influence longevity [6].

Consequentially, the aim of this paper is to investigate possible associations between a diabetes or hypertension diagnosis and PA change. For this, we use well pheno-typed data from a large German population-based cohort study comprising three measurements over a period of 14 years.

2. Materials and Methods

2.1. Study Design and Participants

The data originated from the KORA (Cooperative Health Research in the Region of Augsburg) S4/F4/FF4 cohort study located in Southern Germany. The S4 (1999–2001) study was a population-based cross-sectional health survey including 4261 adult participants (67% response rate of all eligible participants) aged 25 to 74 years [29]. Of those, 3080 (80% response rate) took part in the first follow-up F4 (2006–2008) examination and 2279 (79% response rate) in the second follow-up FF4 (2013–2014) examination (compare caption in Figure 1 for details). For all studies, information on participants was collected during standardized medical examinations, standardized face-to-face interviews conducted by trained medical staff, and self-administered questionnaires. Additional information on the S4 study regarding the sampling methods and data collection has been published elsewhere [30]. All study participants gave written informed consent. The Ethics Committee of the Bavarian Medical Association approved the KORA S4/F4/FF4 studies.

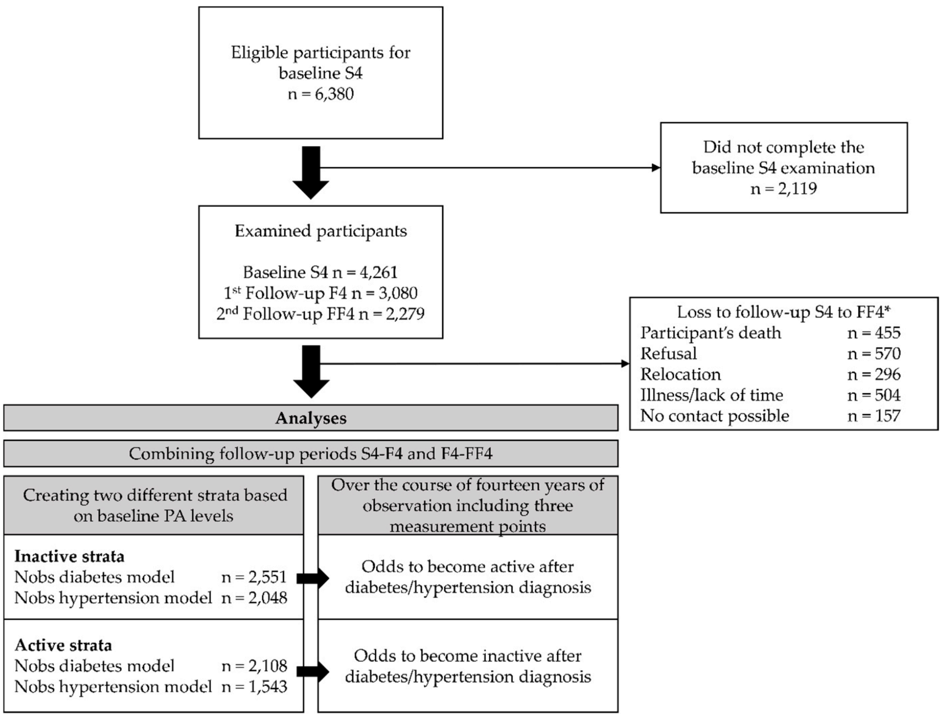

Figure 1. Study population and analysis flow chart. * Of the baseline S4 sample, 174 died, 204 moved outside the study region or to an unknown location, and 12 refused to be further contacted. Of the remaining 3871 eligible participants, 176 could not be contacted, 220 were too ill or busy, and 395 refused to participate further. Thus, 3080 participants (80% response rate) took part in the first follow-up F4 (2006-2008) examination. Of the F4 sample, 168 died, 97 moved outside the study region or to an unknown location, and 67 refused to be contacted further. Of the resulting eligible 2748 participants, 48 could not be contacted, 332 were too ill or busy, and 207 refused to participate further. Adding 118 participants from S4 without F4 information, 2279 (79% response rate, excluding 118 participants without F4 information) participants took part in the second follow-up FF4 (2013–2014) examination. Annotations: *n* = number of participants, Nobs = number of observations.

2.2. Measures

Physical activity: Changes in PA was the main outcome of this study. Participants' levels of PA were assessed during standardized interviews using two separate, four-category item questions reflecting weekly time spent on leisure-time PA during winter and summer. Within the KORA research platform, both items were combined into a single variable with the following categories: (1) "(almost) no activity", (2) "about 1 h per week, irregularly", (3) "about 1 hour per week, regularly" and (4) "regularly, more than 2 h per week". The questions on leisure-time PA were derived from the German Cardiovascular Prevention Study conducted between 1979 and 1995. The questions were validated in the KORA population [31] using a PA diary as comparison.

For the present study, PA was dichotomized by condensing categories (1) and (2), representing irregular PA and inactive individuals, and categories (3) and (4), representing regular PA and active individuals. We decided to draw the line between categories (2) and (3), as (3) represents regular PA, and can therefore be considered as habitualized behavior, whereas category (2) still symbolizes irregular and infrequent PA behavior. This cut-off for the dichotomization of PA was also used in previous KORA studies [32]. The change in PA is a binary variable indicating whether a person showed a change in PA at a follow-up session.

Incident diabetes and hypertension diagnosis: To consider individual awareness of a diabetes or hypertension diagnosis, we used self-reported information on the existence of diabetes (Questionnaire item: "Are you diabetic?", and further information on the intake of antidiabetics) and hypertension (Questionnaire item: "Have you ever had elevated blood pressure or been diagnosed with high blood pressure?") from the standardized interviews. An incident diagnosis of diabetes or hypertension was coded binary if the condition was not present at baseline but present at follow up.

Covariates: Other relevant variables assessed at all three measurement points were sex (male, female), levels of secondary education (lower, intermediate, higher; corresponding to German "Hauptschule", "Realschule", "Gymnasium"), family status (living alone, living together), age (continuous), body mass index (BMI) (continuous), and physical and mental health-related quality of life (both continuous). Both components of health-related quality of life were measured using the SF-12 health survey [33].

2.3. Statistical Analyses

We investigated the association between diabetes or a hypertension diagnoses and changes in PA between two measurement points. Therefore, participants with existing diabetes or hypertension were excluded from the respective models. To increase the statistical power, the two seven-year follow-up periods from S4 to F4 and from F4 to FF4 were combined, comprising the observations of both periods. This means that we treated the S4-F4 follow-up period and the F4-FF4 follow-up period as two separated periods. Consequently, participants with an incident diagnosis in the first follow-up period only appeared once in the final analysis sample, whereas participants without an incident diagnosis in the first follow-up period appeared twice. To account for dependencies due to the repeated measurement of participants, the participant ID was set as a random intercept in the models. To avoid ceiling or floor effects and regression to the mean, we stratified our sample according to baseline PA categories, resulting in an "inactive" and "active" stratum. Thus, for individuals being inactive at baseline, we compared the odds of becoming active between those with an incident diagnosis of diabetes or hypertension and those without such a diagnosis. Conversely, for active individuals at baseline, we compared the odds of becoming inactive between those with a diagnosis of diabetes or hypertension and those without such a diagnosis. Figure 1 provides an overview of the study population and the analysis set-up. Four logistic regression models were fit in order to investigate possible changes in PA after experiencing a diabetes or hypertension diagnosis. For both strata, i.e., active and inactive, changes in PA were regressed on either a diabetes diagnosis or a hypertension diagnosis. The models were adjusted for sex, age, education, family status, baseline BMI, change in BMI, and change in physical and mental health-related quality of life. For a better convergence, all continuous covariates were standardized, with mean equals zero and standard deviation equals one.

All data-related processes and statistical analyses were conducted using RStudio (Version 1.1.456, RStudio Inc., Boston, USA) [34]. Logistic regression models were carried out using the "lme4" package (Version 1.1.20) [35].

3. Results

3.1. Descriptive Analyses

Considering the S4 baseline sample with 4261 participants, 29 participants (0.68%) had missing values for PA, resulting in a baseline sample of 4232 participants of whom 51% were female and for whom the mean age was 49.2 ± 13.9 years. The mean BMI was 27.2 ± 4.7 kg/m^2. According to the baseline PA value, 2058 participants showed active leisure-time PA and 2174 showed inactive leisure-time PA. Table 1 depicts descriptive statistics for the baseline S4 study.

Table 1. Descriptive information on the baseline S4 study for the total sample.

Parameter	Baseline S4	
N	4232	
Female	2158	0.51
Age (mean) (SD)	49.18	13.94
BMI (mean) (SD)	27.22	4.73
Physical activity		
Inactive	1447	0.34
About 1 h/week irregularly	727	0.17
About 1 h/week regularly	1200	0.28
More than 2 h/week	858	0.20
Levels of secondary education		
Lower	2287	0.54
Intermediate	981	0.23
Higher	963	0.23
Family status		
Single, living alone	483	0.11
Single, living together with partner	223	0.05
Married, living together	2901	0.69
Married, separated	79	0.02
Divorced	296	0.07
Widowed	250	0.06
Present diagnosis (Excluded from respective models)		
Diabetes	166	0.04
Hypertension	1079	0.26

Absolute and relative frequencies regarding relevant covariates. Abbreviations: N = number of observations, SD = standard deviation, h/week = hours per week.

Regarding diabetes, there were 166 participants with existing diabetes at S4, 214 with existing diabetes at F4, and 219 with existing diabetes at FF4. Regarding hypertension, there were 1079 participants with existing hypertension at S4, 1043 with existing hypertension at F4, and 831 with existing hypertension at FF4. The present study focuses on a new incident diagnoses of diabetes and hypertension. Therefore, Figure 2 shows the number of incident cases of diabetes and hypertension by PA changes between S4 and F4 (columns 1 & 2), between F4 and FF4 (columns 3 & 4), and for the dataset of the assembled S4/F4 and F4/FF4 periods (columns 5 & 6). The assembled data set is the one used for the main logistic regression models.

		From S4 to F4 PA-level changed	From S4 to F4 PA-level unchanged	From F4 to FF4 PA-level changed	From F4 to FF4 PA-level unchanged	From S4 to F4 and from F4 to FF4 combined PA-level changed	From S4 to F4 and from F4 to FF4 combined PA-level unchanged
Active strata	incident diabetes	13	26	23	31	36	57
	no incident diabetes	348	1132	227	922	575	2054
	incident hypertension	43	158	28	97	71	255
	no incident hypertension	244	814	154	636	398	1450
Inactive strata	incident diabetes	24	60	9	37	33	97
	no incident diabetes	460	907	244	557	704	1464
	incident hypertension	68	126	25	85	93	211
	no incident hypertension	296	574	174	331	470	905

became inactive remained active
became active remained inactive

Figure 2. Overview of the cases with incident diagnosis of diabetes or hypertension for the active and inactive strata by PA change. See Figures S1 and S2 in the supplement for a detailed overview of how the presented numbers were derived. Numbers of observations for the combination of both follow-up periods: Active-Diabetes = 2722; Active-Hypertension = 2174; Inactive-Diabetes = 2298; Inactive-Hypertension = 1679. Deviations from the numbers of Figures 2 and 3 are due to missing values in covariates for which the models of Figure 3 were adjusted. Abbreviations: PA = physical activity; S4 = baseline study (2000); F4 = first follow-up (2007); FF4 = second follow-up (2014).

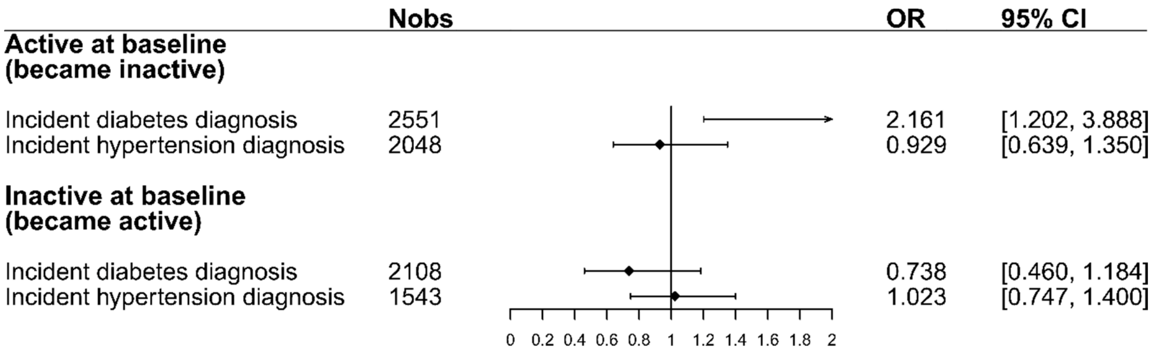

Figure 3. The odds-ratios for changing PA after a diabetes/hypertension diagnosis for both baseline PA strata. ORs for the active stratum display the odds of changing to inactive. ORs for the inactive stratum display the odds of changing to active. All models were adjusted for the following factors: sex, age, education, family status, baseline BMI, change in BMI, and change in physical and mental health-related quality of life. Abbreviations: Nobs = Number of observations, OR = Odds ratio, 95% CI = 95% Confidence interval.

3.2. Associations between Diabetes or Hypertension Diagnosis and PA Change

Figure 3 shows the odds ratios for changing PA after a diabetes or hypertension diagnosis. For participants who were active at baseline, the figure shows the odds of becoming inactive, while for inactive participants at baseline, it shows the odds of becoming active after receiving a diabetes or hypertension diagnosis. The results from the logistic regression models show that participants who were active at baseline had higher odds (OR = 2.16, 95% CI = [1.20,3.89]) of changing PA and becoming inactive after facing a diabetes diagnosis compared to individuals who did not receive such a diagnosis in the same period. Regarding hypertension, the odds of the already-active participants to become inactive after the diagnosis were smaller than those for participants that did not receive a diagnosis (OR = 0.93, 95% CI = [0.64,1.35]). For those participants who were inactive at baseline, the odds of becoming active after a diabetes diagnosis were smaller than those for participants who were not diagnosed with diabetes (OR = 0.74, 95% CI = [0.46,1.18]). The odds of participants who were inactive at baseline to become active after a hypertension diagnosis were the same as those for participants that did not receive a hypertension diagnosis (OR = 1.02, 95% CI = [0.75,1.40]). A complete overview of the four logistic regression models, including all variables, can be seen in Table S1 in the supplement.

3.3. Additional Analyses

We ran several sensitivity analyses to check the robustness of our results. In an additional analysis, we changed the decision line for the dichotomization of PA. In that case, we only classified the category "(almost) no activity" as inactive, and combined the other three categories as active. The association between the two assessed diagnoses and change in PA did not differ from the main analyses. The results of the models, including the altered PA variable, are presented in Figure S3 in the supplement.

In another additional analysis, we ran the same logistic regression models on each follow-up period separately. These models showed similar results, justifying our approach to combine both follow-up periods in the main analyses. The corresponding results are presented in detail in Tables S2 and S3 in the supplement.

4. Discussion

We examined the associations between a diabetes or hypertension diagnosis and changes in PA to investigate whether a diagnosis can be seen as catalyst for health behavior changes. For this, we analyzed the data of 4232 participants, including three measurement points over the course of 14 years. The results showed no indication for improved PA among participants with a diabetes or hypertension diagnosis compared to participants without a diagnosis. Initially active participants showed higher odds of changing their PA and becoming inactive after a diabetes diagnosis. All other results had small effect sizes and were not statistically significant. Active participants did not change their PA after a hypertension diagnosis. Inactive participants prior to a diabetes or hypertension diagnosis were not more likely to become active than participants without a diabetes or hypertension diagnosis. We performed several sensitivity analyses showing the robustness of our findings.

4.1. Interpretation and Implications

Although the literature suggests a pathway from the onset of a chronic disease leading to a change in health behavior, we have to point out that it might as well be the other way around. It might also be possible that a lack of PA leads to the onset of a chronic disease. With our study, we can only investigate associations between an diabetes or hypertension diagnoses and PA changes, but we cannot imply a causal relationship between those parameters. Hence, although we follow a theoretical framework that suggests the plausibility of the effect of a diabetes or hypertension diagnosis on PA, and although our longitudinal models were adjusted for important confounders, our estimates do not imply causality, and should rather be interpreted as descriptive measures.

According to the treatment guidelines for diabetes and hypertension, general practitioners should stress the importance and benefits of regular PA [27,28]. Yet, in our study, we did not see an improvement in PA. Moreover, regarding diabetes diagnoses, we observed a higher decline in PA compared to people without a diabetes diagnosis.

One possible reason for this could be that people might not be aware of the benefits of modified PA behavior in the context of a diabetes or hypertension diagnosis. Other studies report that overweight or obese participants do not attribute their weight to a greater health risk [36,37]. This lack of knowledge concerning the connection of excessive weight and health could also be applicable to PA.

Furthermore, the aforementioned awareness problem might also explain deviations from the Health Action Process Approach model and the Protection Motivation Theory. The perceived future risk of a diabetes or hypertension diagnosis may have too little effect on the theory's risk perception and threat appraisal. The high prevalence of diabetes and hypertension, as well as good treatment options, might be possible reasons for a limited perceived risk. Several studies have reported the limited use of risk perception as a predictor of behavioral changes within, for example, the framework of the Health Action Process Approach Model [38–40].

Another interpretation could be that the patient might be more accustomed to medical treatment than to changes in PA as a proper reaction to a medical diagnosis. Jarbøl et al. suggest that people might prefer a change in their lifestyle behaviors over medicinal treatment when the perceived effects of both options on disease management are equal [41]. Considering that the advantages of regular PA are not immediately noticeable [20,42], people might prefer a medicinal therapy after a diabetes or hypertension diagnosis.

Emotional factors might serve as another explanation for non-improved or even declined levels of PA. Thomas et al. reported that a lack of confidence in the ability to exercise and the fear of deteriorating diabetes are major barriers to physical activity for people with diabetes [43].

In view of these interpretations, there is potential to better communicate the benefits of regular PA to the public. There is a need for better information about the positive effects of behavioral changes in the context of secondary prevention. Public health initiatives should aim to strengthen health literacy, and research should focus on ways in which to effectively communicate the benefits of positive health behavior to the patients and the public. Following the clinical practice guidelines for diabetes and hypertension, increased PA needs to be considered as an important factor in health care management which ought to be better reimbursed by insurers. The importance of adherence to recommended PA levels, especially regarding secondary prevention, has to be stressed by practitioners, and counselling time should be adequately reimbursed by health insurance companies.

4.2. Comparison with Similar Studies

Several studies have mentioned positive changes in health behavior following a diagnosis. When comparing these studies, one has to acknowledge the different characteristics of different diseases and their effect on PA. Chronic diseases like cancer, stroke, or myocardial infarction come along with serious physical impairments that often make it difficult to stay physically active, whereas diabetes or hypertension usually do not restrict people in terms of their physical activity levels. It seems that besides the covered types of diagnoses, the results vary for different health behaviors. While several studies have reported a positive effect on smoking behavior [7,10,15–18], the present study did not show comparably positive effects on PA behavior. In their qualitative study, Dolor et al. found that practitioners consider counseling on PA and weight management to be more time-consuming than counseling on smoking [44].

Compared to previous studies, our results are in line with the majority of the published results reporting no increase in PA after a diabetes diagnosis [6,20]. Leung et al. reported that the observed higher rates of exercise initiation for participants that have been diagnosed with diabetes did not reach statistical significance [21]. In their study, including exclusively women aged from 50 to 79 years, Schneider, et al. observed an increase in PA after a diabetes diagnosis compared to women without a diagnosis [22]. Divergence with the results of Schneider et al. might be due to the different study population and a different operationalization of change in PA. Studies on the association between a hypertension diagnosis and PA change are scarce. Neutel and Campbell reported no lasting changes in lifestyle behavior after a hypertension diagnosis apart from smoking cessation [24]. Hernandez et al. mentioned that only a quarter of inactive participants started to increase their PA after a diabetes diagnosis [23].

4.3. Limitations

The present study has several strengths, including a large population-based sample and a long study period with three measurement points. Further, the study addresses an important public health issue for which only scarce, heterogeneous evidence is available. However, the following limitations should be considered when interpreting the study's results. We have no data on the time of the diagnosis. Thus, we cannot disentangle the timing of a diagnosis and PA change, and do not know if a diagnosis preceded PA change or vice versa. A study investigating the relationship between diabetes and changes in PA found a decrease in PA over time after the diagnosis. Similar to our study, Chong et al. found no significant difference regarding PA changes for people that had been diagnosed with diabetes and those who had not [20]. A further limitation of the present study is the assessment method for PA. Information on PA behavior was self-reported and was gathered in standardized interviews. Therefore, measurement errors and recall bias could be an issue. However, one has to balance the tradeoff between accuracy and feasibility, especially in large cohort studies with many variables, such as the KORA study. Further, the considerably reduced cohort size over the course of the study period could result in biased effects, as healthier and more active people are more likely to remain in the cohort. Admittedly, this could only be considered a bias if, for example, people with a diabetes diagnosis and PA level increase were more likely stay in the cohort than those with a diagnosis but with a decrease in PA levels. Finally, although we adjusted our models for numerous potential confounders, our results still might be affected by additional confounders. Possible further confounders could be age-related comorbidities or prescribed medication for prediabetes or prehypertension. Therefore, residual confounding cannot be ruled out.

5. Conclusions

In conclusion, the present study showed that individuals who practice regular PA are more likely to become inactive after a diabetes diagnosis compared to individuals who did not receive a diabetes diagnosis. Instead, for the same group, a hypertension diagnosis was not associated with changes in PA. Furthermore, a diabetes or hypertension diagnosis is not associated with improved PA levels among inactive individuals. This indicates that the suggested "open window" following a clinical diagnosis in which patients are more likely to adopt health behavioral changes may not exist, or may not yet have been effectively exploited for diabetes and hypertension. In order to make better use of this potential in the future, one should emphasize the general awareness of the benefits of PA in the context of secondary prevention.

Supplementary Materials: The following are available online at http://www.mdpi.com/1660-4601/16/21/4247/s1, Figure S1: Add-on for Figure 2. Description of sample size for the first follow-up period from S4 to F4. Annotations: N = number of participants, PA = physical activity, S4 = baseline study (2000); F4 = first follow-up (2007); FF4 = second follow-up (2014), Figure S2: Add-on for Figure 2. Description of sample size for the second follow-up period from F4 to FF4. Annotations: N = number of participants, PA = physical activity, S4 = baseline study (2000); F4 = first follow-up (2007); FF4 = second follow-up (2014), Figure S3: Sensitivity analysis. This figure is based on new defined cutoff points for the PA dichotomization. The odds for changing PA after a diabetes/hypertension diagnosis for both baseline PA strata. OR's for the active stratum display the odds of changing to inactive. OR's for the inactive stratum display the odds of changing to active, Table S1: In addition to Figure 3. Complete summary of the four logistic regression models with all covariates, Table S2: Sensitivity Analysis: Results of the models only including the first follow-up period from S4 to F4, Table S3: Sensitivity Analysis: Results of the models only including the second follow-up period from F4 to FF4.

Author Contributions: Conceptualization: M.R., F.M. and M.L.; methodology: M.R., F.M.K., S.P., L.S. and M.L.; software: M.R.; validation: M.R., F.M., F.M.K., S.P., L.S., A.P., M.H. and M.L.; formal analysis: M.R.; investigation: M.R., F.M., F.M.K., S.P., L.S., A.P., M.H. and M.L.; data curation: A.P. and M.H.; writing—original draft preparation: M.R.; writing—review and editing: M.R., F.M., F.M.K., S.P., L.S., A.P., M.H. and M.L.; visualization: M.R.; supervision: F.M., F.M.K., S.P., L.S., A.P., M.H. and M.L.; project administration: L.S., A.P., M.H., M.L.; funding acquisition: A.P.

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Ethics Approval and Consent to Participate: All procedures performed in studies involving human participants were in accordance with the ethical standards of the ethics committee of the Bavarian Medical Association and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Availability of Data and Material: The data that support the findings of this study are available from KORA (https://www.helmholtz-muenchen.de/en/kora/for-scientists/cooperation-with-kora/index.html) but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. However, data can be requested through an individual project agreement with KORA via the online portal KORA.passt (https://epi.helmholtz-muenchen.de/).

Conflicts of Interest: The authors declare that they have no competing interests.

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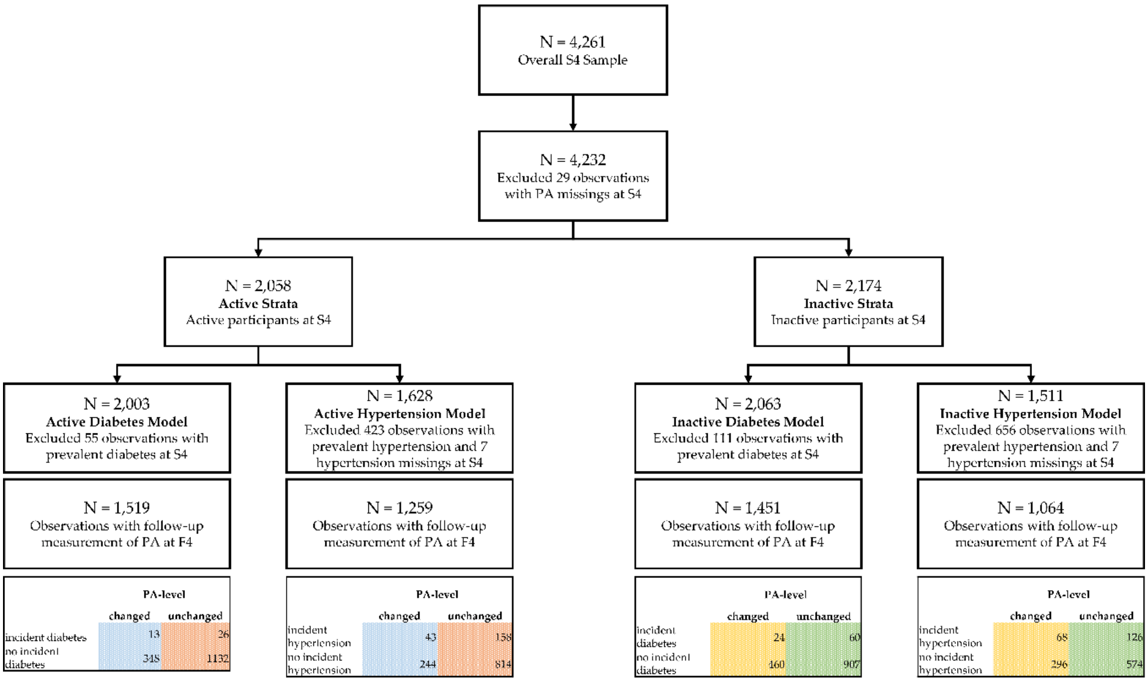

Figure S1. Add-on for Figure 2. Description of sample size for the first follow-up period from S4 to F4. Annotations: N = number of participants, PA = physical activity, S4 = baseline study (2000); F4 = first follow-up (2007); FF4 = second follow-up (2014).

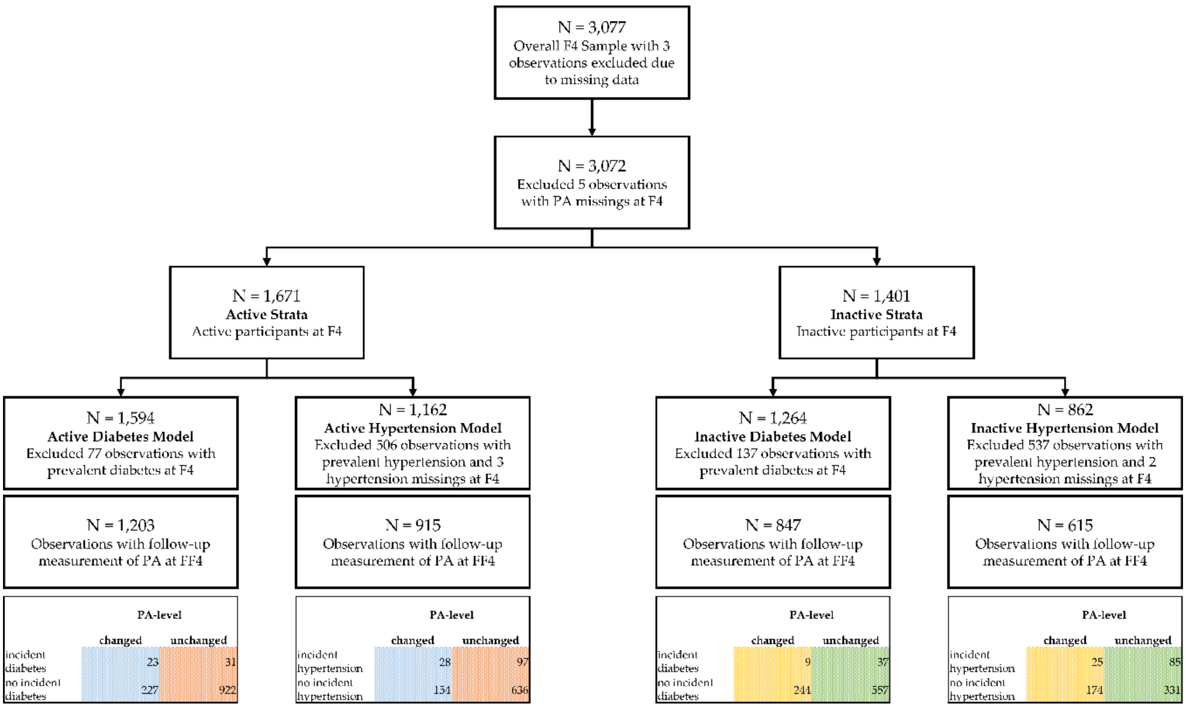

Figure S2. Add-on for Figure 2. Description of sample size for the second follow-up period from F4 to FF4. Annotations: N = number of participants, PA = physical activity, S4 = baseline study (2000); F4 = first follow-up (2007); FF4 = second follow-up (2014).

Table S1. In addition to Figure 3. Complete summary of the four logistic regression models with all covariates.

		95%CI	
	OR	**LL**	**UL**
Model: active, diabetes			
(Intercept)	0.309	0.222	0.429
hs.diab	2.161	1.202	3.888
sexF	1.086	0.858	1.374
scale(age)	0.903	0.793	1.030
fam.together	0.723	0.551	0.950
schulintermediate	0.837	0.629	1.114
schulhigher	0.699	0.517	0.944
scale(bmi)	1.325	1.168	1.504
scale(bmi.diff)	1.218	1.090	1.361
scale(pqol.diff)	0.940	0.840	1.051
scale(mqol.diff)	0.916	0.818	1.024
Model: active, hypertension			
(Intercept)	0.272	0.185	0.401
hs.hyp	0.929	0.639	1.350
sexF	1.074	0.822	1.402
scale(age)	0.830	0.714	0.965
fam.together	0.729	0.536	0.991
schulintermediate	1.014	0.733	1.402
schulhigher	0.779	0.558	1.089
scale(bmi)	1.306	1.131	1.508
scale(bmi.diff)	1.215	1.073	1.377
scale(pqol.diff)	0.944	0.830	1.074
scale(mqol.diff)	0.922	0.811	1.048
Model: inactive, diabetes			
(Intercept)	0.278	0.211	0.366
hs.diab	0.738	0.460	1.184
sexF	1.279	1.045	1.564
scale(age)	0.933	0.832	1.046
fam.together	1.494	1.169	1.910
schulintermediate	1.255	0.978	1.610
schulhigher	1.202	0.932	1.552
scale(bmi)	0.887	0.795	0.989
scale(bmi.diff)	0.870	0.784	0.965
scale(pqol.diff)	1.069	0.965	1.184
scale(mqol.diff)	1.130	1.021	1.250
Model: inactive, diabetes			
(Intercept)	0.267	0.193	0.370
hs.hyp	1.023	0.747	1.400
sexF	1.428	1.130	1.803
scale(age)	0.984	0.859	1.126
fam.together	1.457	1.100	1.930
schulintermediate	1.449	1.089	1.927
schulhigher	1.213	0.906	1.623

scale(bmi)	0.916	0.810	1.036
scale(bmi.diff)	0.883	0.786	0.992
scale(pqol.diff)	1.072	0.952	1.207
scale(mqol.diff)	1.187	1.054	1.336

Annotations: OR = odds ratio, 95%CI = 95% confidence interval, LL = lower limit, UL = upper limit

Note that all scaled variables have been standardized with mean equal to zero and standard deviation equal to one.

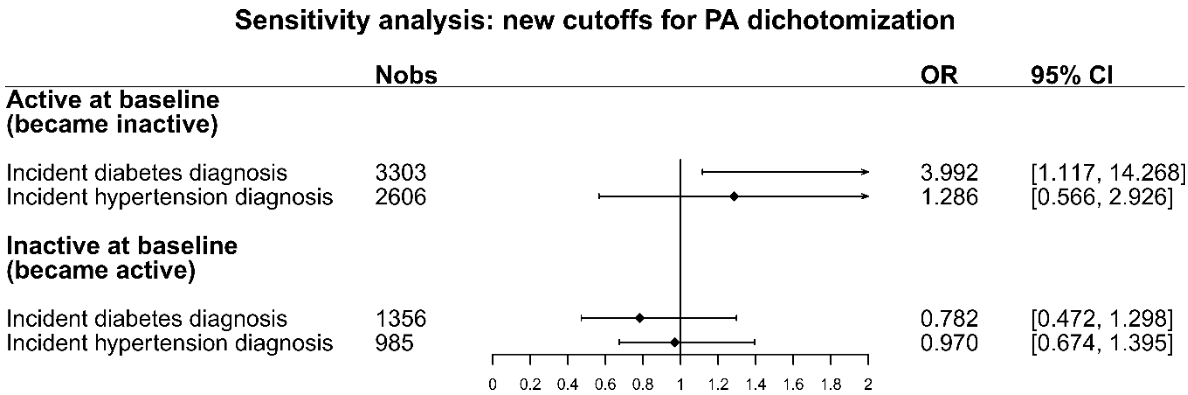

Figure S3. Sensitivity analysis. This figure is based on new defined cutoff points for the PA dichotomization. The odds for changing PA after a diabetes/hypertension diagnosis for both baseline PA strata. OR's for the active stratum display the odds of changing to inactive. OR's for the inactive stratum display the odds of changing to active.

Table S2. Sensitivity Analysis: Results of the models only including the first follow-up period from S4 to F4.

		95%CI	
	OR	**LL**	**UL**
Model: active, diabetes			
(Intercept)	0.216	0.083	0.557
hs.hyp	1.497	0.700	3.043
sexF	1.136	0.886	1.458
scale(age)	0.987	0.976	0.997
fam.together	0.774	0.583	1.032
schulintermediate	0.894	0.658	1.209
schulhigher	0.742	0.536	1.023
scale(bmi)	1.045	1.013	1.077
scale(bmi.diff)	1.095	1.023	1.172
scale(pqol.diff)	0.993	0.978	1.007
scale(mqol.diff)	0.985	0.973	0.997
Model: active, hypertension			
(Intercept)	0.266	0.088	0.804
hs.hyp	0.938	0.616	1.406
sexF	1.157	0.876	1.532
scale(age)	0.980	0.967	0.992
fam.together	0.776	0.568	1.068
schulintermediate	1.091	0.777	1.528

schulhigher	0.854	0.597	1.216
scale(bmi)	1.043	1.005	1.082
scale(bmi.diff)	1.102	1.022	1.189
scale(pqol.diff)	0.993	0.976	1.010
scale(mqol.diff)	0.986	0.972	1.000
Model: inactive, diabetes			
(Intercept)	0.511	0.213	1.222
hs.hyp	0.781	0.443	1.327
sexF	1.264	1.001	1.598
scale(age)	0.997	0.988	1.006
fam.together	1.545	1.165	2.064
schulintermediate	1.269	0.951	1.690
schulhigher	1.018	0.746	1.382
scale(bmi)	0.987	0.962	1.013
scale(bmi.diff)	0.956	0.904	1.011
scale(pqol.diff)	1.011	0.998	1.025
scale(mqol.diff)	1.011	1.000	1.023
Model: inactive, hypertension			
(Intercept)	0.391	0.139	1.096
hs.hyp	1.266	0.876	1.820
sexF	1.339	1.018	1.762
scale(age)	0.999	0.988	1.011
fam.together	1.462	1.052	2.050
schulintermediate	1.392	0.997	1.940
schulhigher	1.037	0.722	1.481
scale(bmi)	0.990	0.959	1.022
scale(bmi.diff)	0.967	0.906	1.033
scale(pqol.diff)	1.018	1.002	1.034
scale(mqol.diff)	1.018	1.005	1.032

Annotations: OR = odds ratio, 95%CI = 95% confidence interval, LL = lower limit, UL = upper limit

Note that all scaled variables have been standardized with mean equal to zero and standard deviation equal to one.

Table S3. Sensitivity Analysis: Results of the models only including the second follow-up period from F4 to FF4.

		95%CI	
	OR	**LL**	**UL**
Model: active, diabetes			
(Intercept)	0.030	0.008	0.104
hs.hyp	2.168	1.133	4.098
sexF	0.968	0.710	1.318
scale(age)	1.011	0.998	1.026
fam.together	0.795	0.554	1.152
schulintermediate	0.802	0.551	1.159
schulhigher	0.707	0.476	1.041
scale(bmi)	1.068	1.031	1.106

scale(bmi.diff)	1.140	1.043	1.248
scale(pqol.diff)	0.992	0.973	1.011
scale(mqol.diff)	1.003	0.986	1.019
Model: active, hypertension			
(Intercept)	0.030	0.006	0.135
hs.hyp	0.978	0.581	1.600
sexF	0.913	0.637	1.309
scale(age)	1.009	0.992	1.027
fam.together	0.798	0.524	1.237
schulintermediate	0.914	0.587	1.412
schulhigher	0.731	0.465	1.138
scale(bmi)	1.073	1.026	1.123
scale(bmi.diff)	1.129	1.019	1.251
scale(pqol.diff)	0.991	0.969	1.014
scale(mqol.diff)	1.005	0.985	1.025
Model: inactive, diabetes			
(Intercept)	1.395	0.392	4.985
hs.hyp	0.676	0.278	1.477
sexF	1.219	0.884	1.683
scale(age)	0.992	0.979	1.005
fam.together	1.302	0.884	1.941
schulintermediate	1.241	0.825	1.859
schulhigher	1.539	1.041	2.272
scale(bmi)	0.961	0.927	0.995
scale(bmi.diff)	0.904	0.828	0.984
scale(pqol.diff)	1.000	0.981	1.020
scale(mqol.diff)	1.013	0.995	1.031
Model: inactive, hypertension			
(Intercept)	0.711	0.153	3.289
hs.hyp	0.684	0.386	1.181
sexF	1.507	1.038	2.195
scale(age)	0.996	0.978	1.013
fam.together	1.433	0.916	2.278
schulintermediate	1.484	0.930	2.363
schulhigher	1.496	0.952	2.348
scale(bmi)	0.973	0.931	1.016
scale(bmi.diff)	0.878	0.785	0.978
scale(pqol.diff)	0.988	0.965	1.011
scale(mqol.diff)	1.014	0.994	1.035

Annotations: OR = odds ratio, 95%CI = 95% confidence interval, LL = lower limit, UL = upper limit

Note that all scaled variables have been standardized with mean equal to zero and standard deviation equal to one.

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Trends in Motor Performance of First Graders: A Comparison of Cohorts from 2006 to 2015

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Background: Motor performance is an important factor for health. Already in childhood, motor performance is associated with, e.g., obesity and risk factors for cardiovascular diseases. It is widely believed that the motor performance of children has declined over recent years. However, this belief is lacking clear evidence. The objective of this study was to examine trends in motor performance of first grade students during a period of 10 years (2006–2015). We examined trends in (a) aerobic fitness, (b) strength, (c) speed, and (d) balance for boys and girls separately and considered body mass index (BMI) as a potential confounder.

Methods: From 2006 to 2015, we tested 5,001 first graders [50.8% boys; mean age 6.76 (0.56) years] of 18 primary schools in Germany. Each year between 441 and 552 students of the same schools were surveyed. Performance tests were taken from the Motorik-Module Study and the "German Motor Ability Test": "6-min run," "push-ups," "20-m sprint," and "static stand." Linear regression models were conducted for statistical analysis.

Results: A slightly negative trend in aerobic fitness performance was revealed in boys ($\beta = -0.050$; $p = 0.012$) but not in girls. In the strength performance test no trend over time was detected. Performance in speed (boys: $\beta = -0.094$; girls: $\beta = -0.143$; $p \leq 0.001$) and balance tests (boys: $\beta = -0.142$; girls: $\beta = -0.232$; $p \leq 0.001$) increased over time for both boys and girls. These findings held true when BMI was considered.

Conclusion: This study only partly supported the assumption that motor performance of children has declined: in our study, aerobic fitness declined (only in boys), while strength remained stable and speed and balance even increased in both sexes. Moreover, it seems as if BMI can explain changes in performance only to a small extent. Changed lifestyles might be a substantial cause. Further research on recent trends of motor performance and interacting variables is needed to support the results of our study and to provide more knowledge on causes of these trends.

Keywords: trend, children, health, motor performance, aerobic fitness, strength, speed, balance

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INTRODUCTION

Already in childhood motor performance is an important factor for health as it is associated with, e.g., obesity (1) and risk factors for cardiovascular diseases (2) in this early age. However, it is widely believed that motor performance of children has declined in recent years (3, 4). An often discussed reason for this potential decline is the verified increase of body mass index (BMI) among youth in the last decades (5, 6). The assumption that changed physical conditions are associated with changed motor performance seems to be reasonable. Though, inverse but independent trends in obesity and fitness levels among children are shown (7) and performance differences persist even after matching for overweight (8). To investigate the question of decline in motor performance among youth by reviewing the scientific literature, we first have to distinguish different aspects of motor performance. Different approaches exist (9–12). Most of them assume that motor performance is a multidimensional construct (13). The dimensionality described by Bös (12) was shown to be valid for children and adolescents (13) and assumes that motor performance can be differentiated by four main dimensions of motor performance ability which are endurance (including aerobic fitness), strength, speed, and coordination (including balance) (12).

Considering the results of extensive systematic reviews there is evidence on an improvement in aerobic fitness from 1958 until about 1970, followed by a decline from the 1970s to 2003. Strength and speed performance seemed to be stable over this time period (3, 4, 14). The aforementioned systematic reviews cover approximately five decades of the last century and, therefore, give an overview of a long period of time, in which substantial societal changes took place. Other studies examine trends over a shorter period of time, reflecting smaller societal changes, which are especially significant for the examined time period [e.g., the rapid increase of media offers within western countries in recent years (15)]. With regard to current literature about trends covering the last two decades and thus representing current societal changes, the picture is fragmentary. There are only few studies which follow heterogeneous designs and present heterogeneous results (7, 16–20): for example, the majority of studies finds a decline in aerobic fitness (7, 16, 17). One study detects a positive change in aerobic fitness, but only in girls (19). In one study, strength performance declines (20), in another study it remains stable (7), in a third study it increases (19). Trends in speed, coordination or in balance performance are less investigated. Most of the studies compare only two measurement points. The age of the examined children as well as tests performed differ between the studies considered. Most studies examine trends in boys and girls separately. This seems to be important as in some instances different results for each sex appear. However, most studies do not adjust for BMI and, therefore, cannot eliminate the possibility that changed physical conditions determine changes in performance.

The objective of this study was to examine trends in motor performance of first grade students during a period of 10 years (2006–2015). More specific, we aimed at examining trends in (a) aerobic fitness, (b) strength, (c) speed, and (d) balance, for boys and girls separately. BMI was considered as a potential confounder.

MATERIALS AND METHODS

Study Design and Participants

Within a project of the foundation "Baden-Badener Sportstiftung Kurt Henn," motor performance of 5,001 first grade students of 18 primary schools was tested each year from 2006 until 2015. The schools are located in southern Germany (region around Baden-Baden), while all schools in the region were represented. Each year between 441 and 552 students of the same schools took part in the survey. The survey was approved by the ethics committee of the University of Freiburg, Germany. Parent of each participant gave informed written consent before enrollment into the survey. It was conducted in accordance with the Declaration of Helsinki. The tests were performed each year in springtime. Participants' mean age was 6.76 (±0.56) years, 50.8% were male. A detailed description of sample size, age, sex, and BMI of each cohort can be found in **Table 1**.

Measurements

Motor Performance

Motor performance was examined using tests that are part of the Motorik-Module Study (21) and the "German Motor Ability Test" (22). Four tests were selected to cover four dimensions of motor performance: (a) aerobic fitness as part of the endurance dimension, (b) strength, (c) speed, and (d) balance as part of the global coordination dimension (12). Content-related validity of all tests was evaluated based on expert ratings with regard to significance and feasibility (rating scale ranging from 1 = "very good" to 5 = "very poor"). Values between 1.3 and 2.1 showed good content-related validity (21, 22). Reliability of all tests was good or very good (r_{min} = 0.73 to r_{max} = 0.92) (22, 23). The exact testing procedure has been described previously (13, 22, 24).

Aerobic fitness was tested using the test "6-min run." Participants were asked to run or walk constantly for 6 min. The distance covered by each participant was measured by test leaders (22). *Strength* was tested using the test "push-ups": The participant lay in prone position and the hands grasped one another on the buttocks, then placed the hands next to the shoulders and pushed his/her body up. One hand clapped onto the other, before the participant moved back to the starting position by flexing the arms. A test leader supervised correct performance and counted repetitions within 40 s (13, 22). *Speed* was tested using the test "20-m sprint." Participants were asked to sprint a 20-m distance as fast as possible, starting in lunge position. Time was measured manually by three independent test leaders. The mean value was calculated. The better attempt out of two was used for analysis (22). The test "static stand" was used to test *balance*. The task was to stand on one leg on a T-shaped

TABLE 1 | Sample description.

Assessment year	*N*	Mean age in years (SD)	Male/female (%)	Mean body mass index (SD)
2006	538	6.66 (0.54)	50.9/49.1	16.53 (2.33)
2007	529	6.83 (0.53)	51.1/48.9	16.00 (2.28)
2008	552	6.70 (0.54)	51.0/49.0	15.79 (1.93)
2009	498	6.81 (0.55)	52.2/47.8	15.68 (2.15)
2010	492	6.77 (0.57)	51.0/49.0	15.70 (2.21)
2011	492	6.74 (0.58)	51.0/49.0	15.63 (2.16)
2012	494	6.81 (0.59)	46.8/53.2	16.25 (2.26)
2013	491	6.78 (0.58)	49.1/50.9	16.54 (2.63)
2014	474	6.76 (0.53)	54.4/45.6	16.12 (2.10)
2015	441	6.71 (0.54)	50.1/49.9	16.10 (2.02)

balancing bar (width 3 cm) wearing sneakers and to rest in the balance position. The number of contacts of the free foot with the ground or the T-bar (correction steps) within 1 min was counted by the test leader and was used for analysis. If the participant left the bar completely, the timer was paused until the participant was back in the initial position.

Anthropometrics

Height was measured with a height measuring scale (accuracy: 0.1 cm) with the participants standing upright not wearing shoes. Weight was measured by using an electronic scale (Soehnle, Murrhardt, Germany; accuracy: 0.1 kg), while participants wore sports clothes and no shoes. The measurements were performed each year by the same skilled test leaders. BMI was calculated as body mass divided by height squared (kg/m^2).

Data Analysis

All statistical tests were conducted using SPSS statistical software for Windows Version 23.0 (IBM Corporation, Armonk, NY, USA). Linear regression models were used to test if assessment year was a significant predictor of performance in the four motoric tests, having the year of examination as independent factor. The assumptions of linear regression were tested and confirmed. Analyses were conducted for each sex and each test separately. In a second step, multiple regression analysis was conducted to detect if the effects of assessment year were influenced by BMI, i.e., assessment year and BMI were included together as independent factors. Again, analyses were made for each sex and each test separately. For expressing temporal trends as change in percent, B coefficient of each test was multiplied by 10 to express the mean change per decade. Subsequently, we calculated the percentage of change in relation to the mean test performance. The significance level for all statistical tests was set *a priori* to $\alpha = 0.05$.

RESULTS

Figure 1 displays mean values of performance in (a) "6-min run," (b) "push-ups," (c) "20-m sprint," and (d) "static stand" for boys and girls separately.

Table 2 shows the results of linear regression analyses, displaying the effects of assessment year on performance within the four tests.

In linear regression analyses, assessment year had a significantly negative effect on the distance covered within the aerobic fitness test "6 min run" in boys. Among girls, the effect of assessment year was positive but not significant. For the strength test "push-ups" no significant effect of assessment year could have been observed neither for boys nor for girls. Values within the speed test "20 m sprint" were negatively affected by assessment year in boys and even more in girls, with lower values reflecting higher performance. For the balance test "static stand" significant effects of assessment year could have been observed, too. Assessment year negatively affected the number of correction steps (reflecting a positive performance trend) in boys and in girls. Overall, the explained variance of

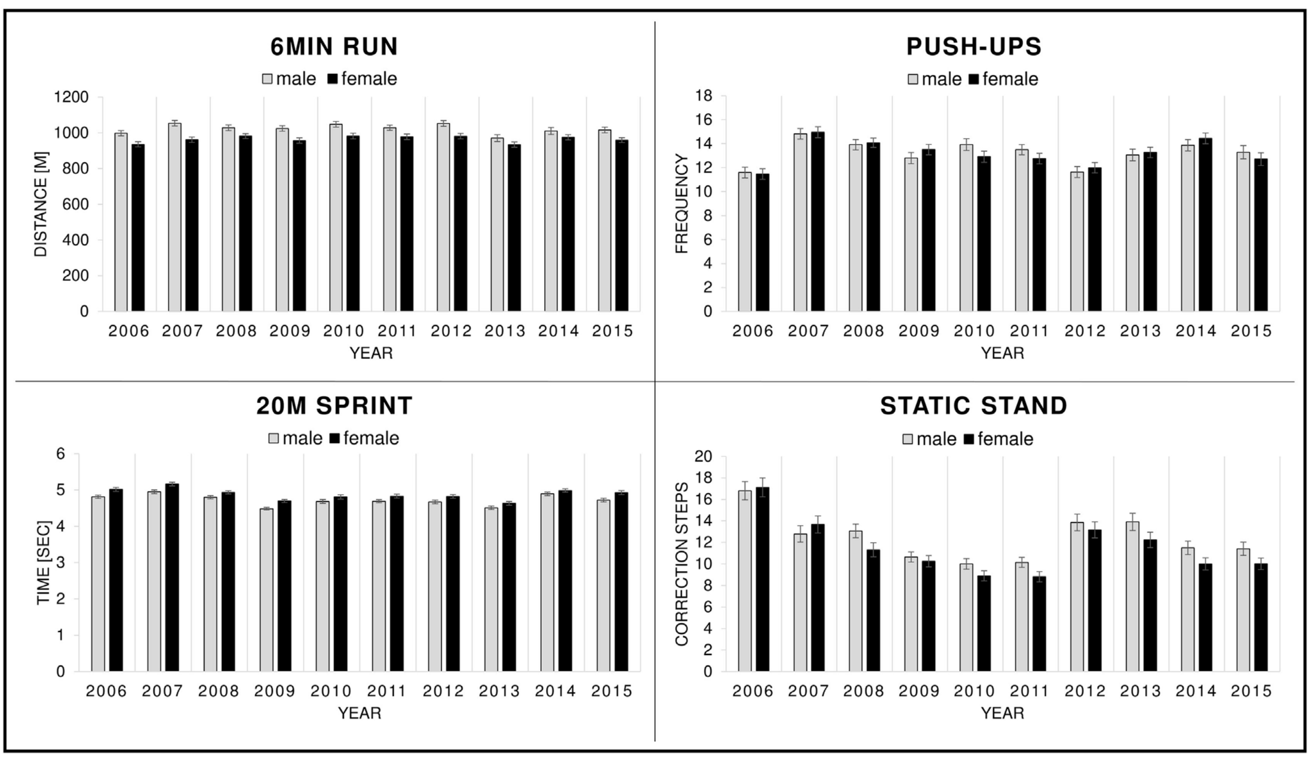

FIGURE 1 | Mean values of the motor performance tests from 2006 to 2015 for boys and girls separately.

TABLE 2 | Results of linear regression analyses for boys and girls separately.

Dependent variable		Boys				Girls			
		B (95% CI)	β	*p*-Value	Adj. R^2	*B* (95% CI)	β	*p*-Value	Adj. R^2
Distance covered 6 min run (m)	Constant	5690.046 (2,033.885 to 9,346.207)				−843.739 (−4131.145 to 2443.668)			
	Year	−2.322 (−4.140 to −0.503)	−0.050	0.012	0.002	0.899 (−0.736 to 2.535)	0.022	0.281	≤0.001
Push-up repetitions	Constant	−4.882 (−111.398 to 101.633)				27.703 (−75.693 to 131.099)			
	Year	0.009 (−0.044 to 0.062)	0.007	0.739	≤0.001	−0.007 (−0.059 to 0.044)	−0.006	0.783	≤0.001
Time for 20 m sprint (s)	Constant	31.163 (20.203 to 42.123)				48.099 (36.238 to 59.959)			
	Year	−0.013 (−0.019 to −0.008)	−0.094	≤0.001	0.008	−0.021 (−0.027 to −0.016)	−0.143	≤0.001	0.020
Static stand correction steps	Constant	581.070 (425.902 to 736.238)				964.125 (805.917 to 1122.333)			
	Year	−0.283 (−0.360 to −0.206)	−0.142	≤0.001	0.020	−0.474 (−0.552 to −0.395)	−0.232	≤0.001	0.054

B, unstandardized coefficient; β, standardized coefficient.

TABLE 3 | Results of multiple regression analyses for boys and girls separately.

Dependent variable		Boys				Girls			
		B (95% CI)	β	*p*-Value	Adj. R^2	*B* (95% CI)	β	*p*-Value	Adj. R^2
Distance covered 6 min run (m)	Constant	5160.031 (1683.288 to 8636.775)				−503.787 (−4037.005 to 2555.367)			
	Year	−1.897 (−3.627 to −0.167)	−0.041	0.032	0.002	0.878 (−0.650 to 2.407)	0.021	0.260	≤0.001
	Body mass index (BMI)	−20.158 (−22.435 to −17.881)	−0.327	≤0.001	0.109	−18.560 (−20.460 to −16.660)	−0.362	≤0.001	0.131
Push-up repetitions	Constant	−2.521 (−109.357 to 104.314)				33.628 (−69.557 to 136.812)			
	Year	0.008 (−0.045 to 0.061)	0.006	0.759	≤0.001	−0.009 (−0.060 to 0.042)	−0.007	0.730	≤0.001
	BMI	−0.061 (−0.130 to 0.009)	−0.034	0.088	≤0.001	−0.142 (−0.206 to −0.078)	−0.088	≤0.001	0.007
Time for 20 m sprint (s)	Constant	31.619 (20.722 to 42.517)				47.186 (35.425 to 58.947)			
	Year	−0.014 (−0.018 to −0.008)	−0.097	≤0.001	0.008	−0.021 (−0.027 to −0.015)	−0.141	≤0.001	0.019
	BMI	0.023 (0.016 to 0.030)	0.126	≤0.001	0.024	0.028 (0.021 to 0.036)	0.151	≤0.001	0.042
Static stand correction steps	Constant	593.689 (440.012 to 747.366)				960.109 (804.189 to 1116.029)			
	Year	−0.292 (−0.369 to −0.216)	−0.146	≤0.001	0.020	−0.476 (−0.553 to −0.398)	−0.233	≤0.001	0.054
	BMI	0.420 (0.319 to 0.520)	0.160	≤0.001	0.045	0.467 (0.371 to 0.564)	0.184	≤0.001	0.087

B, unstandardized coefficient; β, standardized coefficient.

the models was very low, with the highest value for girls in the test "static stand."

Table 3 shows the results of the multiple regression analysis. Except for the test "push-ups," BMI significantly predicted test performance. However, all significant effects of assessment year on test results remained nearly unchanged after including BMI into the model.

Expressing the trends of motor performance in percent, the mean change per decade in aerobic fitness performance was −2.3% (−4.0 to −0.5) in boys and 0.9% (−0.8 to 2.6) in girls. For strength performance, mean change per decade was 0.7% (−3.3 to 4.7) in boys and −0.5% (−4.5 to 3.3) in girls. For speed performance, mean change was 2.7% (1.7 to 4.0) in boys and 4.3% (3.3 to 5.5) in girls, and for balance performance, it was 22.8% (16.6 to 29.0) in boys and 41.1% (34.2 to 47.8) in girls.

DISCUSSION

The aim of the present study was to examine trends in motor performance of first grade students during a period of 10 years (2006–2015). Overall, we found a negative trend in aerobic fitness performance in boys but a stable performance in girls. In the strength performance test no trend over time could have been detected. Performance in speed and balance tests increased in both boys and girls. These findings held true even when BMI was considered as a confounder.

Aerobic fitness performance decreased in boys. This result is in line with the results of the reviews of Tomkinson and Olds (4) and Malina (14), where a negative trend of aerobic fitness between the 1970s and 2000 is shown. Moreover, the majority of the studies on trends over the last two decades also show a decline (7, 16, 17). Thus, our results support the assumption of an ongoing negative trend in aerobic fitness in boys. However, the effect (B- and β-coefficients) was small and the observed decline was smaller than in another examination from Germany, where cross-sectional data of different studies are compared (25). The divergence could be due to different methodological approaches and due to the time periods considered, as in the latter study trends between 1976 and 2005 are analyzed. In girls, aerobic fitness was stable over the 10-year period. This result is contrary to former studies which find a negative trend (4, 7, 16–18, 25). Only one study discovers a positive trend among its female sample (19). However, Tambalis et al. show in their study that performance of children living in rural areas did not change between 1997 and 2007, while performance of children in urban areas decreased (26). In our study, most of the schools where the sample was recruited are located in rural areas. With respect to the results of Tambalis et al., this might be a possible explanation for the stable performance in girls and for the relatively small decline in boys.

Strength performance did not change over time, neither in boys nor in girls. Stability of strength performance in both boys and girls is also shown in a large systematic review for the time period between the 1960s and 2003 (3). While evidence for trends of strength performance during this time period is quite good, trend analyses for the time period between 2000 and today are rare. We found one study by Tambalis et al. reporting a stable performance between 1997 and 2007 (7). Another study reports a positive change between 1992/1993 and 2006/2007 (19), and a third study reports a negative change between 2001 and 2006 (20). Out of these three studies, Tambalis et al. are the only ones who performed tests every year and thus offer a higher reliability. With our results we confirm their results of a stability in strength performance in children. Our results suggest that the stability holds true until today. However, this suggestion should be taken with care, as evidence is small and results showed a huge variability in strength performance for both sexes in our study.

Speed performance increased in both sexes over the period of 10 years. Again, our results are in line with the results of the Greek study of Tambalis et al. (7), but differ from results of the study of Dos Santos et al., where a negative change is observed for boys and girls (16). In our study, effects were relatively high compared to aerobic fitness and strength test results and the positive trend was even higher in girls. Similar findings are reported in the Greek study, where the increase in girls is also higher than in boys (7). Compared to the trend from the 1960s to 2000, where a relative stability of speed performance in children is shown (3), it seems that between 2000 and today the trend line increased and today's children are faster than children were in earlier times.

Balance performance also increased in both boys and girls from 2006 to 2015. Compared to the other test results, effects in balance performance were the highest, reflecting a relatively strong positive trend in balance performance, especially in girls. Another study, comparing the balance performance of Estonian and Lithuanian adolescents finds a decline in the Estonian group, while performance in the Lithuanians increases (27). In addition, German scientists published material on changes in balance performance, comparing their results with results of former German studies. They also find an increase in the test "static stand" in their sample (28). Though, comparability of these studies is limited, as both include adolescents (11 years and older) and their methodological approach is different.

Body mass index predicted test performance. This result was expected, as BMI and motor performance were shown to be associated (1). However, BMI was included into the model to test if BMI was a confounder of the assessment year effects. By adding *BMI* into the regression models, effects of assessment year on test results remained significant. Actually, effects of assessment year remained almost unchanged. Tambalis et al. test the contrary hypothesis, i.e., that motor performance accounts for BMI trends in children. Likewise, after introducing the aerobic fitness variable into their model, obesity trends remain significant with practically unchanged effect sizes (7). In addition, Olds et al. report persisting performance differences after matching their sample for overweight (8). It seems as if BMI can explain changes in performance only to some extent, and our study suggested that this holds true for performance in aerobic fitness, and moreover in speed and balance. These results indicated that changed lifestyle [e.g., level of physical activity, participation in organized sports, media use, transport patterns (15)] might be a substantial cause of changes in motor performance.

Comparing the identified trends overall, our results showed that trends in the four motor performance dimensions differed. It can be speculated that these differences have at least two reasons. First, speed and balance performance could have increased due to the fact that—in contrast to most other Western countries (15)—participation rates in organized sports in young children increased within the last years in Germany (20). Moreover, participation starts at an early age with 41% of the 4-year olds and 54% of the 5-year olds being a member of a sports club (29). Organized sports programs probably focus on games and exercises suitable for young children, which are more likely to train speed and coordination instead of aerobic fitness. This could be a reason for the positive trend in speed and balance, as in former years young children were not specifically trained in such a way. Second, it is shown that everyday physical activity in children declined within recent years, as transport patterns changed from active to passive transport as well as to a more "dependent mobility" and the time playing outside decreased (15) [playing outdoors is strongly related to energy expenditure (30)]. The decrease in everyday physical activity might be a reason for the decline of aerobic fitness in boys in our study. Furthermore, in this study trends in girls were overall more positive than in boys. Similar results were found in other studies, where decreases in girls are smaller than in boys (4, 20, 25), or increases are stronger (19). Different "starting levels" could be a possible explanation: it can be assumed that motor performance in boys was on a higher relative level than in girls in earlier times. This could be due to the assumption that girls were more protected by their parents and thus played less outdoors, their games were more sedentary (e.g., playing with dolls vs. playing soccer) and boys had higher levels of overall physical activity (30). Therefore, their relative motor performance level was probably lower. So changes in lifestyle could have had less negative/stronger positive effects on their motor performance than on boys' motor performance. In addition, it is shown that in Germany sports club participation increased more among girls than among boys (20). This could have had an impact on the more positive trends in girls, too.

The present study has some strengths and limitations that should be considered when interpreting the findings. Examinations took place in each year between 2006 and 2015, allowing the description of trends instead of single comparisons between measurement points. Moreover, data collection was region-exhaustive. However, as data are restricted to a regional sample it is not representative for Germany. Performed tests are validated and approved, but testing procedures were partly suboptimal, as the time needed for "20-m sprint" was measured manually and not with the use of a light barrier. The test "static stand" was used to measure balance. However, balance covers only one part of the complex motor performance ability dimension "coordination." Further, comparisons with other studies should be interpreted with care, as at some stage different motor performance tests were used (e.g., "shuttle run" vs. "6-min run" to test aerobic fitness).

Nevertheless, this study accounted for all four dimensions of motor performance ability (10) which contributed to a comprehensive picture of trends in motor performance of children.

In summary, this study only partly supported the widely believed assumption that the motor performance of children declines: in our study, aerobic fitness declined in boys—which is in line with other studies (4, 14)—but not in girls. All the other assessed dimensions of performance remained stable or even increased in both sexes. Strength performance remained stable. This is also shown by Tomkinson (3). In contrast, speed performance increased, while older studies present it as stable (3). Concerning balance performance, there are few studies to be found in the literature and results are heterogeneous (27, 28). In our study, balance performance increased substantially in both sexes. In addition, we showed that for all performance dimensions BMI explained changes only to a small extent. Changed lifestyles might be a substantial cause. More studies on recent trends and interacting variables are needed to support our results and to provide further knowledge on causes of these trends.

ETHICS STATEMENT

This study was carried out in accordance with the Declaration of Helsinki. Parent of each participant gave written informed consent before enrollment into the survey. The protocol was approved by the ethics committee of the University of Freiburg, Germany.

AUTHOR CONTRIBUTIONS

SS conceptualized and designed the study, interpreted the data, drafted the initial manuscript, and approved the final manuscript as submitted. MR contributed substantially to conceptualization and design of the study, carried out the initial analyses, critically revised the manuscript, and approved the final manuscript as submitted. AK was involved in the data assessment, contributed substantially to analysis and interpretation of data, critically revised the manuscript, and approved the final manuscript as submitted. FM contributed substantially to conceptualization and design of the study and to interpretation of data, critically revised the manuscript and approved the final manuscript as submitted. All authors agreed to be accountable for all aspects of the work ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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RESEARCH ARTICLE

Are primary school children attending full-day school still engaged in sports clubs?

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Abstract

Purpose

Schools and organized sports both offer great chances to promote physical activity among children. Full-day schools particularly allow for extensive participation in extra-curricular physical activities. However, due to time reasons, full-day schools may also prevent children from engagement in organized sports outside school. There is only little national and international research addressing the possible competition of full-day schools and providers of organized sports outside school and the potential effects on children's physical activity behavior. In Germany's educational system, a transformation towards more full-day schools is currently taking place. The existence of both, half-day and full-day schools, gave occasion to the following research question: Do students attending half-day and full-day school differ with respect to a) sports club membership rate and b) weekly amount of sports club training?

Methods

Data were collected in eleven German primary schools. Selected schools offered both half-day and full-day (minimum three days/week with at least seven hours) care. 372 students' data (grades 1–4; N = 153 half-day, N = 219 full-day; 47.4% male, 8.8±1.2y) were eligible for analyses. We assessed sports club membership and weekly training duration via questionnaire. Statistical analyses included Chi-square and Mann-Whitney-U-Tests.

Results

83% of half-day school students and 67% of full-day school students were sports club members ($\chi^2(1) = 12.31$, $p<.001$). Weekly duration of training in sports clubs among sports club members (N = 266) also differed between the groups (mdn = 150 min in half-day, mdn = 120 min in full-day school students; $z = -2.37$, $p = .018$). Additional analyses stratified for age and gender showed similar results.

Conclusion

Primary school students attending full-day schools engage less in organized sports outside school than half-day school students, regardless of age and gender. Future studies should

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examine if the detected lower engagement in sports club physical activity is compensated by physical activities in other settings such as school or non-organized leisure time.

Introduction

Already in childhood, physical activity is a key factor for health [1, 2]. Furthermore, studies show that physical activity behavior adopted in early life most often tracks into adulthood [3, 4]. Therefore, physical activity is promoted as part of a healthy lifestyle [5, 6]. Recommendations for physical activity behavior and its promotion further point to different settings in which children's physical activity should take place, i.e. in the family context, at school and in leisure time (organized sports and free play) [6].

Especially in school, physical activity programs have the potential to reach all children regardless of their socioeconomic background. However, school systems differ between countries. In most countries primary school schedules encompass four to five curriculum-based lessons but schedules differ in terms of organization: E.g. in France, Spain and England children generally spend the full day at school. In Italy parents and children can choose between a half-day and a full-day schedule [7]. In Germany until recently, primary school education mostly took place in the mornings only. However, since 2003 optional full-day school offers were introduced and since then have expanded continuously [8]. Officially accredited full-day schools have to offer at least three days a week with a minimum of seven hours of care on each day (encompassing curricular and extra-curricular activities) [9]. Numbers of students attending full-day school in Germany are continuously rising with less than 10% in 2002 and 42.5% in 2016 [9, 10]. A further expansion of full-day schools is claimed and subsidized until 2021 [11].

In primary school students, in 2016, 40.1% participated in full-day school [9]. As a result, these children spend more time at school–time in which they take part in extra-curricular programs. More than 95% of the primary schools in Germany offering full-day care include voluntary physical activity-related programs in their extra-curricular programs [12–14]. Thus, children can potentially be physically active there. They have less free time out of school though which they could spend on leisure activities such as participating in organized sports.

Next to physical education and extra-curricular physical activities in school, participating in organized sports outside school is another important and suitable way for children to be physically active [6]. Participating in organized sports increases the chances of lifelong physical activeness due to the fact that membership can survive several life changes like finishing school or changing jobs. Furthermore, performance- and competition-oriented athletes find attracting offers in organized sports. Engagement in organized sports offers a chance for social learning and integration with regard to children's development [15, 16]. Participating in organized sports is popular among children. International studies report participation rates between 36% and 66% [17–19]. However, providing institutions differ between countries. In Germany, sports clubs belong to the non-profit sector [15] and build the basis for mass sport provision [20]. Currently there are around 91,000 sports clubs which amounts to one-quarter of all third-sector organizations [21]. They are the main sports providers for the overall population in Germany. They offer affordable sports programs (monthly membership fee for children does not exceed 2.50€ in 50% of the sports clubs [22]) for competitive as well as recreational purposes [23]. German sports clubs are voluntary organizations with autonomous structures, focusing on their members' interests. They follow democratic decision structures and rely on voluntary work [24]. The prevalence of sports club membership in children is comparatively high in Germany. In 2017, 65% of the six- to eleven-year-olds were member of a sports club [25]. Next to offering various sports programs, sports clubs pursue social tasks like educating tolerance and fair play, supporting sociability and integration [26]. Sports clubs are also seen as valuable to society due to their contribution to e.g. youth promotion, social integration, crime prevention and health [15]. Thus, again from a societal perspective, young people's participation in sports clubs is desirable. However, membership rates decrease with children's age [27, 28]. It seems especially crucial to recruit children at an early age aiming at creating a long-term commitment towards the club and by this also towards physical activity.

Both settings–school and organized sports–offer a great chance to promote physical activity in children. Longer school days in full-day schools and hence more possibilities to participate in extra-curricular physical activities can be beneficial for promoting physical activity especially in children who otherwise would not be committed to a sports club or another institution offering organized sports (e.g. children from difficult socioeconomic backgrounds [25, 29]). However, there is also the possibility that children attending full-day school will not engage in organized sports outside school due to a (perceived) lack of time or clash of dates. German sports clubs for example currently struggle to recruit members and volunteers and further fear to loose potential members and volunteers due to the expansion of full-day schools [15]. Consequently, a significantly increasing number of sports clubs started to cooperate with full-day schools (35% in 2014) [26].

From a health perspective, knowing the impact of full-day school on overall physical activity behavior in children is crucial. Furthermore, certainty about the impact of full-day school on engagement in organized sports would form the basis for developing innovative cooperation strategies that motivate children to engage in organized sports. There is only little research concerning the possible competition of full-day schools and providers of organized sports and the potential effects on children's physical activity behavior. Some studies compare physical activity levels between in-school and off-school hours (e. g. [30–34]), indicating that physical activity levels are lower in school than outside school. An Italian study [35] finds that full-day school students spend a higher percentage of time with moderate-to-vigorous physical activity (MVPA) in the afternoon timeslot than half-day school students (18% vs. 15% of MVPA). No differences are present in the morning and evening timeslots. Züchner and Arnold [36] find that sports club membership rates in German secondary school students who attend full-day school at least at two days a week are lower than in students attending half-day school only. Further, they find that in 7^{th} and 9^{th} graders the frequency of training in a sports club is lower in full-day school students. On the contrary, in another German study secondary school students attending full-day school offers obtain higher sports clubs membership rates than their counterparts attending half-day school only [37]. In summary, studies on the relationship of full-day school attendance and overall physical activity behavior of students are rare and results are heterogeneous. Particularly with regard to primary school students as well as to participation in organized sports there is a lack of knowledge to date.

The ongoing change in the German educational system and the existence of both half-day and full-day schools constitutes a beneficial occasion to gain more insight into this field. Due to the detected desiderata, this study aims to answer the following research question: Does habitual sports club participation differ between children attending half-day and full-day school with respect to a) sports club membership rate and b) weekly amount of sports club training?

Methods

Study design

The survey was conducted in eleven German primary schools in Baden-Württemberg between May and July 2017. Selected schools were officially registered and accredited as full-day school and installed an optional full-day school branch in the school year 2016/2017. Eleven out of 25 invited schools (44%) agreed to participate in the study. All students of grade 1 to grade 4 were invited to take part, regardless of their affiliation to full-day or half-day school. To collect data on students' physical activity behavior in different settings, they were asked to fill out a paper-pencil questionnaire [38] together with their parents.

Parents of each participant gave informed written consent before enrolling in the study. The study was approved by the ethics committee of the University of Konstanz, Germany and was conducted in accordance with the Declaration of Helsinki.

Measurements

Sex, age and attendance of half- and full-day school. Sex as well as date of birth was assessed via questionnaire and age was calculated. Two age groups were built by using the median age (8.79 years) as cut off for dividing the sample.

Within the questionnaire participants were asked if they were registered for full-day school (i.e. these children spend at least seven hours a day at three days a week in school, according to the accreditation requirements). If they were not registered, they were further asked if they nevertheless attended full-day school offers. For both groups (registered and non-registered), time spent at full-day school offers was assessed for each day during the week of the assessment. Participants wrote down the exact time when they left school at each day they attended full-day school offers. Participants were divided into two groups regarding their program: Full-day and half-day group. All children that were registered for full-day school were allocated to the full-day group. Children who answered that they were not registered and neither attended full-day offers were allocated to the half-day group. Children who were not registered for full-day school but attended full-day offers which cover–in combination with regular lessons–at least three days with a minimum of seven hours at school were also allocated to the full-day group. This cut-off-point is in accord with the requirements to be accredited and financially supported as full-day school in Germany. Children who attended lower amounts of full-day school offers were not included in the analyses.

Habitual sports club participation. Habitual sports club participation was assessed using the scale from the MoMo Physical activity questionnaire (wave 2) [38]. Sports club participation in Germany standardly includes regular training sessions, commonly on a weekly basis throughout the whole year. Performing sports in a sports club can therefore be seen as a habitual physical activity with fixed weekly practices that take place throughout the whole year. Exceptions can be seasonal sports, e.g. skiing. Participants were asked if they are member of at least one sports club. Further, they were asked how much and which physical activity they exert in sports clubs. The questionnaire included questions considering type (which sport) of their physical activity, weekly duration (in minutes) of each performed sport and months in which each sport was performed throughout the year (to detect seasonal activities). Participants could report data for maximal four different types of sport in sports clubs. From these data, a sum score was calculated reflecting the duration of performed physical activity in sports clubs per week. The scale assessing sports club participation was checked in relation to reliability (kappa = .81) and validity (correlations between scale and Actigraph GT1M: $r = 0.35$) [39]. However, this validation is based on data of adolescents aged 11 to 17 years and on a former

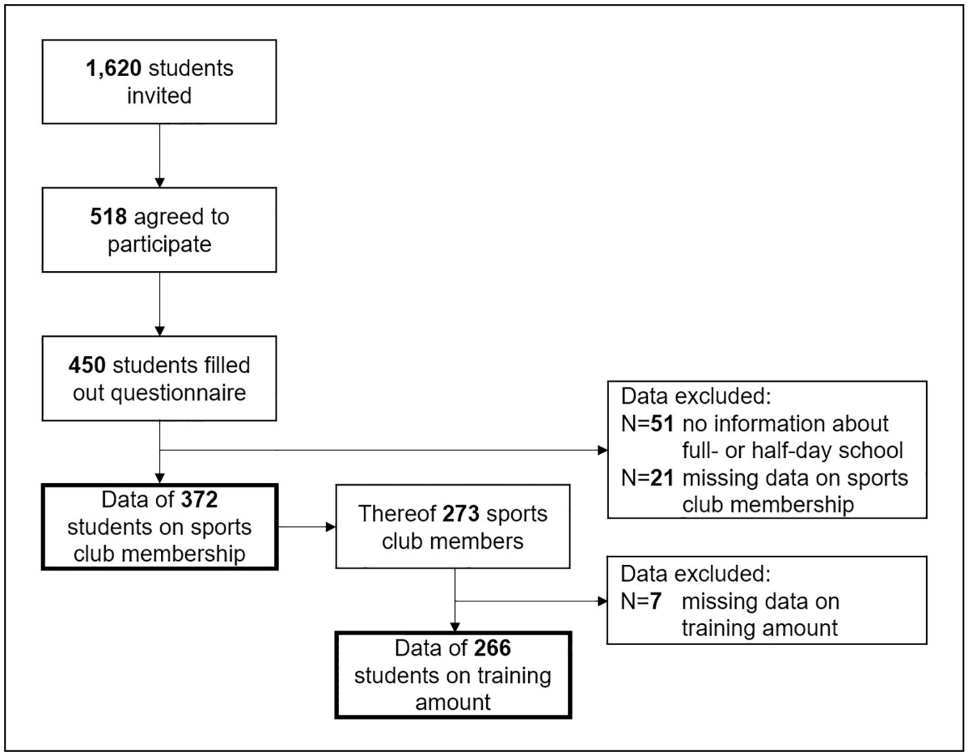

Fig 1. Flow chart of the sample selection process. Bold frames indicate final sample sizes for the statistical analyses.

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version of the scale. The scale used here reflects an optimized version (with slight modifications) published by the authors of the MoMo Study [38].

Participants

Out of 1,620 invited students, 518 (32.0%) agreed to participate in the study. 450 participants filled out the questionnaire (46.8% male, mean age 8.8±1.2y). Fig 1 shows how the final sample size was achieved. Table 1 displays the final sample sizes for the analyses of each part of the research question and shows the students' distribution in grades 1 to 4.

Statistics

All statistical tests were performed in SPSS statistical software for Windows (release 23.0; SPSS Inc., Chicago, IL, USA). Pearson's chi-square test of independence was used to identify differences in sports club membership rate between groups. Mann-Whitney-U tests were performed to compare weekly duration of training in sports clubs between groups. The significance level for all statistical tests was set a priori to $\alpha \leq .05$.

Results

Membership rates in sports clubs differed significantly between students attending half-day and full-day school (Fig 2). 83% of the students attending half-day school were member in a sports club compared to 67% of the students attending full-day school ($\chi^2(1) = 12.31$, $p < .001$). Additional analyses stratified for students' gender and age showed similar patterns for boys and girls as well as for younger and older students: Regarding boys, 90.8% (half-day) and

Table 1. Sample sizes.

	Sports club membership (N)	Habitual PA in sports clubs (N)
Grade 1	45 (m) / 35 (f)	33 (m) / 26 (f)
Grade 2	29 (m) / 55 (f)	23 (m) / 35 (f)
Grade 3	53 (m) / 42 (f)	44 (m) / 30 (f)
Grade 4	27 (m) / 40 (f)	18 (m) / 23 (f)
Inter-grade or no information about grade[a]	23 (m) / 23 (f)	17 (m) / 17 (f)
Average age	8.8±1.2 (m) / 8.7±1.2 (f)	8.8 ±1.1 (m) / 8.6±1.1 (f)
Total	372	266

[a] These students attended an inter-grade class (different combinations: grades 1 and 3; 2 and 4; 1 and 2; 3 and 4); 3 students (100% male) did not mention their grade in the questionnaire.

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71.4% (full-day) were member of a sports club ($\chi^2(1) = 9.13$, p = .003) Regarding girls, 77.3% (half-day) and 61.7% (full-day) were member of a sports club ($\chi^2(1) = 5.46$, p = .019). Further, 85.1% of younger students attending half-day school and 66.4% of younger students attending full-day school were sports club members ($\chi^2(1) = 8.03$, p = .005). In older students, 80.8% (half-day) and 67.0% (full-day) were member of a sports club ($\chi^2(1) = 4.17$, p = .041).

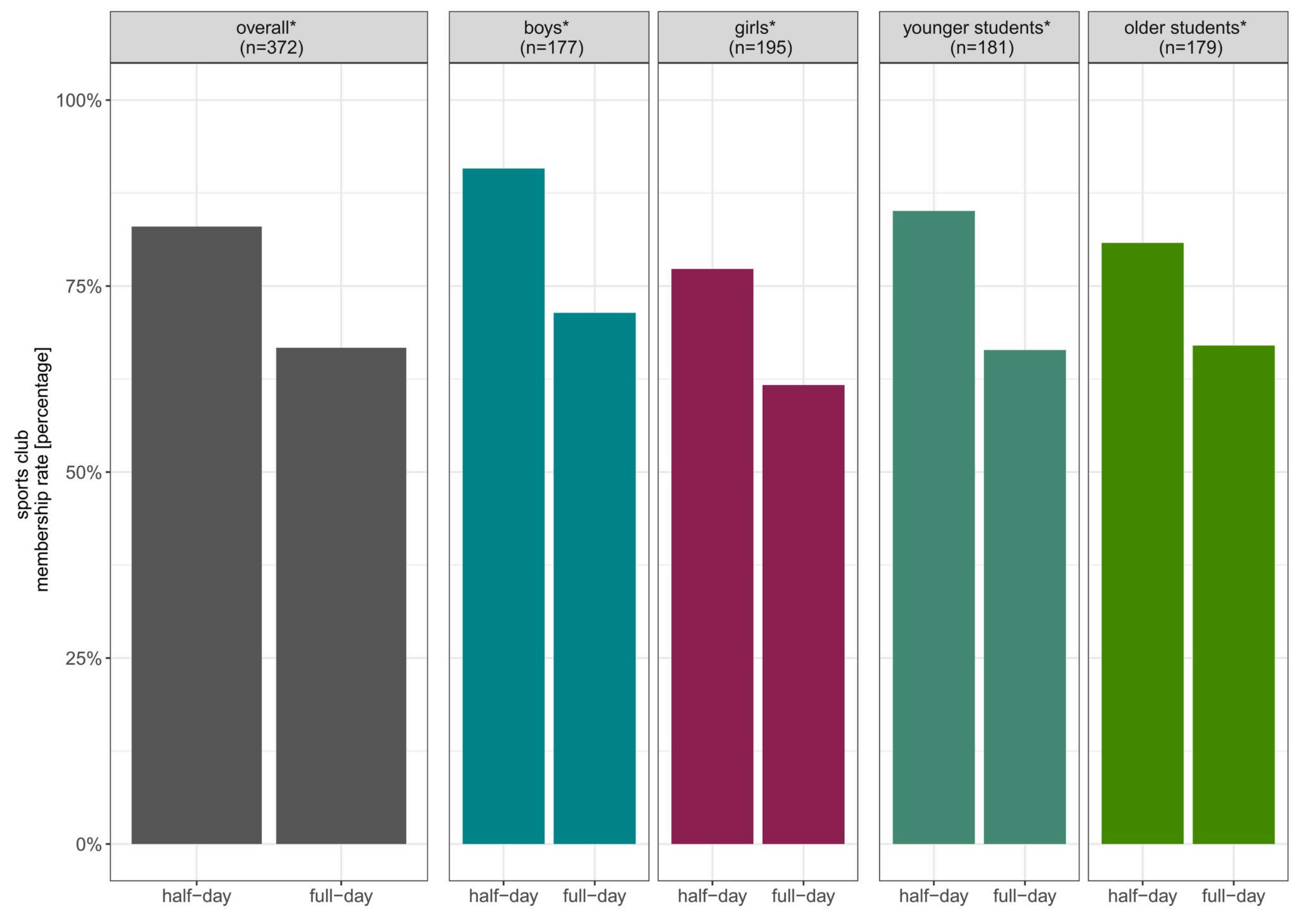

Fig 2. Sports club membership rates overall and stratified for gender and age group (N = 372). * indicates a statistically significant difference on the alpha-level $\alpha \leq .05$.

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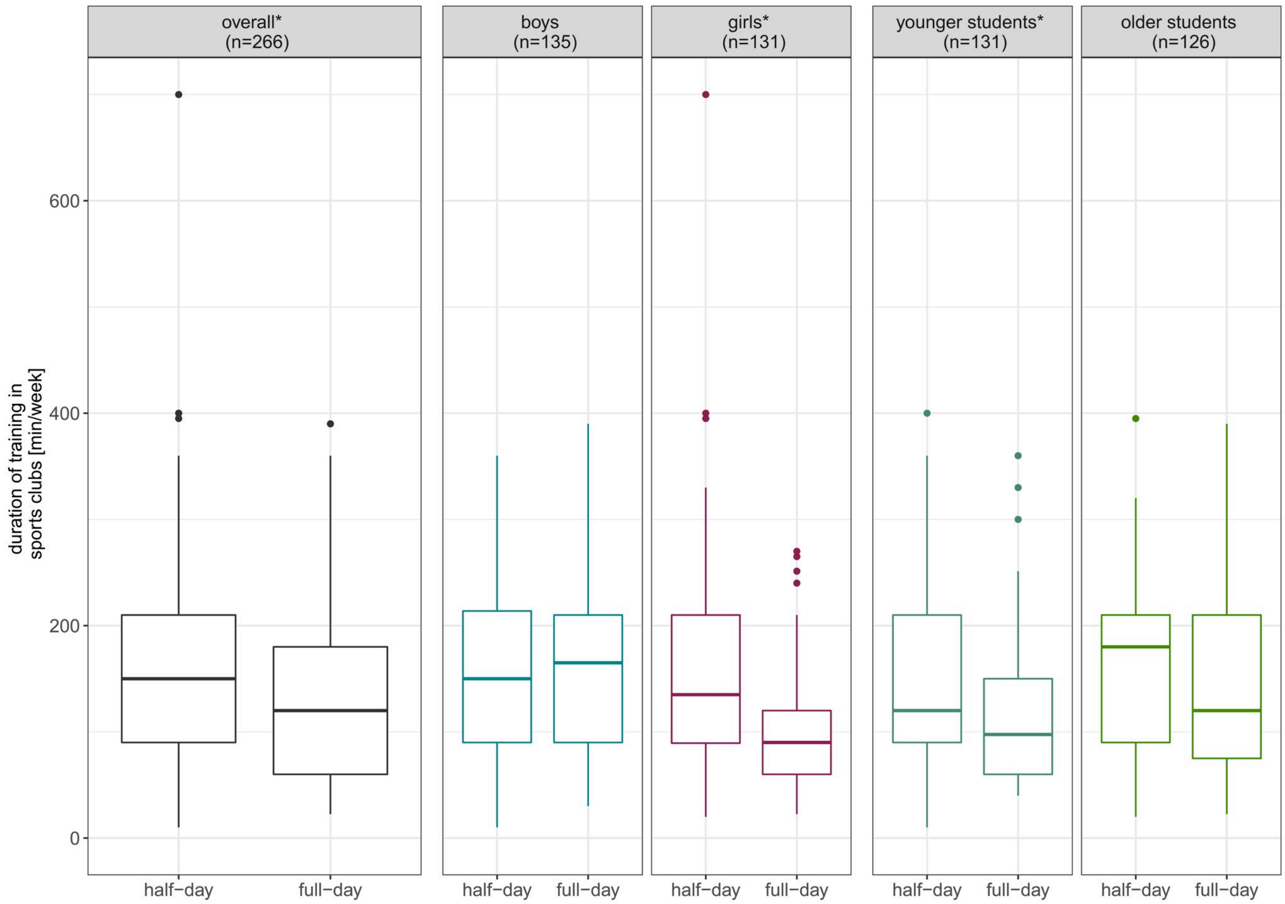

Fig 3. Duration of training in sports clubs per week (Mdn) overall and stratified for gender and age group (N = 266). The boxplots display the median and the 2nd and 3rd quartile. * indicates a statistically significant difference on the alpha-level $\alpha \leq .05$.

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Including only sports club members (N = 266, Fig 3), our analyses showed a significant difference in weekly duration of training in sports clubs with a median of 150 min for students attending half-day school and a median of 120 min for students attending full-day school ($z = -2.37$, $p = .018$, $r = .15$). Stratified additional analyses for boys revealed no significant difference with medians of 150 min (half-day) and 165 min (full-day, $z = -.28$, $p = .821$, $r = .02$). Duration of training among girls differed significantly with medians of 135 min (half-day) and 90 min (full-day, $z = -3.51$, $p < .001$, $r = .31$). In the younger age group, duration of training was also significantly higher for half-day school students (mdn = 120 min) than for full-day school students (mdn = 97.5 min, $z = -2.11$, $p = .035$, $r = .18$). In the older age group, differences were not significant but medians were 180 min for half-day school students and 120 min for full-day school students ($z = -1.15$, $p = .249$, $r = 0,10$).

Discussion

This study aimed to identify potential differences in participation in organized sports (i.e. sports clubs) between primary school students attending half-day or full-day school. We found that full-day school students were less engaged in sports clubs. This holds true for boys and girls as well as younger and older students.

Our result that boys were more often member of a sports club than girls, is in line with other studies in this field [15, 27, 40]. Our results further confirm findings that membership rates decline with children's age [27, 28], as the prevalence was already lower in the older age group. Interestingly, overall membership rates in our study were higher than reported in other national studies [25, 27]. One possible explanation could be the fact that the participating schools in our study are located in well situated areas of Southern Germany (Baden-Württemberg) with a relatively high mean net equivalent income [41]. The proportion of people with a medium or high socioeconomic status (SES) therefore might be relatively high in our sample. It is shown that children from difficult socioeconomic backgrounds tend to be less engaged in organized sports [25, 29, 42, 43]. These children were potentially underrepresented in our sample.

Our results indicate that participating in full-day school prevents some children from engaging in organized sports outside school. One reason could be that these children already attend extra-curricular physical activity programs at school and therefore do not want to engage in further organized physical activity offers. Another reason might be a lack of time due to the longer school day. It can be assumed that these children or their parents are not willing to realize further binding activities during the week in addition to the fixed full-day schedules. There is also the possibility that a clash of dates prevents these children from engaging in a sports club [37], as especially in young children sports club training often takes place in the afternoon. Similar results are found in secondary school students [36], with full-day school students obtaining lower membership rates in sports clubs though with smaller differences between the groups. One reason might be that sports clubs offers for older children and adolescents usually take place in the evening and therefore do not overlap with full-day school schedules. Furthermore, students' age could be a relevant factor with younger children being more protected by their parents from having huge amounts of bonded time, especially with regard to the fact that younger children are more likely to engage in free play [25]. This assumption holds also true for our results with a slightly greater difference in sports club membership prevalence between full-day and half-day school students in the younger age group. Heim and colleagues' [37] contradictory results might be due to the fact that in their study students were allocated to the full-day group even if they attended full-day school only one day per week, which in consequence might not affect their engagement in sports clubs.

Even if full-day school students decide to participate in sports club physical activity they spend a lower amount of weekly time exercising. Possible reasons might be similar to the reasons mentioned before: Attended physical activity programs already at school, a clash of dates and the desire not to have too many fixed appointments during the week. Again, Züchner and Arnoldt [36] show similar results for 7th and 9th graders, with full-day school students participating in less weekly training sessions than half-day school students. However, we found such results in girls but not in boys and assume that if boys decide to participate in organized sports, the performance motivation is more prevalent than in girls and hence they participate more frequently. Studies on motivation towards sports support this assumption, as it is shown that for boys performance is an important motivator for engaging in sports and physical exercise [44]. The fact that the weekly amount of training in our study was lower in girls and in addition the variance was quite low compared to boys, indicates that in female full-day school students the pattern of engaging in sports clubs in a manageable timeframe is typical. A similar picture was found in younger students. It seems as if especially young kids as well as girls might be less willing and/or be more protected by their parents from having several fixed appointments and liabilities. A recent study from 2017 supports this assumption with regard to age differences showing that younger children (six to seven years) participate less also in other (not physical activity-related) clubs and extra-curricular groups than eight to eleven year-olds (68% vs. 80%), but engage more often in free play at home [25].

In summary, students attending full-day school engage less in sports clubs both with regard to membership rate and weekly duration of training. Sports clubs quite often cooperate with schools with the aim of recruiting members [13] but this does not seem to fully compensate the potential loss of members due to full-day school. However, type and amount of cooperation between sports clubs and schools are diverse [45]. Cooperation could include constant engagement in the full-day extra-curricular program or only one-time events to inform students about the offers of the respective club. Studies show that between 30% and 80% (depending on the studied region and schools) of the extra-curricular physical activity programs in full-day school are organized and held by sports clubs [13, 45]. However, only a small number of sports clubs (between 5% and 24%, depending on the studied region) cooperates with full-day schools in terms of extra-curricular physical activity programs [45]. Possibly the participation in physical activity programs at school (organized by other providers than sports clubs) might prevent students from engaging in sports clubs–and maybe also from engaging in leisure time physical activity in general. This assumption is supported by a study on sports schools (with compulsory physical education on each school day) which shows that primary school students attending sports schools are more active at school but less active in leisure time than students from regular schools, resulting in similar overall activity levels [46]. Hence, from a sports club perspective, it could be beneficial to expand the cooperation between sports clubs and full-day schools, both in terms of quantity and intensity.

From a health perspective, it is possible that children compensate the lower amount of physical activity, which might result from fewer engagement in sports clubs [47]. A potential compensation can be realized in several settings. One could be full-day school itself. Participation in extra-curricular programs including physical activity could compensate the lower engagement in sports club. In German schools, more than half of the full-day school students participate in extra-curricular physical activity programs [37, 48]. Pau et al.'s study supports this idea showing that in the afternoon timeslot percentage of MVPA is higher in full-day school students than in half-day school students [35]. The authors further hypothesize that this might result from a one-hour recess in the afternoon in which primary school students accumulate MVPA. Other studies also show that recess time is an important contributor to MVPA [49, 50]. Another possibility to compensate lower engagement in organized sports is being physically active in free leisure time (e.g. active outdoor play), whereby Pau et al. don't find differences in leisure time physical activity levels between half-day and full-day school students, however [35]. Both, being physically active in recess as well as in leisure time, though happens unorganized and unregularly. Therefore physical activity levels might be lower than in organized sports clubs programs, which are held by an educated trainer and take place regularly at least once a week (independent from e.g. weather and other external as well as internal barriers). Due to a lack of studies on this topic, these considerations must be examined by future scientific studies analyzing not only the quantity of children's physical activity behavior, but also the respective settings where physical activity is accumulated.

This is the first study addressing the potential competition of full-day schools and organized sports considering primary school children. However, some limitations must be considered when interpreting the findings. First, this study was based on regional data which might not be representative–neither for Germany nor for the state of Baden-Württemberg–due to regional differences, e.g. SES of the inhabitants, school size as well as a particular structure of sports clubs in the different communities and towns where the schools are located [25, 41]. Second, we did not assess SES of the students and therefore cannot fully preclude that SES was a confounder in our study. Indeed, sports club membership is significantly lower in children and adolescents with a lower SES– 42.8% (low), 61.0% (medium) and 74.1% (high) [43]. However, a representative study on full-day school attendance in (western) German primary schools shows that the distribution of children from low, medium and high SES does not significantly differ between full-day and half-day schools [51]. Thus, we can assume that our full-day and half-day samples are similar regarding their SES distribution. Third, as data was assessed via questionnaire, statements on physical activity behavior can be affected by the difficulty to recall the duration of activities and summarizing as well as rounding this information. Questionnaire data was used because it delivers information not only with respect to the quantity of physical activity but also with respect to the setting in which the activity takes place.

Conclusions

This study showed that primary school students attending full-day school engage less in organized sports outside school than half-day school students. Future studies should examine if the lower engagement in physical activity in sports clubs is compensated in other settings like school or leisure time outside sports clubs. Sports clubs could intensify the cooperation with schools in order to recruit long-term members and thus minimize the loss of members due to full-day school. This is especially important as engagement in sports clubs can continue even after graduation and thus contributes to continuous physical activity in adolescents and young adults.

Supporting information

S1 File. Study dataset.
(XLSX)

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