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Original article

Sports activity patterns and cardio-metabolic health over time among adults in Germany: Results of a nationwide 12-year follow-up study

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Abstract

Background: Physical activity is favorable for health, and vigorous sports activity is particularly beneficial. This study investigates the association between changes in sports participation patterns over time and cardio-metabolic and self-perceived health outcomes.

Methods: Data from 3752 adults (18−79 years of age) who participated in 2 national health interview and examination surveys in 1997−1999 and 2008−2011 were included, with a mean follow-up time of about 12 years. A change in self-reported sports activity was analyzed with respect to the incidence of type 2 diabetes, coronary heart disease (CHD), hypertension, obesity, dyslipidemia, metabolic syndrome, and poor self-perceived health. Participants with pre-existing disease or risk factor of interest at baseline were excluded from the analysis. Being sufficiently active in sports was specified as doing sports for at least 1−2 h per week, and 4 activity categories were defined: 1) inactive at both time points (inactive−inactive), 2) inactive at baseline and active at follow-up (inactive−active), 3) active at baseline and inactive at follow-up (active−inactive), and 4) active at both time points (active−active). Associations between sports activity engagement and health outcomes were estimated by logistic regression models with different stages of adjustments.

Results: Not engaging in any regular sports activity at both time points (inactive−inactive) was associated with higher rates of type 2 diabetes (odds ratio (OR) = 1.82, 95% confidence interval (95%CI): 1.08−3.08), CHD (OR = 1.82, 95%CI: 1.16−2.84), hypertension (OR = 1.36, 95%CI: 1.03−1.81), metabolic syndrome (OR = 1.58, 95%CI: 1.08−2.32), and poor self-perceived health (OR = 2.54, 95%CI: 1.83−3.53) compared to doing regular sports for a minimum of 1−2 h per week over time (active−active). In case of change from inactivity to any regular sports activity (inactive−active), the rate of risk factor occurrence was not statistically different from the active−active reference group except for poor self-perceived health, but it was higher for type 2 diabetes (OR = 2.15, 95%CI: 1.12−4.14) and CHD (OR = 1.77, 95%CI: 1.03−3.03). Being active at baseline but inactive at follow-up (active−inactive) was not associated with higher disease incidence of type 2 diabetes (OR = 0.70, 95%CI: 0.25−1.97) or CHD (OR = 1.20, 95%CI: 0.49−2.99), but was associated with higher rates of hypertension (OR = 1.61, 95%CI: 1.11−2.34), obesity (OR = 2.34, 95%CI: 1.53−3.57), metabolic syndrome (OR = 1.70, 95%CI: 1.11−2.63), and poor self-perceived health (OR = 2.16, 95%CI: 1.53−3.07) at follow-up.

Conclusion: Even a low weekly quantity (1−2 h) of regular sports activity is partly associated with health benefits. Being formerly but not currently active was not associated with an increased disease incidence, but was associated with a higher risk-factor development compared to the reference group (active−active). Becoming active was preventive for risk-factor development but was not preventive for disease incidence, which probably means that the health benefits from sports activity are not sustainable and disease incidence is only shifted to a later period in life. For this reason, the promotion of and commitment to regular sports activity should be addressed as early as possible over the lifespan to achieve the best health benefits.

Keywords: Cohort; Epidemiology; Non-communicable disease; Physical activity; Public health

1. Introduction

Physical activity (PA) is recognized as a key modifiable health resource to prevent or delay the onset of many chronic non-communicable diseases. More vigorous types of PA like sports engagement have more favorable health effects than low or moderate physical activities.[1] Therefore, the recommended amount of regular PA according to national and international guidelines is to perform aerobic PA at moderate intensity for at least 150 min/week or at vigorous intensity for 75 min/week, or a combination of both.[2,3] People who follow these guidelines show a reduced mortality from cardiovascular diseases and all-cause mortality,[4,5] reduced cancer rates,[6] and

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lower diabetes incidence,[7] as well as improved mental health and overall well-being.[8,9] Additionally, PA is associated with improved bone health, reduced absence from work, an increase in working productivity, and overall better physical performance.[10]

In general, PA is an umbrella term that integrates many different types and domains of activities. While leisure-time or transport-related PA (e.g., walking, bicycling, gardening) is mostly associated with moderate intensities, many sports activities (i.e., team sports, running, bicycling) are associated with vigorous PA and performed for recreation.

When looking at the population level and promoting PA as a valuable health resource, there is clear evidence from cross-sectional and cohort studies on the positive association of PA and health.[1,11,12] There are also data on objectively measured physical fitness and health outcomes, indicating that higher levels of physical fitness are associated with greater health benefits and reduced mortality rates.[13−15] Those studies, such as the Aerobics Center Longitudinal Study, are often performed as single center trials.[13] Likewise, numerous studies have examined the effect of PA or fitness change over time.[4,16−18] Some studies have examined PA change in patients after diabetes or myocardial infarction diagnosis or other therapeutic intervention.[19−21] All these studies have reported reduced rates of disease incidence or mortality in those persons who changed their PA behavior over time.

Similarly, there is a large body of evidence for the positive association between sport and health outcomes,[22,23] but as far as we know, there have been no studies, in Germany or elsewhere, explicitly investigating the effects of sports activity change on cardio-metabolic and self-perceived health in the general population. Therefore, the present study uses data from a nationwide population-based sample of the German general population to assess the question of whether a change in sports activity participation over time is associated with cardio-metabolic and self-perceived health. The focus of our analysis is on the association of sports activity change and the incidence of type 2 diabetes, coronary heart disease (CHD), hypertension, obesity, dyslipidemia, and the metabolic syndrome (MetS), as well as poor self-perceived health.

2. Methods

2.1. Study design

The present study used data from the German National Health Interview and Examination Survey 1998 (GNHIES98), which was collected between 1997 and 1999, and the German Health Interview and Examination Survey for Adults (DEGS1), which was conducted between 2008 and 2011. Both surveys are part of the ongoing health-monitoring system of the Robert Koch Institute. The recruitment strategies of GNHIES98 and DEGS1 were based on a 2-stage cluster sampling procedure. In the first stage, a random selection of primary sampling units reflecting community sizes and structures in Germany was identified. In the second stage, age- and sex-stratified random samples from within these primary sampling units were recruited from local population registries. These samples consisted of adults 18−79 years old in proportion to the sex and age structure of the population in Germany. This 2-stage approach allowed an initial sample to be recruited that was representative of the general population. A subgroup of the DEGS1 sample included participants from GNHIES98 who were invited to also participate in DEGS1 and agreed to do so.

The study populations consisted of 7124 persons in GNHIES98 and of 8151 persons in DEGS1. A total of 3959 GNHIES98 re-participants were included in the DEGS1 group, with a median follow-up time of 12.1 years. These 3959 re-participants comprised the study sample for the present analyses.

Methods, study design, and details on the study compositions like demographics and age and sex distribution are described elsewhere.[24,25]

Participation in both surveys was voluntary, and informed written consent was obtained from all participants. Both surveys were approved by the Federal Commissioner for Data Protection. DEGS1 was approved by the Charité Universitätsmedizin Berlin ethics committee. The implementation of both surveys conforms to the principles of the Declaration of Helsinki.

2.2. Participants

In the present analyses, we focused on the data from the 3959 persons who took part in both surveys. After excluding persons with missing data on sports activity, the dataset comprised 3752 participants. Because the main focus of the study was on diseases and risk-factor incidence, we also excluded from the analyses participants with pre-existing type 2 diabetes, CHD, hypertension, obesity, dyslipidemia, and MetS, as well as those with poor self-perceived health at baseline. As a result, sample sizes differ according to outcome parameters because only participants without the particular disease at baseline were included in the analyses.

2.3. Data collection and study variables

Data were collected by standardized self-administered questionnaires, physician-administered computer-assisted personal interviews, and physiological measurements. The data collected included information on sociodemographic characteristics (age, sex, region of residence, and educational attainment), health-related behaviors (diet, tobacco use, alcohol consumption, and sports activities), self-reported physician-diagnosed health conditions, and anthropometric and biochemical measures.[26,27]

2.3.1. Sports activity participation

Sports activity participation was assessed using a standardized self-administered questionnaire. Participants were asked the following question about sports participation: “How often do you engage in sports activity?” Response choices were: “never”, “less than 1 h/week”, “regular 1−2 h/week”, “regular 2−4 h/week”, and “regular more than 4 h/week”. For the purposes of the present study, to be “active” was defined as “engaging in regular sports for at least 1−2 h/week”. To be “inactive” was defined as “engaging in less than 1 h/week” or "never". Change in sports activity participation was then categorized in the following ways: A person was categorized as "inactive−inactive" (absence) if he or she was classified as inactive at the time of both surveys. A person was categorized as a "inactive−active" (commencement) if he or she was inactive at baseline (GNHIES98) and active at follow-up (DEGS1). A person was categorized as "active−inactive" (drop-out) if he or she was active at baseline and inactive at follow-up. A person was categorized as "active−active" (maintenance) if he or she was active at the time of both surveys.

2.3.2. Diseases

Type 2 diabetes and CHD were defined as incident cases when a participant reported not being diseased at baseline but reported a physician-diagnosed disease at follow-up by self-report in a standardized, computer-aided personal interview conducted by specially trained physicians.

Type 2 diabetes was also defined as an incident case when a participant was taking oral anti-diabetic drugs or insulin (Anatomical Therapeutic Chemical Code A10), documented through an automated assessment of medication taken within the 7 days preceding the survey interview. Undiagnosed diabetes was defined as an incident case, and was considered in addition to reported physician-diagnosed diabetes, when glycated hemoglobin (HbA1c) values for participants were $\geq$6.5%. Participants with physician-diagnosed diabetes, those who were taking anti-diabetic medication and those who had undiagnosed diabetes at baseline (as well as participants with incident cases of type 1 diabetes and gestational diabetes) were excluded, as previously described.[28] Values of HbA1c were measured in whole blood using a Diamat high-performance liquid chromatography analyzer (Bio-Rad Laboratories, Munich, Germany) and reagents of Recipe (Recipe Chemicals and Instruments, Munich, Germany) in GNHIES98. An immunoturbidimetric method (Architect ci8200; Abbott, Wiesbaden, Germany) was used in DEGS1. Both methods were traceable to the National Glycohemoglobin Standardization Program, and no systematic deviation of HbA1c measurements between the surveys was evident.[29]

The incidence of CHD was defined by a self-reported history of myocardial infarction or angina pectoris. In DEGS1, questions regarding CHD were only asked to participants between the ages of 40 and 79 years. Thus, our analyses are restricted to this particular age group. Participants with prevalent CHD at baseline were excluded from the analyses.

2.3.3. Cardio-metabolic risk factors

The incidence of hypertension was defined by a self-reported physician-based diagnosis or by blood pressure measures $\geq$140/90 mmHg. Blood pressure was measured on the right arm following a standardized protocol using either a standard mercury sphygmomanometer (GNHIES98) or an automated oscillometric device (Datascope Accutorr Plus, DEGS1). The blood pressure values from GNHIES98 were corrected by a calibration formula validated for DEGS1.[30]

Body mass index (BMI) was calculated using the following formula: BMI = body weight (kg)/body height (m)^2. Body weight was measured using a calibrated electronic scale (column scale 930; Seca GmbH, Hamburg, Germany). In GNHIES98, body height was measured with a leveling board on the electronic scale, and in DEGS1, it was measured with a portable stadiometer (Holtain Ltd., Crosswell, UK); both had a precision of 0.1 cm.[31] In accordance with the definition of the World Health Organization, obesity was defined as BMI $\geq$ 30 kg/m^2.

Incidence of dyslipidemia was defined as either reporting a physician-based diagnosis or by serum concentrations of total cholesterol (TC) $\geq$ 200 mg/dL. Serum concentrations of TC were determined within 6 weeks after blood collection using an enzymatic procedure (CHOD-PAP method). While the principle of measurement remained the same, the analytic system for serum lipids changed during the study period (GNHIES98: MEGA, Merck, Germany; DEGS1: Architect ci2800; Abbott). Since TC is recommended to be used in screening programs to estimate total cardiovascular risk,[32] we defined concentrations $\geq$ 200 mg/dL as elevated.

MetS was defined based on the National Education Program ATP III criteria, as described by van Vliet-Ostaptchouk et al.[33] and applied by Truthmann et al.[31] in the DEGS1 analyses. According to this algorithm, MetS is present among persons fulfilling $\geq$ 3 criteria of the following 5 criteria: (1) waist circumference $\geq$ 88 cm (women) or $\geq$ 102 cm (men), (2) HbA1c $\geq$ 5.7% or diagnosis of diabetes or any use of antidiabetic medication, (3) blood pressure $\geq$ 135/85 mmHg or diagnosis of hypertension or use of any antihypertensive medication, (4) fasting triglycerides $\geq$ 1.7 mmol/L or non-fasting triglycerides $\geq$ 2.1 mmol/L or diagnosis of dyslipidemia or use of lipid-lowering medication, and (5) high-density lipoprotein cholesterol < 1.30 mmol/L (women) or < 1.03 mmol/L (men).

In accordance to the definition of disease incidence (see above) prevalent cases of all 4 cardio-metabolic risk factors at baseline were excluded from the respective analyses.

2.3.4. Self-perceived health

Self-perceived health, as a single item in the minimum European health module, has shown to be a reliable indicator for overall health and is recognized as highly predictable for the development of functional or cognitive impairment and mortality in the general population.[34−36]

Self-perceived health was determined by asking the following question: "How is your health in general?" Response choices were made from one of 5 categories ranging from "*very good*" to "*very bad*". Poor self-perceived health was defined as reporting "*bad*" or "*very bad*". Cases of poor self-perceived health at baseline were excluded from the analyses.

2.4. Data analysis

For unadjusted analyses, the Rao-Scott χ^2 test for associations between age group, sex, education, BMI, diet, alcohol consumption, smoking, and sports activity change (4 categories) was applied. For adjusted analyses, multivariable logistic regression models were applied to account for potential confounding in the relationship between sports activity and health outcome. The exposure variable was the change in sports activity participation over time, with "active−active" as the reference category. The outcome variables of interest were incidence of type 2 diabetes, CHD, obesity, hypertension, dyslipidemia, MetS, and poor self-perceived health. Three separate models were run for each outcome. The 1st model was adjusted for sex and age only, the 2nd model was additionally adjusted for context variables known to be associated with cardio-metabolic outcomes (i.e., education at baseline: low, middle, high), and the 3rd model was additionally adjusted for potentially modifiable lifestyle factors other than sports activity (i.e., smoking: current, former, never; diet: daily *vs.* not daily intake of fruits and vegetables; and alcohol consumption: no alcohol, ≤10 g/d for women and ≤20 g/d for men, >10 g/d for women and >20 g/d for men) at baseline.[28,37] Since we expect that BMI lays in the causal pathway between exposure and outcome variables and acts as a mediator, we decided not to mutually adjust for BMI in the multivariable logistic regression models.

For sensitivity analyses, we used slightly different definitions for the active and inactive categories. In this case, being active was defined as regularly engaging in sports activity for a minimum of 2−3 h/week.

All analyses were performed using cluster and weighting factors to account for different sampling probabilities and deviations of the sample due to non-response from the general population in Germany as of December 31, 1997, with respect to age, sex, education, nationality, community size, federal state, and East/West Germany in GNHIES98. The weighting factors additionally included the inverse of the re-participation probability derived from logistic regression models.[25] Analyses were performed with the statistical software package SAS Version 9.4 (SAS Institute, Cary, NC, USA), using survey procedures for complex samples. $p < 0.05$ were considered to indicate statistical significance.

3. Results

Table 1 shows significant differences in the distribution of characteristics at baseline (GNHIES98) by change in sports activity patterns, with men being more likely active (active−active) than women and normal weight persons being more often active than persons with overweight or obesity. Moreover, younger and more highly educated persons are

Table 1
Distribution of baseline characteristics by change of sports activity patterns in a 12-year follow-up from baseline (GNHIES98) to follow-up (DEGS1) in a nationwide study population of German adults ($n = 3752$).

	Inactive−inactive ($n = 1463$)	Active−inactive ($n = 448$)	Inactive−active ($n = 750$)	Active−active ($n = 1091$)	p
Sex					0.0222
M	41.2 (706)	12.9 (218)	16.7 (305)	29.2 (529)	
W	42.1 (757)	11.2 (230)	21.1 (445)	25.7 (562)	
Age (year)					<0.0001
18−34	34.0 (338)	15.5 (167)	21.5 (214)	28.9 (302)	
35−64	42.7 (998)	9.7 (253)	19.3 (517)	28.3 (747)	
65−79	63.6 (127)	13.1 (28)	7.2 (19)	16.0 (42)	
Education					<0.0001
Low	52.2 (682)	11.1 (159)	15.7 (244)	20.9 (328)	
Middle	35.8 (634)	12.7 (213)	21.6 (370)	29.9 (498)	
High	24.7 (142)	12.9 (75)	21.4 (134)	40.9 (262)	
Body mass index					<0.0001
Normal (<25 kg/m^2)	34.7 (518)	12.7 (197)	19.7 (308)	32.9 (549)	
Overweight (25−<30 kg/m^2)	42.1 (577)	12.1 (173)	18.5 (300)	27.3 (433)	
Obese (≥30 kg/m^2)	57.3 (368)	10.4 (78)	18.0 (142)	14.3 (109)	
Diet (fruit/vegetable intake)					<0.0001
Daily	57.9 (919)	65.8 (310)	65.2 (507)	71.0 (815)	
Not daily	42.1 (544)	34.2 (138)	34.8 (243)	29.0 (276)	
Alcohol					0.0250
No	21.8 (270)	16.7 (57)	19.5 (118)	15.0 (130)	
≤20 g/d (M), ≤10 g/d (W)	57.1 (889)	65.0 (307)	62.4 (489)	64.3 (714)	
>20 g/d (M), >10 g/d (W)	21.1 (298)	18.3 (83)	18.1 (141)	20.7 (244)	
Smoking					0.0012
Never	42.8 (664)	44.6 (202)	45.6 (366)	50.4 (547)	
Former	18.7 (303)	21.2 (101)	21.6 (172)	22.1 (267)	
Current	38.5 (496)	34.2 (145)	32.8 (212)	27.5 (277)	

Notes: Data are weighted percentage (%) and unweighted number. Rounding errors may cause little differences in 100%. Differences to total numbers occur due to missing data for some outcomes.
Abbreviations: DEGS1 = German Health Interview and Examination Survey for Adults; GNHIES98 = German National Health Interview and Examination Survey 1998; M = men; W = women.

more often active than older and less-educated persons, respectively. Furthermore, active persons are more likely to meet nutrition recommendations (daily intake of fruits and vegetables) and smoke less than inactive persons.

Table 2 shows the associations of change in sports activity patterns with diseases and risk-factor incidence in a 12-year nationwide follow-up study estimated by multivariable logistic regression for 7 different outcomes and samples. Except for the dyslipidemia sample, absence of sports activity during follow-up (inactive−inactive) was significantly associated with higher chances of disease and risk-factor incidence (type 2 diabetes, CHD, MetS, hypertension, obesity, and poor self-perceived health) in Model 1. Persons who changed from the inactive to the active category (commencement) had still higher odds ratios (ORs) for disease incidence (type 2 diabetes, CHD) but not for risk-factor occurrence. Persons who were only formerly active (drop-out) had higher OR for risk-factor occurrence (hypertension, obesity, MetS) but not for disease incidence (type 2 diabetes, CHD). The chance of poor self-perceived health was significantly higher in all other activity groups compared to persons who were classified as active at both time points (maintenance).

In the fully adjusted Model 3, participants who had a change in sports activity patterns towards no regular sports activity during the follow-up (active−inactive) showed significantly higher chances for risk-factor occurrence in the obesity (OR = 2.34, 95%CI: 1.53−3.57), hypertension (OR = 1.61, 95%CI: 1.11−2.34), and MetS (OR = 1.70, 95%CI: 1.11−2.63) sample. Furthermore, prolonged inactivity (inactive−inactive) was associated with a higher risk for disease incidence in the type 2 diabetes (OR = 1.82, 95%CI: 1.08−3.08), CHD (OR = 1.82, 95%CI: 1.16−2.84), hypertension (OR = 1.36, 95%CI: 1.03−1.81), and MetS (OR = 1.58, 95%CI: 1.08−2.32) sample compared to active persons.

Table 2
Association of change in sports activity patterns with incidence of diseases and risk-factor occurrence in a 12-year follow-up from baseline (GNHIES98) to follow-up (DEGS1) in a nationwide study population of German adults.

	Case/*n*	Model 1		Model 2		Model 3	
		OR	95%CI	OR	95%CI	OR	95%CI
Type 2 diabetes (187 new cases of *n* = 3488; 18−79 years old)							
Inactive−inactive	99/1216	**2.11**	**1.26−3.53**	**1.90**	**1.13−3.20**	**1.82**	**1.08−3.08**
Active−inactive	16/405	0.92	0.41−2.08	0.90	0.40−2.04	0.88	0.39−1.98
Inactive−active	41/660	**2.19**	**1.14−4.21**	**2.15**	**1.13−4.12**	**2.15**	**1.12−4.14**
Active−active	31/1020	Ref.		Ref.		Ref.	
CHD (198 new cases of *n* = 2236; 40−79 years old)							
Inactive−inactive	99/722	**2.14**	**1.37−3.32**	**1.99**	**1.28−3.10**	**1.82**	**1.16−2.84**
Active−inactive	21/192	1.57	0.74−3.35	1.55	0.73−3.29	1.46	0.68−3.14
Inactive−active	38/362	**1.83**	**1.07−3.12**	**1.80**	**1.05−3.09**	**1.77**	**1.03−3.03**
Active−active	40/564	Ref.		Ref.		Ref.	
Hypertension (866 new cases of *n* = 2183; 18−79 years old)							
Inactive−inactive	360/436	**1.42**	**1.08−1.87**	**1.40**	**1.06−1.85**	**1.36**	**1.03−1.81**
Active−inactive	109/157	**1.64**	**1.13−2.36**	**1.62**	**1.12−2.35**	**1.61**	**1.11−2.34**
Inactive−active	178/276	1.34	0.99−1.83	1.34	0.98−1.83	1.36	0.97−1.81
Active−active	219/448	Ref.		Ref.		Ref.	
Obesity (321 new cases of *n* = 2345; 18−79 years old)							
Inactive−inactive	127/700	**1.49**	**1.07−2.07**	1.35	0.96−1.89	1.26	0.91−1.76
Active−inactive	60/211	**2.47**	**1.63−3.75**	**2.37**	**1.55−3.64**	**2.34**	**1.53−3.57**
Inactive−active	54/420	1.19	0.81−1.76	1.17	0.79−1.72	1.14	0.77−1.69
Active−active	80/693	Ref.		Ref.		Ref.	
Dyslipidemia (267 new cases of *n* = 982; 18−79 years old)							
Inactive−inactive	97/234	1.32	0.81−2.15	1.27	0.79−2.02	1.29	0.80−2.08
Active−inactive	42/92	1.32	0.71−2.46	1.28	0.69−2.37	1.30	0.70−2.43
Inactive−active	52/143	0.75	0.45−1.26	0.75	0.44−1.26	0.77	0.46−1.29
Active−active	76/246	Ref.		Ref.		Ref.	
MetS (394 new cases of *n* = 2098; 18−79 years old)							
Inactive−inactive	163/568	**1.77**	**1.22−2.58**	**1.71**	**1.17−2.49**	**1.58**	**1.08−2.32**
Active−inactive	54/198	**1.74**	**1.13−2.67**	**1.71**	**1.11−2.63**	**1.70**	**1.11−2.63**
Inactive−active	85/361	1.40	0.94−2.09	1.39	0.93−2.08	1.34	0.89−2.01
Active−active	92/577	Ref.		Ref.		Ref.	
Poor self-perceived health (515 new cases of *n* = 2652; 18−79 years old)							
Inactive−inactive	252/698	**3.05**	**2.20−4.23**	**2.76**	**1.98−3.86**	**2.54**	**1.83−3.53**
Active−inactive	77/253	**2.31**	**1.64−3.25**	**2.22**	**1.56−3.14**	**2.16**	**1.53−3.07**
Inactive−active	83/422	**1.74**	**1.15−2.64**	**1.74**	**1.15−2.63**	**1.66**	**1.09−2.50**
Active−active	103/764	Ref.		Ref.		Ref.	

Notes: Numbers in bold indicate statistical significance. Model 1 is adjusted for sex and age; Model 2 is additionally adjusted for education; and Model 3 is additionally adjusted for smoking, diet, and alcohol consumption.

Abbreviations: 95%CI = 95% confidence interval; CHD = coronary heart disease; DEGS1 = German Health Interview and Examination Survey for Adults; GNHIES98 = German National Health Interview and Examination Survey 1998; MetS = metabolic syndrome; Ref. = reference.

Self-perceived health is the outcome with the strongest association and a clear gradient towards regular sports activity for health promotion. Persons who were constantly inactive had a 2.5-fold increase (OR = 2.54, 95%CI: 1.83−3.53) in poor self-perceived health status compared to persons who regularly engaged in sports activity over time. Persons who had become inactive at follow-up had an OR of 2.16 (95%CI: 1.53−3.07), and persons who had become active had still an OR of 1.66 (95%CI: 1.09−2.50) compared to their active−active counterparts. For the sensitivity analyses, all findings were stable when we used slightly different activity categories (>2 h/week).

4. Discussion

4.1. Findings

To the best of our knowledge, our study is the first that focuses on the change of sports activity patterns over time with respect to cardio-metabolic and self-perceived health outcomes. First, our data show that persons who are not engaging in regular sports activity have a greater risk for the development of type 2 diabetes, CHD, hypertension, MetS, and poor self-perceived health compared to those who are doing a minimum of 1−2 h of sports activity per week. Next, our results show that it seems beneficial to change from inactivity to any regular sports activity to prevent the onset of MetS and hypertension and that being formerly active was not associated with an increased disease incidence (type 2 diabetes, CHD) but was associated with higher rates of risk-factor occurrence. This may mean that health benefits from sports activity are not sustainable and that disease incidence is only shifted to a later period in life. Finally, our results show that there is a clear association between regular sports activity and self-perceived health status, suggesting that, for active individuals compared to inactive individuals, maintaining regular sports activity over time is clearly associated with a better overall health status. Compared to those who were persistently inactive (inactive−inactive), those who were formerly active (active−inactive) or became active (inactive−active) showed a trend towards reduced rates of poor self-perceived health.

4.2. Comparison with other studies

Our findings on sport activity are not always in line with previous prospective studies that examined the effect of PA (daily PA) on cardio-metabolic health.[11] For example, some studies have shown that a change from physical inactivity to moderate or low PA, as well as an improvement in fitness, can reduce diabetes incidence by 38%.[17,38] Leskinen et al.[16] reported that improving PA (total PA) reduced obesity incidence by 31% over a 4-year period and observed a trend towards a lower risk of developing hypertension and diabetes. Also, PA, especially moderate-to-vigorous PA, has been associated with a reduction in obesity rates and reduced weight gain.[39] In looking at the effects of sports activity, we found these kinds of positive effects only for hypertension and MetS. In the British Regional Heart Study, a lower risk of all-cause and cardiovascular disease mortality was observed for persons who increased PA over a 16.4-year period.[40] A dose−response relationship was also observed, with higher levels of PA from midlife to old age associated with additional benefits.[40] Similar to the findings in our study, a recent analysis of a prospective cohort study with 3080 persons showed that a change in PA behavior (leisure-time PA) towards a more active lifestyle has effects on physical health-related quality of life as well as mental health-related quality of life.[41] The difference between the studies mentioned above is that they mostly focused on overall PA while our study focused solely on sports activity.

The estimates for the development of diabetes and CHD in our sample are comparable with other studies. For example, a 10-year study using a Greek cohort estimated a diabetes incidence of 10% for initially metabolic healthy people,[42] and a study using a Swedish population of more than 32,000 persons estimated that 7% of the population developed diabetes over a 10-year period.[43] For CHD, we estimated that 9.7% of our study sample developed CHD compared to 13.7% in the Cardiovascular Health Study, which had almost 4000 participants,[44] and a CHD risk of 6.5%−7.2% in the 10-year National Health and Nutrition Examination Survey study,[45] which had 7751 participants. In our study, the relatively high estimates for hypertension and MetS may be partly explained by the increase in Germany in medication rates for antihypertensive drugs over the last few decades, as described by Finger et al. 2016.[46]

4.3. Outlook

Currently, the Robert Koch Institute is working on the development of a continuous and systematic Public Health Surveillance System in Germany, starting with a surveillance of diabetes.[47] In this context, PA is one of the core indicators for a healthy lifestyle and disease prevention.[48] Next to disease prevention and health promotion, the Public Health Surveillance will focus on healthcare performance and economic aspects of most non-communicable diseases. It will then be possible to estimate the effectiveness and efficiency of interventions targeting PA promotion and sports engagement in the public health context. Nevertheless, objectively measured data on PA with accelerometers could deliver more accurate data on physical and sports activity behavior compared to self-reported data we used in our analyses.

4.4. Strengths and limitations

The strengths of this study include its appropriate sample size, its use of comparable sports activity data over time, and its use of a nationwide population-based study sample drawn from the general population. Furthermore, data ascertainment was performed with standardized and quality controlled procedures.

A limitation is that in our analyses sample sizes differed between outcomes; therefore, differences in disease or risk-factor development are not clearly comparable. This was unavoidable due to the exclusion of already diseased persons at baseline.

Unfortunately, we had no other overall or domain-specific PA data for comparison. This also may have impacted the validity of the reported associations because differences in non-sport PA across the sport change categories may have confounded our results. Moreover, the sports participation variable was limited because we only asked for duration and not for frequency, intensity, or type of activity. Another limitation is that the data on disease and risk-factor prevalence were partly based on self-reports, and sports activity behavior was solely based on this method of data collection. For this reason, our study outcomes may have been affected by recall bias and social desirability. Finally, we collected information for only 2 time points, and we cannot say when the participants' sport activity change occurred or when their incidence of disease and change in risk factor took place. This issue seems relevant in terms of potential reverse causation, especially for the self-rated health measure. Thus, it may be that inactivity cause poor health and *vice versa*. This—and the fact that we had comparatively small sample sizes for some outcomes—could be a reason why our estimated effects of sports activity change are not always as consistent as they were in other studies that focus on PA change.

5. Conclusion

Our findings indicate that a change in sports activity is partly associated with cardio-metabolic and self-perceived health outcomes. Based on our results, the current study supports the findings of previous studies that inactivity (inactive−inactive) is associated with a higher risk for non-communicable disease and risk-factor development compared to being active (active−active). Being formerly but not currently active was not associated with an increased disease incidence but was associated with a higher risk-factor occurrence compared to the reference group (active−active). This means that our findings related to the positive effects of becoming active or being formerly active in sport activities are not as consistent as the findings from previous studies on PA. This may in part be explained by the fact that we only used 2 time points for data collection, and overall we had small samples for some outcomes. Nevertheless, the application of regular sports engagement could serve as an additional strategy for disease prevention and health promotion in the general population and should be addressed as early as possible over the lifespan to achieve the best health benefits.

As far as we know, there is no study (including ours) that has shown negative effects from regular sports or PA engagement in initially healthy persons. In addition to encouraging an overall active lifestyle and reducing sedentary time, engagement in regular sports activity may serve as a further focus in complex PA intervention programs.

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Authors' contributions

LG developed the research question, carried out the analyses, and drafted the manuscript; JB supported and supervised the analyses; CH was part of the working group that designed the study protocol (DEGS1) and defined type 2 diabetes incidence; MB was part of the working group that designed the study protocol (DEGS1); JDF was part of the working group that designed the study protocol, was responsible for physical activity assessment, and helped to draft the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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