

Associations of leisure time and occupational physical activity with tobacco smoking and dual use of e-cigarettes among adults – a representative cross-sectional survey in Germany

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Abstract

Background

Physical inactivity and tobacco smoking are risk factors for chronic diseases, and the combination of both further increase health risks. While leisure time physical activity (LTPA) improves cardiovascular health and is associated with lower smoking prevalence, occupational physical activity (OPA) may have adverse health effects and is associated with higher smoking prevalence. To date, there is limited evidence on the associations between LTPA, OPA and smoking behaviour – more specifically the use of tobacco and e-cigarettes, and their dual use – in the German adult population.

Methods

We used data from GEDA 2019/2020-EHIS, a representative cross-sectional survey of the German population conducted by structured computer assisted telephone interviews in people aged ≥ 18 years. Questions on physical activity and smoking were based on the European Health Interview Survey (EHIS) and Physical Activity Questionnaire (EHIS-PAQ). Multinomial and binary logistic regressions were applied to assess associations between LTPA, OPA, and their interaction effect and smoking status, cigarettes per day, dual use of tobacco and e-cigarettes, adjusted for confounding factors.

Results

Overall, 22,708 people responded. Active levels of LTPA were associated with lower odds of current vs. never tobacco smoking (e.g., OR for very vs. not active = 0.60, 95%CI = 0.54;0.67). Active levels of OPA were associated with higher odds (e.g., OR for very vs. not active = 1.70, 95%CI = 1.52;1.90). In addition, active levels of LTPA were associated with lower odds of dual-use with e-cigarettes vs. no dual-use (e.g., OR for moderately vs. not active = 0.56, 95%CI = 0.41;0.78). Active levels of OPA were associated with higher odds (OR for very vs. not active = 1.63, 95%CI = 1.24;2.15). The interaction effect of LTPA and OPA showed that being active during leisure time was associated with smoking fewer cigarettes per day, regardless of OPA level.

Conclusion

In the German population, people who are physically active during leisure time are less likely to be current tobacco smokers and dual users with e-cigarettes, while this was vice versa for people who are physically active during their occupation. Targeting tobacco control efforts, including smoking cessation programs, at physically demanding occupational environments seems to be important to prevent health risks in people working in such environments.

INTRODUCTION

The risks of physical inactivity and tobacco smoking are well known and both are major risk factors for chronic diseases including cancer, cardiovascular and respiratory diseases [1–3]. The additive effect of physical inactivity and smoking are contributing to an increase in the onset of these diseases [4]. This highlights the need for

preventive measures and interventions for people with the additive behaviour of smoking and physical inactivity to promote a healthier lifestyle, including increasing physical activity and smoking cessation. Almost one third of the global population does not meet the recommended level of physical activity for health prevention which includes a minimum of 150 min of moderate aerobic exercise per week [5]. Additionally, it is estimated that almost 18.1% of the world's population will still use tobacco products by 2030 [6]. In a recent study, we showed that around 30% of the German population is physically inactive in their leisure time, which was shown to be almost 40% among current tobacco smokers [7]. At the same time, the prevalence of smoking in Germany is high: 28% of the population are cigarette smokers and 2.3% e-cigarettes users of which 77% are dual users of tobacco [8].

In our previous study, we were able to identify associated behaviours between leisure time physical activity (LTPA) and several smoking outcomes in the German adult population [7], but did not distinguish between different forms of PA. Many studies have provided evidence for the different health effects of LTPA and occupational physical activity (OPA) [9]. This topic has been debated for years and labelled as the PA paradox [10–13]. While LTPA has been shown to have positive effects on cardiovascular health due to its voluntary nature and sufficient recovery time to improve cardiovascular fitness [10], OPA has been associated with adverse outcomes, such as increased 24-hour heart rate and elevated blood pressure [13]. This was among others attributed to higher physical exertion and lower recovery periods during working hours [10]. Moreover, studies have demonstrated that individuals with high levels of LTPA exhibit lower smoking prevalence and tend to smoke less [7, 14–16], whereas those with high levels of OPA are more likely to smoke [17, 18]. Given these previous observations of the different harmful effects of LTPA and OPA [9, 13], and the well-known negative effect of smoking on cardiovascular health [4], it is necessary to understand these additive behaviours for possible future interventions to increase an overall healthier lifestyle.

In addition, the use of e-cigarettes to reduce or quit smoking has become increasingly popular among smokers [19]. However, it is important to note that smokers do not always switch from tobacco to e-cigarettes, but often use both, making them dual users [19–21]. Studies have shown that the addition of e-cigarette use to tobacco smoking may contribute to greater health risks, such as cardiopulmonary and especially respiratory risks [20, 22]. However, to our knowledge, there are only a few studies that have investigated associations between physical activity and dual use. A population-based study from Korea showed that single use of tobacco cigarettes, but not dual use with e-cigarettes was associated with the odds of physical inactivity in older adults > 40 years, moreover dual users were more physically active than single users or non-smokers [23]. By contrast, a population-based study in the United States showed that, among adolescents aged 12–17 years, dual users were the least likely to be physically active, compared with those who used tobacco or e-cigarettes as their only substance, and non-smokers [24]. Furthermore, it was found that a higher prevalence of e-cigarette use was found in people with a higher level of education in the United states [25]. As a higher level of education is associated with lower physical activity at work, we assume that dual use is higher among people who tend to be inactive at work. However, the link between dual use and LTPA in Germany, as well as OPA, remains unclear. Further research is required in the German adult population due to the lack of knowledge of these behaviours.

The aim of this study is to investigate the associations of LTPA and OPA with smoking behaviours, more precisely smoking status of tobacco cigarettes, number of tobacco cigarettes smoked per day and dual use of tobacco and e-cigarettes. It will also be investigated whether there is an interaction effect between LTPA and OPA with smoking outcomes. Knowledge of these associations could support the development of smoking cessation interventions for specific target groups in recreational or workplace settings, depending on product use, and potentially inform public health campaigns. Therefore, it is essential to use representative population data to address this research

gap. As the WHO recommendations for physical activity differ for different age groups, we will focus our analyses on the adult population (≥ 18 years) [26]. Specifically, our research aims to answer the following questions:

1. In the German adult population, what is the association between smoking status of tobacco cigarettes and physical activity (leisure time, occupational, and their interaction)?
2. Among current tobacco smokers, what is the association between cigarettes smoked per day and physical activity (leisure time, occupational, and their interaction)?
3. Among current tobacco smokers, what is the association between dual use of tobacco cigarettes and e-cigarettes and physical activity (leisure time, occupational, and their interaction)?

We hypothesized that lower LTPA and higher OPA are associated with a higher odds of being a current smoker compared to being an ex- or never smoker. Among current tobacco smokers, we assumed that lower LTPA and higher OPA is associated with a higher number of cigarettes smoked per day. Moreover, lower LTPA and higher OPA is associated with a lower odds of being a dual user. We also expected that the associations of LTPA and OPA with smoking outcomes mentioned above are more pronounced if on type of physical activity is lower relative to the other.

METHODS

Study design and setting

A detailed a priori study protocol was published on the Open Science Framework (<https://osf.io/23769>). Data was used from the German Health Update (GEDA 2019/2020-EHIS) study from the Robert Koch Institute for the time period 04/2019–09/2020 with a sample size of 23,001 people aged > 15 years [27]. This representative cross-sectional survey was conducted by structured computer assisted telephone interviews on an ongoing basis. The content of the GEDA 2019/2020-EHIS questionnaire was based on the third wave of the European Health Interview Survey (EHIS) conducted in all EU Member States, which is a key source of information for European health policy and health reporting [28]. As part of the EHIS, physical activity was assessed using the European Health Interview Survey-Physical Activity Questionnaire (EHIS-PAQ) [29]. For our study, we used data from the adult population > 18 years, who answered questions about physical activity and smoking.

Measures

Predictor variables

Physical activity was measured by two items to assess leisure time and occupational physical activity. To understand physical activity behaviour during leisure time, people were asked: “When answering the next question, exclude the physical activity related to work and commuting that you have already mentioned. For the following questions, think about sports, fitness and leisure activities that cause at least a slight increase in your breathing or heart rate. For example: Nordic walking, team sports, jogging, cycling, swimming, aerobics, rowing or badminton. In a typical week, how much time do you spend exercising or doing physical activities in your leisure time?” [30]. The WHO recommendation on physical activity for the adult population includes 150 to 300 minutes of moderate exercise or 75 to 150 minutes of vigorous aerobic endurance training per week, plus additional strength training twice a week [26]. For analysis we coded LTPA into four categories according to the WHO recommended guidelines for moderate aerobic exercise: (1) not active (0 min/week) (2) low active (< 150 min/week) (3)

moderately active (150–300 min/week) (4) very active (> 300 min/week). Vigorous physical activity recommendation and strength training were here not taken into account.

To understand OPA, it was asked: “Now let's look at how much physical activity you do in different areas in a typical week. First, think about the time you spend working. When we say 'work', we mean tasks you have to do, such as paid and unpaid work, housework, childcare, caring, school or study. Base your answers on your main job. If you have more than one job, list them all. If you work, which of the following best describes what you do? Would you say...” The response options were (1) mostly sitting or standing, e.g., light office work, studying, teaching, or driving (2) mostly walking or moderately strenuous physical activities, e.g., delivering mail, plumbing, cleaning, or playing with children (3) mostly heavy physical work or physically demanding activities, e.g., construction work, mining, or gardening (4) I do not engage in work-related activities [30]. As the question refers to both paid and unpaid work, such as caring for relatives, the results could not clearly been calculated for the working population in terms of paid employment. For analysis OPA was coded into three categories (1) not active (mostly sitting or standing), (2) moderately active (mostly walking or moderately strenuous physical activities), (3) very active (mostly heavy physical work or physically demanding activities), according to the EHIS-PAQ categorisation described above. In addition, we assessed the interaction effect of LTPA and OPA and coded both into two categories with LTPA as not active (1) and active (2–4) and OPA as not active (1) and active (2–3) as defined above.

Outcome variables

Different questions were used to assess smoking outcomes. To determine type of current tobacco smoking behaviour all participants were asked: “The next questions are about your smoking habits and whether you are exposed to tobacco smoke. Do you smoke tobacco products, including heated tobacco products? Please exclude electronic cigarettes or similar products”. The response options were (1) daily (2) occasionally (3) not anymore (4) I have never smoked before. For analysis, we coded type of current tobacco smoking behaviour into current tobacco smoker (1–2) ex tobacco smoker (3) and never tobacco smoker (4), based on the answer categories [30].

Only daily tobacco smokers were asked about the number of cigarettes smoked per day [30]: “How many cigarettes do you smoke on average per day?”. The amount of cigarettes was given as a numeric value. Based on the results of previous studies, the variable cigarettes smoked per day was divided into three categories (1) < 10 (2) 10–20 (3) > 20 [31].

All participants were asked about the use of electronic cigarettes. They were asked: “Do you currently use electronic cigarettes or similar electronic products, e.g. e-shisha, e-pipe?”. Response options were (1) daily (2) occasionally (3) not anymore (4) I have never smoked before [30]. To find out whether current smokers consume both, tobacco cigarettes and e-cigarettes, a new variable was coded for dual current use. Current tobacco smokers who answered (1–2), were considered as current dual users, while those who answered (3–4) were considered as single tobacco smokers. The question on type of current tobacco smoking behaviour included heated tobacco products and the question on e-cigarettes included similar electronic devices such as e-shisha or e-pipe. For the sake of simplicity, this analysis refers to tobacco and e-cigarettes.

Confounders

Furthermore, several confounders were used for analyses: age, gender, educational attainment and income. A detailed description of the confounders can be found in the protocol (<https://osf.io/23769>).

Statistical analyses

The prevalence rates were estimated for the total sample stratified by age, gender, educational attainment, income, LTPA and OPA with corresponding 95% confidence interval (CI). For these estimations, data were weighted to be representative for the German adult population. Details on weighting technique from the GEDA study have been published elsewhere [27]. Subsequently, the main effects between smoking outcome variables and physical activity predictor variables (LTPA and OPA) were tested.

Therefore, associations of smoking status and of cigarettes smoked per day with physical activity variables were calculated through multinomial logistic regression models. In deviation from the protocol, cigarettes smoked per day were not calculated by ordinal regression model due to violation of the proportional odds assumption. Association of dual use of tobacco and electronic cigarettes with physical activity variables were calculated by binary logistic regression. The predictor variables were also analysed for interdependence by obtaining the VIF and tolerance values using multicollinearity diagnostics.

After testing for main effects, we tested for interactions between LTPA and OPA on smoking outcomes using a cross product term for LTPA and OPA as binary variables (inactive and active respectively). A stepwise regression was applied. The p-value for the interaction was obtained using the Wald test for the cross product term. In addition, individual interactions of each categories of LTPA and OPA (inactive and active) were considered and related to each other for each outcome variable. P-values are two-tailed and all statistical analyses are performed using IBM SPSS Statistics 29.0. For all main and interaction effects weighted data were used and adjusted for the potential confounders of age, gender, educational attainment and income. Adjusted odds ratios (OR) and corresponding 95% CIs are reported. In order to understand whether the weighting affects the results, a sensitivity analysis was performed for all regression models using unweighted data. A second sensitivity analysis was held for all models only including people who consider themselves to be in part-time or full-time paid employment. Differences in the results may indicate a bias in our analysis for the working population. The results of both sensitivity analyses (unweighted data and part-time and full-time paid employment) are presented as supplementary material in our report. Data with missing values were deleted and not included in the analysis.

RESULTS

A total of 22,708 individuals aged ≥ 18 years were included in the study, of which 22,485 (99.0%; $n = 223$ missing) replied to the question on LTPA and 18,346 (80.8%; $n = 4,362$ missing) on OPA. In total 33.8% stated not being active during leisure time, 29.3% were low active, 21.5% were moderately active and 15.4% were very active during leisure time. In addition, 47.4% stated not being active at work (mostly sedentary or standing), 38.6% were moderately active and the minority of 14.0% were very active at work (Table 1). The highest amount of current tobacco smokers were in the group of people who were not active during leisure time (35.7%) and very active at work (46.1%). The results are described in Table 2. Men were more likely than women to report being physically active both at work and during leisure time. As age increased, levels of both LTPA and OPA declined. While higher educational attainment and income were associated with higher levels of LTPA they were linked to lower OPA (Table 3).

Associations of occupational and leisure time physical activity with smoking outcomes

In our main analyses, we used physically inactive people and never smokers as reference groups. We showed that individuals with low to very high levels of LTPA (vs. inactive individuals), were less likely to be current smokers (vs. never smokers). For instance, those with very high activity levels showed 40% lower odds of being a current smoker instead of being a never smoker (OR = 0.60; 95%CI = 0.54;0.67). No significant association was found between LTPA and ex-smoking. In contrast, individuals who were moderately and very active at work (vs. inactive individuals) were more likely to be a current smoker (vs. being a never smoker; OR = 1.17; 95%CI = 1.07; 1.27 and OR = 1.70; 95%CI = 1.52;1.90 respectively). In addition, people with very active OPA (vs. inactive OPA) was associated with a higher likelihood of being an ex-smoker (vs. being a never smoker; OR = 1.22; 95%CI = 1.08; 1.39). Regarding smoking intensity, individuals with low to very high LTPA level (vs. inactive individuals) reported smoking fewer cigarettes per day (e.g., less than 10 instead of 10–20; OR = 0.67; 95%CI = 0.53;0.86), while individuals with very high levels of OPA (vs. inactive individuals) were more likely to smoke more than 20 cigarettes per day rather than fewer than 10 (OR = 1.32; 95%CI = 1.04;1.67). With respect to dual use, individuals with low to moderately high LTPA (vs. inactive individuals) were less likely to be dual users than single tobacco cigarette smokers (e.g., low LTPA: OR = 0.60, 95%CI = 0.45;0.81), whereas individuals with very high OPA were more likely to be dual users of tobacco cigarettes and e-cigarettes (OR = 1.63; 95%CI = 1.24;2.15) than single tobacco cigarette smokers. The results of the main effects can be found in Table 4.

Looking at the interaction effect between LTPA and OPA, it was found that people who were physically inactive in their leisure time but active at work were more likely to be current smokers (vs. never smokers; OR = 1.37; 95%CI = 1.06; 1.77). Conversely, those who were physically active during leisure time but inactive at work were less likely to be current smokers (vs. never smokers; OR = 0.55; 95%CI = 0.44; 0.70). In addition, people who were physically active during leisure time—regardless of their OPA status—were also less likely to smoke heavily. However, no significant associations were found between the interaction term and ex-smoking or dual use (Table 5).

Sensitivity analyses using unweighted data revealed fewer significant associations between OPA and smoking variables, except for one additional significant result for OPA and cigarettes smoked per day, as well as for LTPA and dual use. For the interaction effects of LTPA and OPA, an additional significant association was found with smoking status.

Fewer significant associations were found for the main analyses and interaction effects of sensitivity analyses of part-time and full-time paid employment. Detailed results are presented in the supplementary material.

DISCUSSION

This study investigated associations between LTPA and OPA with various smoking behaviour in a large, population-based sample in Germany. Our findings show a clear distinction in how both types of physical activity relate to smoking outcomes.

Leisure time physical activity and smoking

LTPA was consistently associated with healthier behaviours. Individuals engaging in at least low levels of LTPA were less likely to be current smokers. Among those who smoked, LTPA was associated with lower cigarette

consumption and reduced dual use of e-cigarettes. These findings are consistent with previous studies that have emphasised the protective role of LTPA in smoking behaviour [7, 15, 16]. This association may be explained, in part, by greater health awareness, which encourages individuals to adopt a more comprehensive approach to a healthy lifestyle [15, 16].

Contrary to our expectations, however, we did not observe that current tobacco smokers who are physically active during leisure time were more likely to additionally use e-cigarettes, for example as part of an attempt to quit smoking. Our results contradict these expectations and differ from those of the Korean study which found that dual users were more physically active in their leisure time than exclusive tobacco smokers [23].

One possible explanation for this discrepancy is that, unlike our study, the Korean study assessed moderate and vigorous aerobic activity across multiple domains, including work, transport, and household activities. By contrast, we separated LTPA and OPA, and did not differentiate between moderate and vigorous LTPA. In this context, dual users in the Korean study may have appeared more active because some of their activity was work-related – typically less linked to health-conscious behaviour and more to occupational strain – rather than purely voluntary, as with LTPA.

In light of our findings, it could be speculated that even low levels of LTPA might prevent individuals from additionally taking up e-cigarettes. Furthermore, all tobacco smokers were surveyed regarding dual use, regardless of their smoking intensity. Therefore, it is possible that individuals with higher levels of physical activity already smoke less, experience fewer cravings [7] and consequently use e-cigarettes less frequently. However, the specific mechanisms underlying these associations remain unclear.

Occupational physical activity and smoking

In contrast to LTPA, higher levels of OPA were associated with a greater likelihood of being a current or ex-smoker. Among current tobacco smokers, being very active at work was associated with increased cigarette consumption (more than 20 cigarettes per day rather than fewer than 10) and a higher likelihood of dual use with e-cigarettes. This result contradicts our assumption that higher OPA levels are associated with lower dual use, as we attributed the increased use rather to higher socioeconomic status. However, OPA especially when physically demanding, do not provide the same psychological or physiological benefits as LTPA [12]. Instead, it might be associated with higher levels of stress or [13, 32], which in turn could increase the likelihood of smoking as a coping mechanism—particularly among individuals with lower socioeconomic status [33]. Thus, this may in turn further hinder the adoption of health-promoting behaviours and may among other reasons lead to higher dual use with e-cigarettes. Therefore, a higher dual use cannot be explained solely by socio-economic background, but may instead be attributed to psychological or social factors in different working environments. For example, some individuals may prefer e-cigarettes over tobacco cigarettes at the workplace due to the less noticeable odor. Depending on the specific work setting, the conditions may either facilitate or restrict smoking to varying degrees. However, this aspect was not considered in the present study.

Interaction effect between LTPA and OPA

To build upon previous findings, we examined the interaction effect of LTPA and OPA on smoking behaviour: individuals who were physically inactive during leisure time, but physically active at work were more likely to smoke and people who were physically active during leisure time, but not at work were less likely to smoke. Furthermore, people who are physically active during leisure time, regardless of their physical activity status at work, tend to smoke less cigarettes per day. However, it is important to note that such associations likely depend

on additional factors, such as individual motivation, readiness to change, and supportive environmental or social conditions that facilitate both physical activity and smoking reduction.

Several mechanisms may help explain these associations. In our recent study we could have shown that higher LTPA has been associated with lower nicotine cravings [7]. In addition, individuals who engage in LTPA often adopt broader health-conscious behaviour [15, 16]. Physiologically, endurance-based activities improve cardiovascular function [34] which is known to be acutely impaired by smoking [35]. This effect could make smoking less attractive for athletes or people who exercise during leisure time. Therefore, people who engage in LTPA may find it easier not to smoke or smoke fewer cigarettes per day, regardless of their OPA status, which is partly due to a combination of physiological and behavioural mechanisms.

Public health implications

Based on these findings, combining physical activity promotion with smoking cessation interventions may be particularly beneficial, as physical activity during leisure frequently co-occur with lower smoking rates and people tend to smoke less when being active during leisure, regardless of their OPA level. Moreover, the results indicate that smoking cessation interventions should especially target settings where physically demanding work is common, as smoking prevalence is particularly high in these occupational groups. This knowledge can help to implement educational campaigns or interventions targeting this behaviour. However, as the underlying mechanisms remain unclear, further research is needed to better understand how physical activity patterns during both leisure time and work relate to smoking behaviour.

STRENGTH AND LIMITATION

A major strength of this study is the use of a large, nationally representative dataset on LTPA and OPA and smoking outcomes. This allowed for a nuanced analysis of their independent and combined effects of physical activity in different settings and smoking behaviour. However, the study has some limitations. Our cross-sectional design does not allow for causal inference. Furthermore, self-reported data may be prone to social desirability bias which could have led participants to overestimate weekly amount of physical activity or underestimate smoking behaviours, potentially underestimating the true associations. Recall bias may also have affected the accuracy of reported physical activity and smoking behaviour. The study also lacks detailed information on the type and intensity of LTPA as well as information on the type of work. The intensity of LTPA or the working environment could also have an influence on smoking behaviour, which was not taken into account here. In addition, health status was not included as a control variable, which can influence both physical activity and smoking behaviour.

CONCLUSION

In conclusion, our findings revealed different associations between physical activity during leisure time and at work with smoking outcomes at a population level. LTPA was consistently associated with lower odds of current smoking, reduced tobacco cigarette consumption, and a lower likelihood of dual use with e-cigarettes, while higher OPA levels were linked to higher odds of current smoking, higher tobacco cigarette consumption and dual use. The results of the study show the importance of promoting sport activities during leisure time. Knowledge about the association with smoking behaviour can be used for public health campaigns for specific target groups. In addition, tobacco control efforts, including workplace smoking bans and smoking cessation programmes, should focus on physically demanding workplaces, where smoking prevalence is particularly high.

Declarations

Competing interests

None declared.

Patient consent for publication

Participation in the study was voluntary. The participants were informed about the aims and the contents of the study and about data protection. Informed consent was given verbally.

Ethics approval

The GEDA study has a strict compliance with the data protection provisions set out in the EU General Data Protection Regulation (GDPR) and the Federal Data Protection Act (BDSG) and has been approved by the Ethics Committee of the Charité – Universitätsmedizin Berlin (EA2/070/19).

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Author Contribution

Z.A. was mainly responsible for conceptualisation of the study; dataanalysis; drafting and revising of the manuscript. D.K., A.S., K.M. and S.K. contributed to the studydesign; data analysis and writing of the manuscript. All authors reviewed and approved the final version ofthe manuscript.

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Data Availability

Data are available upon reasonable request. The data supporting this study will be made available upon reasonable request to the RKI Institute.

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Tables

Table 1
Characteristics of study participants in the German Health Update Study
(weighted)

	Total sample†	Female[#]	Male
	% (n)	% (n)	% (n)
	100 (22,708)	51.1 (11,557)	48.9 (11,056)
Age, year (categories)	100 (22,708)	51.1 (11,557)	48.9 (11,056)
18–39	31.8 (7,229)	48.2 (3,467)	51.8 (3,728)
40–59	33.6 (7,620)	50.7 (3,846)	49.3 (3,745)
60+	34.6 (7,859)	54.2 (4,244)	45.8 (3,583)
Educational attainment [‡]	100 (22,596)	51.2 (11,513)	48.8 (10,990)
Low	29.6 (6,697)	49.3 (3,275)	50.7 (3,373)
Middle	52.3 (11,826)	54.2 (6,399)	45.8 (5,397)
High	18.0 (4,073)	45.3 (1,839)	54.7 (2,220)
Income [§]	100 (22,201)	50.8 (11,222)	49.2 (10,889)
Low	19.4 (4,304)	52.4 (2,229)	47.6 (2,024)
Middle	60.2 (13,370)	52.6 (7,022)	47.4 (6,317)
High	20.4 (4,527)	43.6 (1,971)	56.4 (2,548)
OPA [§]	100 (18,346)	50.1 (9,149)	48.9 (9,126)
very active	14.0 (2,564)	29.6 (755)	70.4 (1,799)
moderately active	38.6 (7,088)	58.5 (4,131)	41.5 (2,927)
not active	47.4 (8,694)	49.2 (4,263)	50.8 (4,400)
LTPA [§]	100 (22,485)	51.1 (11,451)	48.9 (10,940)
very active	15.4 (3,463)	39.7 (1,372)	60.3 (2,087)
moderately active	21.5 (4,828)	51.9 (2,497)	48.1 (2,310)
low active	29.3 (6,599)	56.3 (3,698)	43.7 (2,868)
not active	33.8 (7,594)	51.4 (3,884)	48.6 (3,675)

[†]Total sample data are presented as 100% in the columns in percentages (absolute numbers) and includes all respondents from the study. [#]Gender are presented as 100% within the rows; sum below 100% due to missing values. [¶]German equivalents to education attainment listed from lowest to highest: low = no qualification / junior high school equivalent, middle = secondary school equivalent, high = advanced technical college equivalent / high school equivalent. ^βIncome (OECD equivalent net monthly household income in € [36]). ^{\$}not active (mostly sitting or standing), moderately active (mostly walking or moderately strenuous physical activities), very active (mostly heavy physical work or physically demanding activities). ^{\$}not active (0 min/week), low active (1-150 min/week), moderately active (151–300 min/week), very active (> 300 min/week).

Table 2
Sample description (total sample) stratified by smoking outcomes (weighted).

	Total sample[†]	Current	Ex	Never
	% (n)	Smoker	Smoker	Smoker
	100 (22,708)	% (n)	% (n)	% (n)
		28.9 (6,562)	26.7 (6,058)	44.4 (10,079)
Occupational physical activity^{\$}	100 (18,346)			
Very active	14.0 (2,564)	46.1 (1,182)	23.2 (595)	30.7 (786)
Moderately active	38.6 (7,088)	28.9 (2,047)	26.6 (1,888)	44.5 (3,150)
Not active	47.4 (8,694)	26.1 (2,270)	25.3 (2,203)	48.5 (4,219)
Leisure time physical activity^{\$}	100 (22,485)			
Very active	15.4 (3,463)	28.2 (976)	27.1 (937)	44.8 (1,550)
Moderately active	21.5 (4,828)	24.7 (1,190)	27.5 (1,327)	47.8 (2,309)
Low active	29.3 (6,599)	24.7 (1,630)	27.5 (1,818)	47.8 (3,152)
Not active	33.8 (7,594)	35.7 (2,708)	25.1 (1,908)	39.2 (2,971)

Data are presented as percentages (absolute numbers). Sum below 100% due to missing values or rounding of cell frequencies. [†]Total sample includes all respondents and are presented as 100% in the columns. Occupational and leisure time physical activity stratified by smoking status and dual use are presented as 100% within the rows; sum below 100% due to missing values or rounding of cell frequencies. ^{\$}not active (mostly sitting or standing), moderately active (mostly walking or moderately strenuous physical activities), very active (mostly heavy physical work or physically demanding activities). ^{\$}not active (0 min/week), low active (1-150 min/week), moderately active (151–300 min/week), very active (> 300 min/week).

Table 3
Person characteristics stratified by occupational and leisure time physical activity (weighted).

	Occupational physical activity [§]			Leisure time physical activity [§]			
	% (n)			% (n)			
	very	moderately	not active	very	moderately	low	not active
Gender							
Female	8.3 (755)	45.2 (4,131)	46.6 (4,263)	12.0 (1,372)	21.8 (2,497)	32.3 (3,698)	33.9 (3,884)
Male	19.7 (1,799)	32.1 (2,927)	48.2 (4,400)	19.1 (2,087)	21.1 (2,310)	26.2 (2,868)	33.6 (3,675)
Age, year (categories)							
18–39	16.9 (1,150)	33.6 (2,292)	49.6 (3,382)	20.9 (1,496)	25.8 (1,851)	28.7 (2,055)	24.7 (1,770)
40–59	14.6 (1,006)	34.1 (2,351)	51.3 (3,532)	13.6 (1,026)	21.9 (1,657)	31.1 (2,353)	33.4 (2,528)
60+	8.8 (408)	52.8 (2,445)	38.4 (1,780)	12.2 (942)	17.0 (1,320)	28.3 (2,191)	42.5 (3,295)
Educational attainment [¶]							
Low	20.2 (905)	49.2 (2,199)	30.6 (1,367)	12.2 (804)	13.8 (911)	25.6 (1,693)	48.4 (3,197)
Middle	15.0 (1,521)	39.2 (3,969)	45.8 (4,647)	16.6 (1,947)	23.6 (2,760)	29.4 (3,445)	30.4 (3,563)
High	3.3 (120)	24.3 (889)	72.4 (2646)	17.4 (706)	27.7 (1,124)	35.3 (1,432)	19.6 (795)
Income [¶]							
Low	14.1 (425)	43.7 (1,315)	42.2 (1,268)	15.1 (640)	15.1 (639)	27.8 (1,181)	42.0 (1,785)
Middle	15.8 (1,726)	41.3 (4,500)	42.9 (4,675)	14.3 (1,899)	21.5 (2,851)	29.2 (3,868)	35.0 (4,633)
High	9.1 (367)	27.6 (1,110)	63.3 (2,550)	18.8 (844)	27.0 (1,212)	31.8 (1,427)	22.4 (1,005)

Data are presented as percentages (absolute numbers). Sum below 100% due to missing values. Person characteristics are stratified by occupational and leisure time physical activity and are presented as 100% within the rows; sum below 100% due to missing values. [¶] German equivalents to education attainment listed from lowest to highest: low = no qualification / junior high school equivalent, middle = secondary school equivalent, high = advanced technical college equivalent / high school equivalent. [¶] Income (OECD equivalent net monthly household income in € [36]). [§] not active (mostly sitting or standing), moderately active (mostly walking or moderately strenuous physical

activities), very active (mostly heavy physical work or physically demanding activities) [§]not active (0 min/week), low active (1-150 min/week), moderately active (151–300 min/week), very active (> 300 min/week).

Table 4
Associations between occupational and leisure time physical activity with smoking outcomes.

	Current vs. never smoker ^β		Ex vs. never smoker		> 20 cpd vs. <10 cpd [#]		10–20 cpd vs. <10 cpd		Dual use vs. single use [Ⓜ]	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
OPA[§]										
very active	1.70***	1.52; 1.90	1.22**	1.08; 1.39	1.32**	1.04; 1.67	1.17	0.93; 1.48	1.63***	1.24; 2.15
moderately active	1.17***	1.07; 1.27	1.06	0.97; 1.15	0.88	0.72; 1.08	1.06	0.88; 1.27	1.22	0.94; 1.57
not active	1		1		1		1		1	
LTPA[§]										
very active	0.60***	0.54; 0.67	1.08	0.96; 1.21	0.36***	0.28; 0.47	0.67**	0.53; 0.86	1.25	0.95; 1.64
moderately active	0.57***	0.51; 0.63	1.00	0.90; 1.11	0.38***	0.30; 0.49	0.66***	0.53; 0.83	0.56***	0.41; 0.78
low active	0.59***	0.53; 0.64	0.98	0.89; 1.08	0.52***	0.42; 0.65	0.72**	0.59; 0.89	0.60***	0.45; 0.81
not active	1		1		1		1		1	

[§]Occupational physical activity (OPA): very active (mostly heavy physical work or physically demanding activities), moderately active (mostly walking or moderately strenuous physical activities), not active (mostly sitting or standing = reference) [§]Leisure time physical activity (LTPA): very active (> 300 min/week), moderately active (151–300 min/week), low active (1-150 min/week), not active (0 min/week = reference) [#] cigarettes smoked per day (cpd) refers to current daily tobacco smokers (< 10 = reference). [Ⓜ] dual use of tobacco cigarettes and e-cigarettes, single use (= reference) means only tobacco cigarettes ***significant result $p < 0.001$ ** $p < 0.01$ * $p > 0.05$.

Table 5

Associations between interaction effects of occupational and leisure time physical activity with smoking outcomes

	Current vs. never smoker [§]		Ex vs. never smoker		> 20 cpd vs. <10 cpd [#]		10–20 cpd vs. <10 cpd		Dual use vs. single use [¶]	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Interactions^{&}										
OPA*LTPA	0.80	0.63; 1.01	0.97	0.76; 1.25	0.44***	0.33; 0.57	0.73**	0.56; 0.95	1.28	0.91; 1.82
OPA*No LTPA	1.37**	1.06; 1.77	0.98	0.73; 1.31	0.97	0.73; 1.30	1.04	0.78; 1.39	1.41	0.99; 2.01
No OPA* LTPA	0.55***	0.44; 0.70	0.76*	0.59; 0.97	0.36***	0.27; 0.48	0.64**	0.48; 0.84	0.86	0.60; 1.25
No OPA*No LTPA	1		1		1		1		1	

[§]Occupational physical activity (OPA): very active (mostly heavy physical work or physically demanding activities), moderately active (mostly walking or moderately strenuous physical activities), not active (mostly sitting or standing = reference) [§]Leisure time physical activity (LTPA): very active (> 300 min/week), moderately active (151–300 min/week), low active (1–150 min/week), not active (0 min/week = reference) [&]OPA and LTPA are binary coded in either being physically active or inactive, No OPA*No LTPA = reference [#] cigarettes smoked per day (cpd) refers to current daily tobacco smokers (< 10 = reference). [¶] dual use of tobacco cigarettes and e-cigarettes, single use (= reference) means only tobacco cigarettes ***significant result $p < 0.001$ ** $p < 0.01$ * $p > 0.05$

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