Patterns of cross-sectional and predictive physical activity in Swiss adults aged 52+: results from the SAPALDIA cohort

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Summary

BACKGROUND: Non-communicable diseases (NCDs) account for the vast majority of deaths in Switzerland. Insufficient physical activity (PA) is an established NCD risk factor and PA is known to be beneficial for physical and mental wellbeing. Sedentary behaviour (SB) is an additional, independent risk factor and associated with frailty in older adults. This study aimed at describing cross-sectional PA patterns in a general population sample of subjects aged 52 years and older (52+) from eight areas across different language regions of Switzerland. Additionally, the predictive association of self-reported PA for objectively measured PA was tested.

METHODS: Participants 52+ of the Swiss Cohort Study on Air Pollution And Lung and Heart Disease In Adults (SAPALDIA) who completed accelerometer data collection at the most recent follow-up (SAPALDIA4 in 2017/18) and provided information on determinants of interest (sex, age, body mass index [BMI], language region, education, employment status, civil status, smoking) were included in the analysis (n = 1314). The accelerometer-derived average time spent in different PA intensities (SB, light PA [LPA], moderate-to-vigorous PA [MVPA]) was estimated according to participant characteristics with control for season and wear time using multiple linear regressions. In further analyses, the predictive effect of changes in self-reported PA over roughly ten years between SAPALDIA2 (2001/02) and SAPALDIA3 (2010/11) (remaining inactive [RI]; becoming inactive [BI]; becoming active [BA]; remaining active [RA]) on the objectively measured SB, LPA and MVPA obtained seven years later by accelerometry (SAPALDIA4), was assessed using multiple linear regression models.

RESULTS: Overall, 21.7% of 52+ participants met the Swiss recommendations for subjectively assessed PA. Obese participants, 75+ year-olds, smokers and subjects living alone spent more time in SB and less time in LPA and MVPA compared with participants with a BMI below 25 kg/m^2, between 52 and 64 years old, not smoking and

being married, respectively. Residents living in the French-speaking part of Switzerland were less likely to engage in MVPA compared with residents from the German-speaking part and thus were less likely to meet the PA recommendations. A trend for increasing PA and decreasing SB was observed consistently across the four groups (RI, BI, BA, RA) of predictive self-reported PA patterns with participants remaining active over the course of roughly ten years showing highest levels of PA and lowest levels of SB measured objectively at SAPALDIA4.

CONCLUSION: The high proportion of SB points to the need of physical activity promotion for the older part of the population in Switzerland. According to our data, behavioural changes in PA are possible and sustainable as we can see in the group of participants becoming active and this is essential for health promotion recommendations.

Keywords: physical activity, sedentary behaviour, accelerometry, cohort, older adults

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ABBREVIATIONS:

BA	becoming active
BI	becoming inactive
BMI	Body Mass Index
LPA	light physical activity
MPA	moderate physical activity
MVPA	moderate-to-vigorous physical activity
NCD	non-communicable disease: PA = physical activity
RA	remaining active
RI	remaining inactive
SAPALDIA	Swiss Cohort on Air Pollution And Lung and Heart Disease In Adults
SB	sedentary behaviour
UI	uncertainty interval
VPA	vigorous physical activity

Introduction

In Switzerland, non-communicable diseases (NCDs) accounted for 90.2% (95% uncertainty interval [UI] 89.9–90.5%) of deaths in 2017 [1]. The most important, but not modifiable, risk factor for NCDs is the ageing of the population; the latter accounted for 19.5% (95% UI 17.3–22.0%) more deaths between 2006 and 2016 [2]. Several personally and not personally modifiable risk factors, such as dietary risks, tobacco consumption, air pollution, and low physical activity (PA), as well as excess weight also contribute to NCD risk and are important targets for primary prevention [2].

Low PA is of particular interest as people can be positively encouraged to engage in a health promoting behaviour, whereas for most other NCD determinants recommendations go in the direction of prohibition. Remaining physically active reduces all-cause mortality [3]. Physical inactivity increases the risk of several diseases, such as type 2 diabetes [4], cardiovascular disease [5] and chronic obstructive pulmonary disease [6], as well as mental disorders such as depression [7]. Sedentary behaviour (SB) is increasingly recognised as having adverse health effects even in people who engage in moderate and vigorous levels of PA [8]. Most importantly and of particular relevance for the older part of populations, SB has been shown to have a negative impact on frailty in elderly [9] and on all-cause as well as cardiovascular mortality [10].

Effective PA promotion relies on an in-depth understanding of the distribution of PA and SB in population subgroups. So far, several studies have looked at correlates of PA and SB in older adults. As a first limitation, most of them were of cross-sectional design [11]. Cohort studies are of great value for studying longitudinal course and persistency of lifestyle patterns, as it is ultimately the chronicity of lifestyle that influences health and disease. Cohort studies also help to identify life course periods such as retirement [12] where people are particularly susceptible to decreasing PA or receptive to increasing PA. These studies then also help to identify determinants of temporal PA changes [13]. A second limitation of many studies was their relying on self-reported PA and SB. The validity of self-reported observations is hampered by recall bias, social desirability and the lack of precision in rating PA intensities. These problems are likely leading to an overestimation of vigorous PA (VPA) [14]. Therefore, objectively measured PA and SB is a reliable alternative. Finally, PA differs between [15] and also within countries and cultures [16], making it difficult to transfer observed PA patterns from one country to another.

There is a lack of knowledge about objectively measured PA patterns in older Swiss adults and little is known about the existence of subgroups at increased risk of inactivity. According to the Swiss Health Survey, 76% of Swiss residents above 15 years of age reported sufficient activity according to Swiss recommendations for subjectively assessed PA [17]. In the subgroup of persons 55 years and older, the percentage meeting these recommendations ranged from 58% in 75+-year-old females to 82% in 65- to 74-year-old males [18]. The above studies relied on self-reported PA, for which the Swiss PA recommendations advise spending at least 150 minutes per week in moderate PA (MPA) or 75 minutes in VPA [19]. Despite being de-

veloped on the basis of self-reported data, these recommendations are also widely used in accelerometer studies [20–22].

Therefore, general population data including objectively measured PA data collected in the context of the SAPALDIA cohort was applied to (a) investigate the distribution of mean minutes spent in different PA levels including SB in the older part of the Swiss population and subgroups thereof; (b) understand to what degree these population groups meet Swiss recommendations for PA; and (c) test if self-reported PA patterns over a period of 10 years are predicting objectively measured PA 7 years later. SAPALDIA participants come from different geographical and cultural contexts in Switzerland. Cultural differences in Switzerland are related to the three language regions, but could also refer to different lifestyles and attitudes [23].

Materials and methods

Sample

This study was embedded into the Swiss Cohort on Air Pollution And Lung and Heart Disease In Adults (SAPALDIA). SAPALDIA was initiated in 1991, when random samples of persons aged 18 to 60 were selected from population registries in eight geographically and culturally different Swiss regions (Basel, Wald, Davos, Lugano, Montana, Payerne, Aarau, Geneva) [24]. Baseline participants (SAPALDIA1; n = 9651) were invited for follow-up interviews and examinations three times for SAPALDIA2 in 2001/2002 (n = 8047), SAPALDIA3 in 2010/2011 (n = 6088), and SAPALDIA4 in 2017/2018 (n = 5149). In the third follow-up (SAPALDIA4), participants aged 52 years and older were invited for a 52+ health assessment. The 52+ participants were also invited to wear an accelerometer for at least 8 days prior to the health assessment. 1746 participants underwent a 52+ health assessment at a local study centre and 1402 52+ participants also completed the accelerometer data collection.

The SAPALDIA cohort study protocol complies with the Declaration of Helsinki. All participants provided written informed consent at each survey. Ethical approval was obtained from the Ethics Committee northwest/central Switzerland (EKNZ) as lead agents (EKNZ PB_2016-02348) as well as from the respective regional ethics committees.

Objectively measured physical activity and sedentary behaviour at SAPALDIA4

The main outcomes of the study were the minutes per day spent in the different PA levels, including SB, which were objectively measured using the accelerometer model ActiGraph wGT3X-BT. ActiGraph accelerometers measure on three axes with a dynamic range of ± 8 G [25]. In this study, only data from the vertical axis were analysed for reasons of comparability with published studies [20, 26]. The data was measured by a 12 bit analogue to a digital converter at a rate of 30 Hz [25]. The participants were instructed to wear the accelerometer on the right hip either above or below their clothes during the daytime over a period of 8 days. Participants were instructed not to wear the device while performing water activities, such as taking a shower or swimming. Participants filled in a diary during

the time that they were wearing the accelerometer, indicating particular periods when the device was not worn. ActiLife software (v6.13.3) was used to extract and score data recorded with an epoch time of 5 seconds. A non-wear period was defined as zero counts for 60 minutes with a tolerance of 2 minutes [27]. For scoring of PA, different cut offs were defined, based on Troiano et al. [28] as depicted in table 1. Accelerometry data was considered valid for days where the accelerometer was worn for at least 10 hours [28] and for participants providing data for at least four valid days with a minimum of three weekdays and a minimum of one weekend day as recommended by Trost et al. [30].

Self-reported predictive physical activity at SAPALDIA2 and SAPALDIA3

Self-reported PA at SAPALDIA2 and SAPALDIA3 were investigated as predictors of the primary endpoint (objectively measured PA at SAPALDIA4). Self-reported PA was assessed with the help of standardised and validated [31] questionnaires (long International Physical Activity Questionnaire [32]) in the first and the second follow-up. Based on self-reported minutes spent in MPA and VPA, participants were categorised into those "meeting the recommendations" and those "not meeting the recommendations" in SAPALDIA2 and SAPALDIA3. Based on the changes in fulfilling versus not fulfilling the recommendations from SAPALDIA2 to SAPALDIA3, predictive PA was derived and grouped into four categories: remaining inactive (RI), becoming inactive (BI), becoming active (BA) and remaining active (RA), as described elsewhere [33].

Determinants of physical activity and sedentary behaviour

Information on sex, residential language region (Swiss German; French; Italian) and education level (low: primary school; medium: secondary school, middle school or apprenticeship; high: technical college or university) was derived from the baseline questionnaire. Age (categorised into 52–64, 65–74 and ≥75 years), employment status (employed, house person, pensioner and other) and civil status (married [including registered relationship], divorced [including living apart], widowed [including partner died] and single) as well as smoking status (never, former and current) were derived from a questionnaire administered at the third follow-up (SAPALDIA4), when accelerometry was applied. Body mass index (BMI; weight in kg / height in m squared) was derived from measurements at SAPALDIA4 and categorised into: normal/underweight: BMI <18.5–24.9 kg/m² (only 0.9% of participants were underweight) and overweight: 25.0–29.9 kg/m²; obese: ≥30 kg/

m²). All covariates were considered as categorical variables.

Statistical analysis

All analyses were done using STATA/IC 15.1. In a first step to evaluate participation bias, we compared characteristics at baseline (SAPALDIA1) for those participating in the SAPALDIA4-52+-assessment and those who did not participate in the accelerometry study, but had attained age 52+ at the time of SAPALDIA4, using a logistic regression model (supplementary table S1 in appendix 1).

In a second step, chi²-tests were performed to evaluate bias due to invalid accelerometry data. We compared characteristics of SAPALDIA4 52+ participants providing valid versus non-valid accelerometry data. Participants with invalid data were excluded from further analyses.

In a third step, the distribution by sex and age for SB and PA determinants (BMI, language, education, civil, employment and smoking status) were analysed, using chi²-tests.

Next, the distribution of SB and PA in the overall study population was calculated as average daily minutes spent in the respective PA intensity, stratified by sex and age. This allowed assessment of the time spent in each intensity by participants. In addition, the total percentage of participants fulfilling the Swiss recommendations for PA was determined. The characteristics of the participants who fulfilled the Swiss recommendations for PA were then compared to the ones who did not fulfil them, using univariate logistic regression.

In a fifth step, the determinants of PA and SB were assessed in the context of three separate linear regression models assessing associations of covariates with (1) SB, (2) light PA (LPA), and (3) moderate-to-vigorous PA (MVPA), respectively. We first tested the association of each covariate with these outcomes separately in the context of univariate regression models (table S2). We next tested the mutually adjusted associations of the covariates with these outcomes in the context of multiple linear regression models. Association results are presented as (adjusted) mean minutes spent in the three different PA intensities according to covariate level. Because of skewness of the residuals in MVPA, bootstrap methods had to be applied using 1000 bootstrap samples, a very general technique that allowed us to derive confidence intervals making only very limited assumptions about the probability distribution of the outcome [34]. All models were adjusted for wear time and season. Effect modification by sex (categorical), age (categorical), BMI (categorical) and smoking (categorical) was tested by including according interaction terms with all covariates in the models. Using backward selection, interactions not reaching the significance level of 0.05 were excluded from the regression models. All analyses including linear regression and bootstrap methods took into account inverse probability weighting in order to control for unbalanced missing data across the different categories of the determinants.

In a last step, predictive analyses were performed to investigate the predictive association of the four long-term PA categories (RI, BI, BA, RA) derived from self-reports at SAPALDIA2 and SAPALDIA3, roughly 10 years apart, with objectively measured PA at SAPALDIA4 7 years later. These three predictive multiple linear regression models

Table 1: Definition of cut offs used for physical activity intensities.

Intensity	Counts per minute	Metabolic equivalent of task	Activity example
Sedentary	0–99	>1.5	Sitting
Light	100–2019	1.5–3	Casual walking*
Moderate	2020–5998	3–5.99	Brisk walking*
Vigorous	≥5999	≥6	Running*

* US Department of Health and Human Services [29]

(one for each PA level) contained the same covariates as the cross-sectional models. Results are reported as adjusted mean minutes spent in the different PA intensities.

Results

All SAPALDIA4 participants aged 52+ who took part in the accelerometer examination and additionally provided information on all relevant covariates were included in the first and second step of the analysis (n = 1381; fig. 1).

Participants in the accelerometry study whose data were not valid (n = 67) differed only in BMI and civil status from subjects with valid data (supplementary table S2 in appendix 1). Participants with non-valid data were excluded from further analyses. Overall, 1314 participants with valid accelerometry data were included in the subsequent analyses. Table 2 depicts the characteristics of these participants, of whom 51.3% were male and 48.7% female. The mean age of the participants was 67.9 years (standard deviation [SD] 7.9). Whereas 41.3% and 40.1% of the participants were normal/underweight and overweight, respectively, only 18.6% were in the obese group. The participants represented the three language regions of Switzerland. The distribution of education and civil status differed for males and females in all age groups. The proportion of males having higher education was greater than the proportion of females, in all age groups. In the youngest age category, a higher proportion of males were married compared with their female counterparts and the proportion of

being a house person was greater in females than in males. Smoking status and BMI were equally distributed in the youngest and oldest age groups, respectively.

Figure 1: Participation from SAPALDIA1 to the current accelerometry study among participants aged 52+ at SAPALDIA4 (1991–2018).
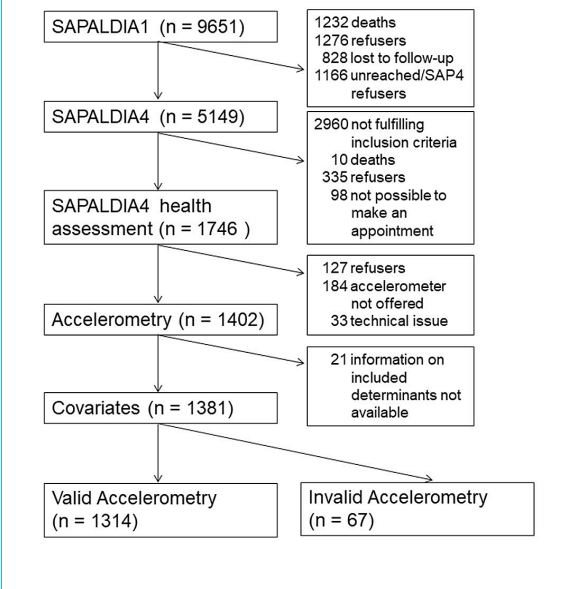

Table 2: Characteristics of participants in the SAPALDIA4 55+ accelerometer sub-study, by sex and age group.

		Age categories								
		52–64			**74**			**75+**		
		Male (n = 222)	**Female (n = 231)**	**p-value[*]**	**Male (n = 311)**	**Female (n = 287)**	**p-value[*]**	**Male (n = 141)**	**Female (n = 122)**	**p-value[*]**
	n	%	%		%	%		%	%	
Language region										
German	721	53.6	47.6		59.2	55.1		58.2	55.7	
French	444	36.9	42.0		30.2	31.4		28.4	33.6	
Italian	149	9.5	10.4	0.44	10.6	13.6	0.45	13.5	10.7	0.58
BMI (kg/m^2)										
<25	543	31.1	61.9		28.6	47.7		38.3	41.8	
25–30	527	49.1	26.8		52.4	30.7		43.3	36.1	
>30	244	19.8	11.3	<0.001	19.0	21.6	<0.001	18.4	22.1	0.47
Education level										
Low	39	1.8	1.7		1.6	5.6		1.4	6.6	
Middle	826	53.2	73.6		53.7	72.1		52.5	73.8	
High	449	45.0	24.7	<0.001	44.7	22.3	<0.001	46.1	19.7	<0.001
Employment status										
Employed	425	86.9	76.2		11.3	5.9		1.4	1.6	
House person	38	0.5	10.4		0.6	3.1		0.0	1.6	
Pensioner	827	8.1	8.2		87.8	90.6		98.6	96.7	
Other	24	4.5	5.2	<0.001	0.3	0.3	0.02	0.0	0.0	0.31
Civil status										
Married	871	73.9	60.6		78.1	57.5		76.6	41.8	
Divorced	201	14.9	18.2		11.9	22.6		8.5	9.8	
Widowed	120	0.9	7.4		4.2	9.8		9.9	37.7	
Single	122	10.4	13.9	0.001	5.8	10.1	<0.001	5.0	10.7	<0.001
Smoking status										
Never	549	40.5	46.8		35.0	44.6		30.5	58.2	
Former	591	41.0	34.2		51.4	46.0		61.0	35.2	
Current	174	18.5	19.0	0.30	13.5	9.4	0.04	8.5	6.6	<0.001

* Comparison of sex using chi^2 test

Figure 2 shows how much time the participants spent in SB, LPA and MVPA during a whole day. Most of the time they were in a sedentary state, and for only around 5% of the daytime were they engaged in MVPA.

In table 3, the mean number of minutes spent in different PA levels are presented according to mutually adjusted participant characteristics and additionally adjusted for wear time and season. PA level differences were observed with regard to sex, age, BMI and smoking status. Females tended to have less SB and MVPA whilst having more LPA compared with males. Participants aged 75+, obese participants and smokers were more likely to have a sedentary lifestyle and were less likely to spend time in LPA and MVPA compared with their youngest counterparts, the under- and normal-weight participants and non-smokers, respectively. Interestingly, MVPA differed by the residential language region. Swiss residents living in the German part spent more time in MVPA compared with residents living in the French and Italian parts of Switzerland. Moreover, the civil status was observed to be a determinant for SB and LPA. Age, sex, BMI and smoking did not modify any of the above associations. The non-weighted analyses were comparable to the weighted results (data not presented).

Overall, 21.7% of the participants fulfilled the Swiss recommendations for PA. The recommendations were less likely to be fulfilled by subjects aged 75+, by overweight or obese participants, by Swiss residents living in the French or Italian speaking region, by current smokers and by widowed compared with participants who were be-

tween 52–64 years old, of normal weight, from the German speaking part, non-smokers and married (fig. 3).

Participants who self-reportedly remained active over a period of about 10 years from SAPALDIA2-3 were ,7 years later, less likely to spend time in a sedentary state and more likely to spend time in LPA and MVPA than those self-reporting less consistent PA patterns (fig. 4, table S4). Participants remaining active spent 25.17 (17.22–33.10) minutes per day less in SB, and 12.34 (6.66–18.02) minutes per day and 11.74 (8.98–14.50) minutes per day more in LPA and MVPA, respectively, compared to participants remaining inactive. We observed consistent trends for decreasing SB and increasing LPA and MVPA from those remaining inactive, to those becoming inactive, becoming active, and remaining active.

Discussion

The main results of this study showed that patterns of PA levels in a Swiss general population sample aged 52+ depended especially on age, BMI, smoking and sex at lower levels of PA, whereas MVPA intensity differed by language region and SB by civil status. We expected to find socioeconomic differences, but no association was found for educational level. A rather high percentage of the participants met the recommendations of Swiss PA guidelines.

Comparison of the results of this accelerometry-based study with those for self-reported PA obtained in the population-representative Swiss Health Survey 2017 showed that our results for the main correlates of PA are principally

Figure 2: Average daily minutes (number in boxes) and percent of accelerometer measuring time (x-axis) spent in different levels of physical activity intensity, by sex and age group (n = 1314).
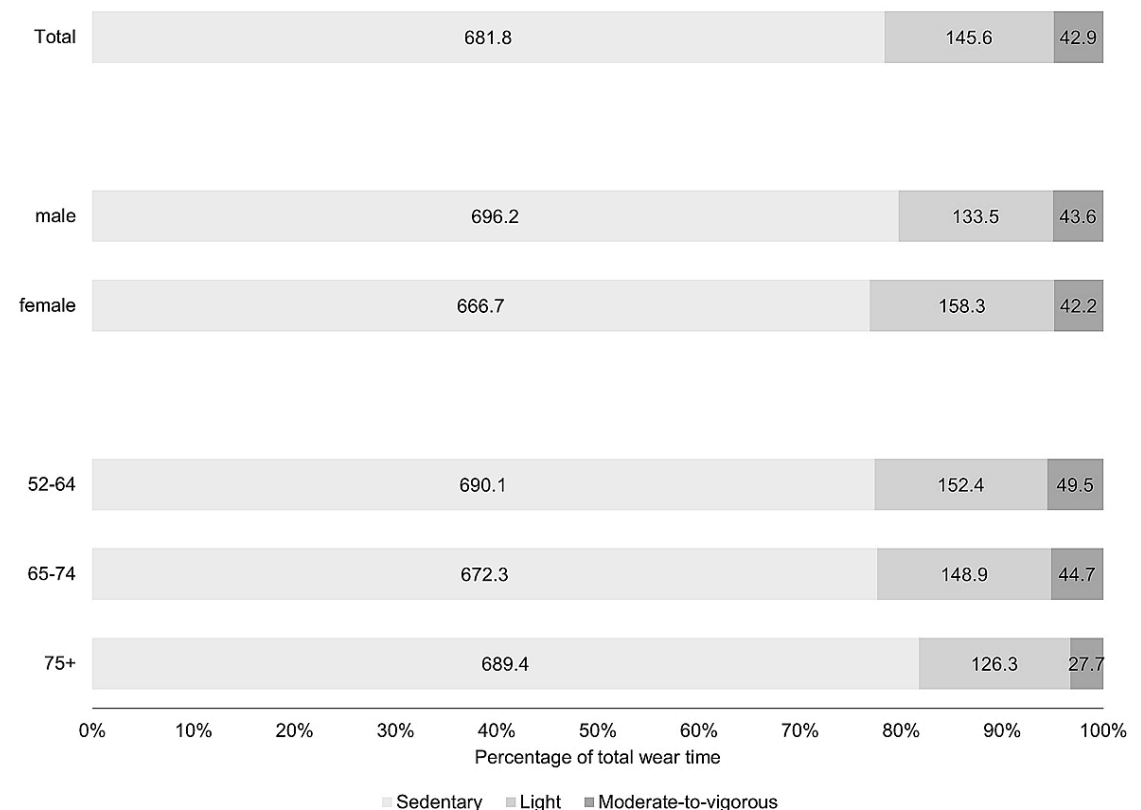
in line [17]. According to the Swiss Health Survey, it was estimated that 76% of adults were sufficiently active, meaning that they met the Swiss PA recommendations [17]. The prevalence decreased from 73.7% in older adults between 55 and 64 years old to 64.4% in those aged 75+ year [18]. Thus, the observed age trend was similar to the one in this current study, but the overall prevalences of PA were higher. The higher prevalence of being categorised as physically active in the Swiss Health Survey is most likely explained by the fact that subjective measurements are prone to recall and response bias [35] and generally lead to an overestimation of PA and an underestimation of SB compared with objectively obtained data [31, 36].

The overestimation of PA might mask association with determinants, such as education, if the overestimation differs by persons in the subgroups. Previous studies, including our own, observed that the difference in PA according to educational level was smaller when PA was measured objectively as compared with self reports [37, 38]. This is al-

so what we see when comparing our results with the Swiss Health Survey. In contrast to our data, the Swiss Health Survey pointed out the importance of educational background related to PA [17]. Whereas 61% of Swiss residents having a low education level were sufficiently active, this was true for 79% of highly educated residents. However, as socio-demographic differences are also inconsistently observed between studies that relied on objectively measured PA, more research considering a range of socio-demographic factors is needed to improve understanding of how these factors impact on PA in a culture- as well as social- and physical environment-specific context.

Previously reported prevalences of fulfilling recommendation for subjective PA ranged from 1% to 31% in older adults [26, 28, 39–41], depending on the thresholds and bouts (contiguous activity periods) used to determine the adherence to PA recommendations. Thus the overall prevalence of 21.7% observed in our data seems to exceed observations in other accelerometer-based studies. Neverthe-

Table 3: Mutually adjusted mean minutes per day† spent in specific levels of physical activity intensity (n = 1314), according to patient characteristics‡.

	Sedentary§	Light¶	Moderate-to-vigorous‖
	Adjusted mean (95% CI)	Adjusted mean (95% CI)	Adjusted mean (95% CI)
Sex			
Male (ref.)	693.4 (688.4–698.4)	130.1 (126.5–133.8)	41.3 (38.7–43.6)
Female	671.8 (667.0–676.6)***	155.5 (151.8–159.2)***	37.6 (35.5–39.7)*
Age			
52–64 (ref.)	665.9 (657.6–674.3)	151.6 (145.4–157.9)	47.2 (43.4–50.9)
65–74	675.6 (670.5–680.7)	146.8 (143.0–150.7)	42.4 (39.9–45.2)*
75+	708.4 (700.7–716.0)***	129.6 (123.9–135.4)***	26.9 (23.6–30.6)***
BMI (kg/m2)			
<25 (ref.)	672.3 (666.8–675.0)	145.8 (141.8–149.9)	46.7 (44.1–49.3)
25–29.9	679.7 (675.0–684.5)*	145.5 (141.9–149.1)	39.6 (37.3–41.8)***
≥30	700.9 (693.8–708.1)***	135.9 (130.5–141.3)**	28.0 (25.2–31.2)***
Language region			
German (ref.)	682.6 (678.3–686.9)	140.5 (137.4–143.6)	41.7 (39.4–44.0)
French	682.7 (677.3–688.1)	145.5 (141.3–149.7)	36.6 (34.3–39.1)**
Italian	679.0 (669.8–688.2)	148.1 (140.8–155.4)	37.7 (34.5–40.9)*
Employment			
Employed (ref.)	685.3 (677.0–693.6)	139.7 (133.6–145.9)	39.8 (36.2–43.7)
House person	682.3 (662.6–702.0)	147.4 (132.8–161.9)	35.4 (28.0–44.3)
Pensioner	679.9 (675.2–684.6)	145.2 (141.6–148.8)	39.7 (37.4–41.9)
Other	714.5 (690.2–738.8)*	124.0 (105.1–143.0)	26.5 (17.2–36.7)*
Education level			
Low (ref.)	678.7 (661.0–696.4)	148.1 (134.6–161.6)	38.1 (32.2–44.4)
Middle	679.7 (675.6–683.7)	145.6 (142.6–148.7)	39.5 (37.6–41.4)
High	688.9 (683.8–697.1)	136.7 (132.9–140.5)	39.3 (36.7–42.2)
Civil status			
Married (ref.)	678.6 (674.4–682.9)	146.3 (143.1–149.6)	39.9 (37.9–41.8)
Divorced	685.9 (676.6–695.3)	139.5 (132.6–146.4)	39.4 (35.5–43.7)
Widowed	687.5 (678.3–696.7)	138.8 (131.9–145.7)	38.4 (34.5–42.9)
Single	692.0 (683.8–700.1)**	135.6 (129.6–141.5)**	37.3 (32.8–41.8)
Smoking status			
Never (ref.)	677.8 (673.3–682.3)	146.0 (142.6–149.4)	41.0 (38.9–43.0)
Former	680.6 (675.4–685.8)	144.5 (140.6–148.4)	39.8 (37.3–42.1)
Current	696.7 (688.0–705.5)***	133.7 (127.3–140.1)**	34.3 (30.2–38.2)**
Season			
Spring (ref.)	676.3 (667.9–684.6)	148.9 (142.4–155.4)	39.8 (35.9–44.1)
Summer	680.2 (671.8–688.7)	146.7 (140.2–153.1)	38.0 (34.4–41.8)
Autumn	680.8 (676.0–685.6)	144.2 (140.6–147.7)	39.9 (37.4–42.1)
Winter	687.1 (681.0–693.2)*	138.4 (133.9–142.9)**	39.2 (36.6–41.8)

CI = confidence interval; CPM = counts per minute; ref. = reference * p-value ≤0.05; ** p-value ≤0.01; *** p-value ≤0.001 † Adjusted mean minutes were derived from three separate multiple linear regression models, one for each level of physical activity, containing all the listed covariates as independent variables ‡ In addition adjusted for wear time § 0–99 CPM ¶ 100–2019 CPM ‖ ≥2020 CPM

less, from a health perspective the current observed PA prevalence in Switzerland may still be considered as too low to compensate for the assumed adverse health effects of SB [8]. Physical inactivity, and thus SB, is an acknowledged risk factor and considerably related to adverse health conditions [8–10]. Being physically active has been shown to benefit health whereby a certain dose-response can be observed [42].

To further promote PA and prevent too much sedentariness past age 50, this study has identified important target groups. We identified important biological, socioeconomic, cultural and lifestyle factors as associated with SB and PA (e.g., sex, age, language region, smoking and BMI). For instance, obese participants in particular spent more time in SB and were less physically active compared with subjects with a BMI below 25 kg/m², as observed in other

Figure 3: Number (boxes) and percent (x-axis) of participants meeting the Swiss recommendations for Physical Activity (150 minutes in moderate physical activity or 75 minutes in vigorous physical activity) according to participant characteristics using logistic regression. An asterisk * indicates a statistically significant difference between the groups at p-value ≤0.05.
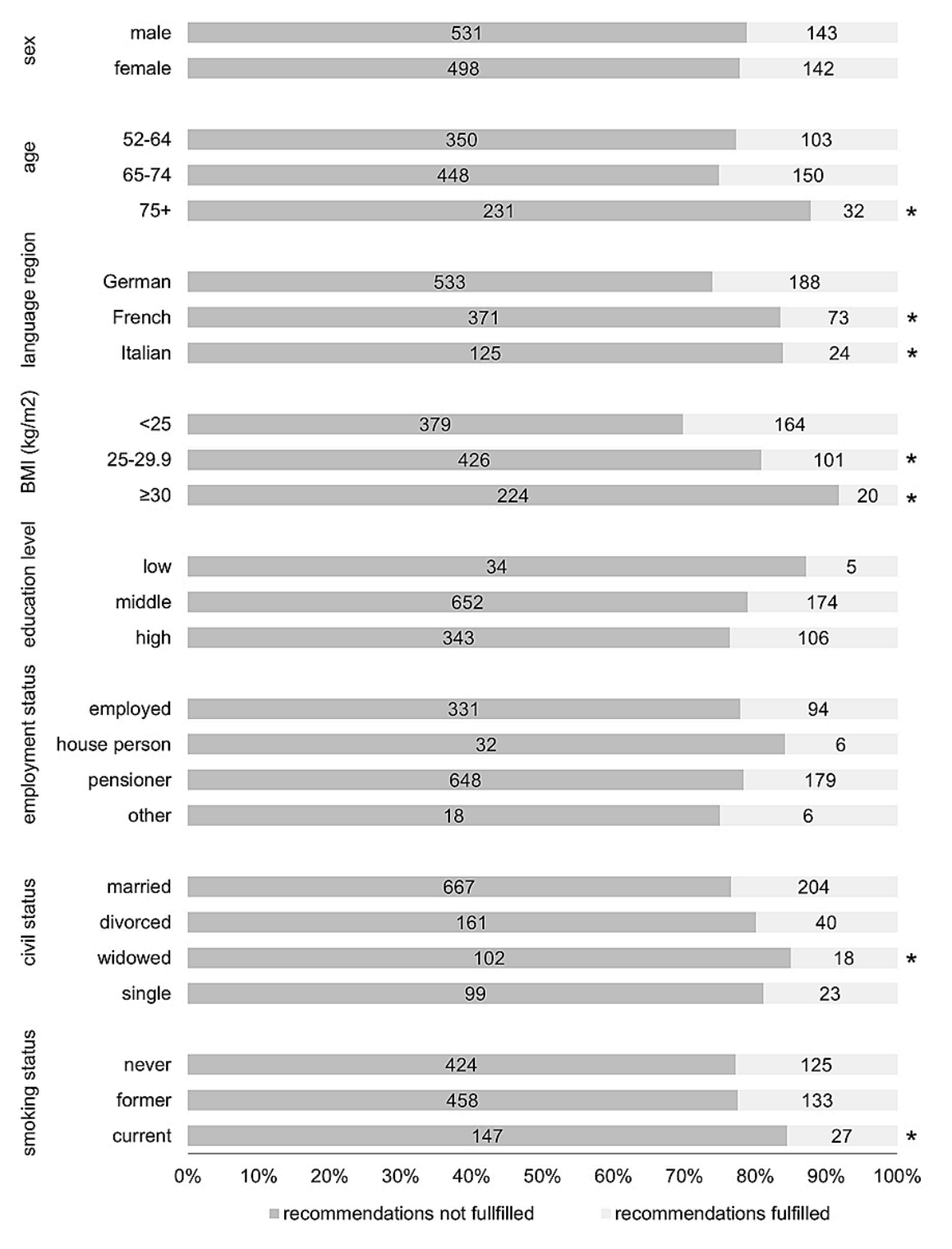
studies [26, 43]. In previous studies, a more attenuated age-related increase in BMI was observed in participants being constantly physically active [3], also in younger SAPALDIA participants [44]. Furthermore, smoking is likely to have an adverse impact on PA in part by influencing respiratory and cardiac function [45]. In our study, only current smokers spent statistically significantly more time in SB and less in LPA and MVPA than never smokers. In a previous study, conducted in a much younger age group, the smoking effect on PA was observed to be independent of the quantity and the frequency of smoking [46].

From a prevention perspective, the results of this study point to the importance of intervening at younger ages. Our predictive results demonstrate that SB and PA patterns are established over decades. Remaining active as well as becoming active is possible and seemed to have a sustainable effect: Participants becoming active had less SB and were more physically active than those who remained or became inactive even 7 years later. From a health perspective, it seems never too late to become active. Being physically active was previously shown to be associated with the greatest health gains among those who had been barely active before [47].

But it is also important to consider specific needs in maintaining PA at a more advanced age. Higher age has been seen to reduce balance, strength and coordination and thus to increase the risk of falling [48]. Consequently, the worry of falling was identified as one of the barriers to engage in PA among older adults [49]. It is important to avoid a vicious cycle among older adults whereby they are not physically active out of fear of falling and thereby further deteriorate with regard to balance, strength and coordination. In the current study, this vicious cycle could be part of the explanation for the more sedentary lifestyle and lower PA observed in the age group of 75+. Comparable associations between age and PA levels have also been reported in Norwegian [26, 50] and English studies [13].

An additional important aspect to consider in PA promotion in the older groups of population is the lack of a partner, which becomes more frequent with aging. Not having a partner was previously reported as barrier to being physically active [49]. This complements our finding that single and widowed subjects were less physically active and having a more sedentary lifestyle than married participants, similarly observed in other studies [51, 52]. Cobb et al. (2016) confirmed that the PA of a spouse influences the partner's PA [53]. PA engagement in specific domains, such as dancing and hiking, are also known to fight loneliness among older adults. The loneliness ministry in the UK established the prescription of dancing courses, which are refunded by the National Health Service, to older adults [54]. Some municipalities in Switzerland offer health promotion such as group activities (e.g., "zämegoloufe") [55].

Finally, of interest to PA promotion in the multicultural Swiss context is the observed difference in PA patterns across language region. The Swiss Health Survey reported 79% of Swiss from the German-speaking part were sufficiently active compared with 67% and 68% of their counterparts from the French- and Italian-speaking parts, respectively [17]. Our data support the observation that older adults from the German-speaking part are more likely to meet the recommendation for subjective PA than residents from the French- and Italian-speaking parts. Corresponding regional differences have previously been reported for younger age groups. French-speaking children in Switzerland were reported to be less physically active and more sedentary than children from other language regions [56, 57]. A study in a bilingual city in Switzerland showed that the difference between French- and German-speaking children may be culturally rooted as French-speaking children spent less time playing vigorously outdoors [58] and were more often brought to school by car [59], despite similar characteristics of the built environment and the infrastructure. Language region differences in PA patterns observed in the SAPALDIA study were similar to PA differences between respective neighbouring countries. The majority of Italians and French never perform VPA, whereas it is the minority of Germans who never engage in VPA [60].

Strengths and limitations

Objective measurements of PA in a general population is a clear strength of our study, because so far SB and PA studies in adults in Switzerland were mostly based on subjectively measured PA. The objective measurement improves precision and prevents recall bias, which is an issue in self-reported PA [35]. Unfortunately, the accelerometer does not measure activities such as carrying weight or activities

Figure 4: Adjusted mean minutes per day in specific levels of physical activity intensity objectively measured at SAPALDIA4 (2017/18), according to self-reported moderate-to-vigorous physical activity change patterns from SAPALDIA2 (2001/02) to SAPALDIA3 (2010/11) (remained inactive n = 87; became inactive n = 162; became active n = 175; remained active = 729 according to Swiss recommendation for Physical Activity cut-offs). All analyses were adjusted for sex, age, body mass index, language region, education, employment status, civil status, smoking status, wear time and season An asterisk * indicates a p-value of ≤0.05.

§ based on multiple regression models adjusted for sex, age, language region, BMI, education, employment status, civil status, smoking status, wear time and season asterix indicates a p-value ≤0.05
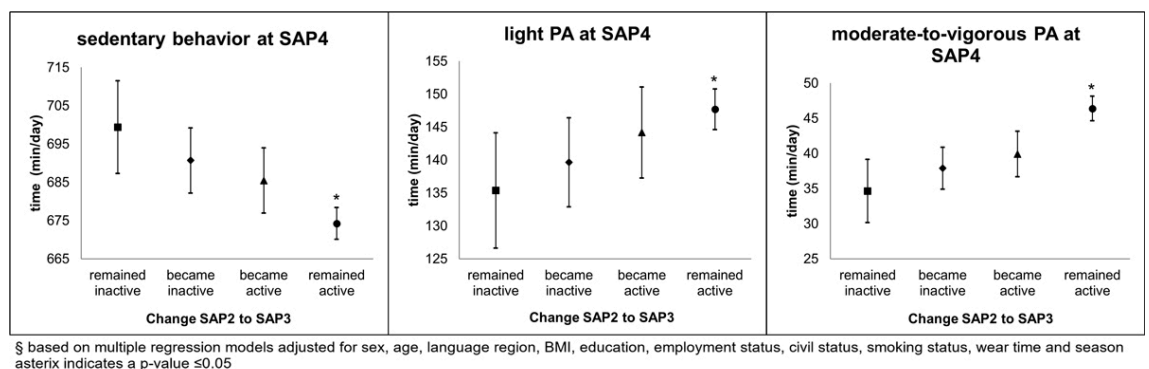
related to water. This can result in an underestimation of relevant aspects of PA, particularly in older adults. An additional strength of the cohort study was its large sample size of 1314 participants. The cohort was population-based with participants recruited as random samples in eight different communities in 1991. This allows in principle the results to be generalised to the Swiss population. Furthermore, the extensive characterisation of participants allows study of independent associations of PA with many factors. The SAPALDIA cohort was conducted in the three main cultural regions of Switzerland. These regions have a similar education system and legal background and it was therefore possible to investigate culturally patterned PA.

The participants included in this analysis were recruited in 1991 and followed-up over 25 years and therefore there is a risk of sample bias. Unfortunately, PA was not assessed at baseline in SAPALDIA. We can therefore not estimate how this selection influenced our assessment of the prevalence of PA patterns in the general Swiss population. Compared with participants at baseline, the persons still participating in the health assessment including accelerometry were more likely to be male, from the German-speaking part of Switzerland, under- or of normal weight, employed or pensioner, of middle or high education and never smokers. As these characteristics were associated with PA in different directions, and these characteristics might influence participation at follow-up differently across PA levels, it is difficult to assess the bias this may cause in estimating PA and its determinants in the general population of Switzerland. The fact that we identified comparable trends and determinants of PA as in the Swiss Health Study provides some assurance about the generalisability of our results. Also, the consistency of our results with PA determinants in other studies strengthens the validity of our observations. Another potential weak point of the study is the fact that it did not consider data from the x- and z-axes of triaxial accelerometry. However, studies with the prior version of the accelerometer (GT3X) showed that the x- and z-axes did not necessarily add information beyond data from the y-axis for assessing the level of PA in the population according to recommendations [61]. Restricting analysis to data from the y-axis strengthens comparability with data from previous studies. It is important to point out, though, that objectively measured PA was tested against recommendations derived for subjectively obtained PA. As subjectively and objectively measured PA can show considerable discordance, the applied recommendation cut-offs may not adequately reflect health risk.

Conclusion

It is essential to remain physically active until older age to maintain a healthy life and uphold quality of life. PA promotion strategies for the older part of the population in Switzerland should take the strengthening of social contacts into consideration. Single and widowed persons in this study were especially inactive. The results of this study can additionally guide PA promotion in identifying population subgroups with specific needs, such persons of different cultural and language background as well as overweight and obese persons. According to our data, behavioural changes in PA are possible and sustainable as we can see in the group of participants becoming active

and this is essential for health promotion recommendations.

Potential competing interests
The authors declare that they have no conflict of interest.

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Appendix 1

Supplementary tables

Table S1: Baseline characteristics at SAPALDIA1 of participants who reached the age of 52+ at the time of accelerometry assessments, stratified by participant status in the accelerometry sub-study.

	No Accelerometer		Accelerometer		OR (95% CI)
	n	%	n	%	
Sex					
Male	3341	48.0	723	51.9	1.00
Female	3617	52.0	669	48.1	0.85 (0.76–0.96)**
Age (years)					
26–38	2263	32.5	529	38.0	1.00
39–48	2151	30.9	566	40.7	1.13 (0.99–1.29)
49+	2544	36.6	297	21.3	0.50 (0.43–0.58)***
BMI (kg/m^2)					
<25.0	4258	61.2	1017	73.1	1.00
25–29.9	2105	30.3	322	23.1	0.64 (0.56–0.73)***
≥30	595	8.6	53	3.8	0.37 (0.28–0.50)***
Language region					
German	3479	50.0	769	55.2	1.00
French	2365	34.0	459	33.0	0.88 (0.77–1.00)*
Italian	1114	16.0	164	11.8	0.67 (0.56–0.80)***
Employment status					
Employed	5570	80.1	1198	86.1	1.00
House person	1114	16.0	174	12.5	0.73 (0.61–0.86)***
Pensioner	34	0.5	5	0.4	0.68 (0.27–1.75)
Other	240	3.4	15	1.1	0.29 (0.17–0.49)***
Education					
Low	1369	19.7	114	8.2	1.00
Middle	4472	64.3	930	66.8	2.50 (2.04–3.06)***
High	1117	16.1	348	25.0	3.74 (2.99–4.69)***
Civil status					
Married	4972	71.5	1020	73.3	1.00
Divorced	504	7.2	107	7.7	1.03 (0.83–1.29)
Widowed	153	2.2	15	1.1	0.48 (0.28–0.82)**
Single	1329	19.1	250	18.0	0.92 (0.79–1.07)
Smoking status					
Never	2794	40.2	669	48.1	1.00
Former	1727	24.8	361	25.9	0.87 (0.76–1.01)
Current	2437	35.0	362	26.0	0.62 (0.54–0.71)***

CI = confidence interval; OR = odds ratio * p-value ≤0.05; ** p-value ≤0.01; *** p-value ≤0.001

Table S2: Characteristics of participants at the time of the accelerometry study (SAPALDIA4) according to the validation status (at least 10 hours wear time per day; at least three valid weekdays and at least one valid weekend day).

	Accelerometry data						p-value χ^2
	Invalid		Valid		Total		
	n	%	n	%	n	%	
Sex							
Male (ref.)	41	61.2	674	51.3	715	51.8	
Female	26	38.8	640	48.7	666	48.2	0.11
Age (years)							
52–64 (ref.)	21	31.3	453	34.5	474	34.3	
65–74	26	38.8	598	45.5	624	45.2	
75+	20	29.9	263	20.0	283	20.5	0.15
BMI (kg/m^2)							
<25 (ref.)	20	29.9	543	41.3	563	40.8	
25–29.9	27	40.3	527	40.1	554	40.1	
≥30	20	29.9	244	18.6	264	19.1	0.04
Language region							
German (ref.)	36	53.7	721	54.9	757	54.8	
French	23	34.3	444	33.8	467	33.8	
Italian	8	11.9	149	11.3	157	11.4	0.98
Employment status							
Employed (ref.)	20	29.9	425	32.3	445	32.2	
House person	1	1.5	38	2.9	39	2.8	
Pensioner	42	62.7	827	62.9	869	62.9	
Other	4	6.0	24	1.8	28	2.0	0.11
Education							
Low (ref.)	3	4.5	39	3.0	42	3.0	
Middle	42	62.7	826	62.9	868	62.9	
High	22	32.8	449	34.2	471	34.1	0.77
Civil status							
Married (ref.)	40	59.7	871	66.3	911	66.0	
Divorced	6	9.0	201	15.3	207	15.0	
Widowed	8	11.9	120	9.1	128	9.3	
Single	13	19.4	122	9.3	135	9.8	0.03
Smoking status							
Never (ref.)	23	34.3	549	41.8	572	41.4	
Former	33	49.3	591	45.0	624	45.2	
Current	11	16.4	174	13.2	185	13.4	0.45

BMI = body mass index; ref. = reference

Table S3: Mean minutes per day[†] spent in specific levels of physical activity intensity (n = 1314), according to patients characteristics[‡].

	n	Sedentary[§] Adjusted mean (95% CI)	Light[¶] Adjusted mean (95% CI)	Moderate-to-vigorous[‖] Adjusted mean (95% CI)
Sex				
Male (ref.)	674	694.8 (689.9–699.8)	129.4 (125.9–132.9)	40.3 (38.5–42.4)
Female	640	670.5 (665.7–675.2)***	156.1 (152.6–159.6)***	37.8 (35.9–39.6)
Age (years)				
52–64 (ref.)	453	669.7 (663.3–676.1)	148.6 (143.8–153.3)	46.6 (44.0–49.3)
65–74	598	674.7 (669.8–679.7)	147.9 (144.1–151.7)	42.3 (40.1–44.5)*
75+	263	705.5 (698.8–712.2)***	131.6 (126.2–136.9)***	27.8 (25.0–30.8)***
Language region				
German (ref.)	721	682.6 (677.9–687.3)	140.1 (136.8–143.5)	42.1 (39.8–44.6)
French	444	681.4 (675.2–687.6)	146.7 (141.9–151.5)*	36.8 (34.3–39.4)**
Italian	149	682.4 (673.0–691.9)	146.5 (138.8–154.1)	35.9 (32.3–39.7)**
BMI [kg/m²]				
<25 (ref.)	543	669.9 (664.1–675.7)	148.3 (144.1–152.6)	46.7 (44.0–49.1)
25–30	527	682.2 (677.0–687.4)**	142.9 (139.0–146.8)	39.7 (37.5–42.0)***
>30	244	700.4 (692.9–707.9)***	136.5 (130.5–142.6)**	27.8 (24.9–31.2)***
Employment status				
Employed (ref.)	425	671.3 (664.7–677.9)	146.2 (141.3–151.1)	47.4 (44.6–50.2)
House person	38	658.7 (637.9–679.5)	167.7 (153.4–182.1)**	38.6 (30.0–49.0)
Pensioner	827	687.2 (682.9–691.5)***	141.4 (138.1–144.7)	36.3 (34.4–38.3)***
Other	24	705 (679.7–730.2)*	129.8 (111.4–148.2)	30.6 (19.5–44.2)**
Education level				
Low (ref.)	39	682.4 (662.2–702.7)	150.2 (134.7–165.6)	32.4 (25.4–39.9)
Middle	826	678.6 (674.2–683.1)	147.0 (143.6–150.3)	39.3 (37.4–41.2)
High	449	690.6 (685.3–695.9)	133.0 (129.1–136.8)*	41.3 (38.5–44.2)*
Civil status				
Married (ref.)	871	679.3 (674.7–683.8)	144.9 (141.4–148.3)	40.7 (38.8–42.8)
Divorced	201	684.5 (674.2–694.7)	140.4 (133.0–147.9)	39.9 (35.9–44.2)
Widowed	120	693.0 (684.4–701.5)**	141.0 (134.2–147.9)	30.8 (26.8–35.2)***
Single	122	683.5 (674.8–692.2)	140.6 (134.4–146.7)	40.8 (36.5–45.5)
Smoking status				
Never (ref.)	549	675.9 (671.1–680.8)	148.1 (144.5–151.7)	40.8 (38.3–43.3)
Former	591	682.7 (677.2–688.2)	142.7 (138.5–146.8)	39.4 (37.2–41.9)
Current	174	694.5 (684.9–704.1)***	134.3 (127.1–141.6)***	36.0 (32.0–40.3)*
Season				
Spring (ref.)	146	680.9 (672.9–689.0)	145.6 (139.3–151.8)	38.4 (34.5–42.7)
Summer	203	679.8 (670.6–689.1)	149.0 (142–155.9)	36.1 (32.0–40.5)
Autumn	559	678.1 (672.8–683.5)	145.7 (141.7–149.7)	41.1 (38.9–43.5)
Winter	406	689.3 (682.6–695.9)	136.3 (131.3–141.4)*	39.2 (36.5–42.1)

CI = confidence interval; CPM =counts per minute; ref. = reference * p-value ≤0.05; ** p-value ≤0.01; *** p-value ≤0.001 † Mean minutes were derived from univariate linear regression models separately for each level of physical activity and each covariate ‡ In addition adjusted for wear time and season § 0–99 CPM ¶ 100– 019 CPM ‖ ≥2020 CPM

Table S4: Covariate adjusted mean minutes per day spent in specific levels of physical activity intensity objectively measured at SAPALDIA4, according to self-reported moderate-to-vigorous physical activity change patterns between SAPALDIA2 and SAPALDIA3 (remained active n = 87; became inactive n = 162; became active = 175; remained active = 729) according to Swiss recommendation for Physical Activity cutoffs.

	Sedentary Adjusted mean (95% CI)	Light Adjusted mean (95% CI)	Moderate-to-vigorous Adjusted mean (95% CI)
Remained inactive (ref.)	699.41 (687.30–711.51)	135.37 (126.61–144.13)	34.66 (30.15–39.17)
Became inactive	690.70 (682.17–699.23)	139.66 (132.90–146.42)	37.90 (34.91–40.89)
Became active	685.45 (676.95–693.96)	144.18 (137.26–151.09)	39.91 (36.67–43.15)
Remained active	674.24 (670.08–678.41)***	147.71 (144.63–150.79)**	46.40 (44.65–48.15)***

CI = confidence interval; ref. = reference * p-value ≤0.05; ** p-value ≤0.01; *** p-value ≤0.001