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## No effect of physical activity in the management of diabetes. The CoLaus|PsyCoLaus study

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3 4	1	NO EFFECT OF PHYSICAL ACTIVITY IN THE MANAGEMENT OF DIABETES. THE COLAUS   PSYCOLAUS STUDY
5	2	Running title: physical activity and diabetes in Switzerland
6 7	3	Gaël Vonlanthen, student; Pedro Marques-Vidal, MD, PhD, FESC
8 0	4	Department of medicine, internal medicine, Lausanne university hospital and university of Lausanne,
9 10	5	46 rue du Bugnon, 1011 Lausanne, Switzerland
11 12	6	
13	7	Authors' emails:
14 15	8	Gaël Vonlanthen: Gael.vonlanthen@unil.ch
16 17	9	Pedro Marques-Vidal: Pedro-Manuel.Marques-Vidal@chuv.ch
18	10	
19 20	11	Authors' ORCIDs:
21 22	12	Gaël Vonlanthen: none
23	13	Pedro Margues-Vidal: 0000-0002-4548-8500
24 25	14	Address for correspondence and reprints
26 27	15	Pedro Marques-Vidal
28	16	Office BH10-642
29 30	17	Department of medicine, internal medicine
31 32	18	Lausanne university hospital
33	19	Rue du Bugnon 46
34 35	20	1011 Lausanne
36 37	 21	Switzerland
38	22	Phone : +41 21 314 09 34
39 40	23	Fax: +41 21 314 09 55
41 42	24	Email : Pedro-Manuel Margues-Vidal@chuv.ch
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## 30 ABSTRACT

Introduction: physical activity (PA) is recommended in all type 2 diabetes mellitus (T2DM)
 patients to improve their glycaemic control. Whereas PA levels are associated with T2DM
 control has seldom been assessed.

Research design and methods: three cross-sectional analyses of a prospective cohort conducted in Lausanne, Switzerland. PA levels (sedentary, light, moderate and vigorous) were either self-reported via questionnaire (first and second survey) or objectively assessed using accelerometry (second and third survey). T2DM control was defined by a FPG <7.0 mmol/L or a glycated haemoglobin <6.5% (48 mmol/mol). 

Results: data from 195 (30.3% women), 199 (30.1% women) and 151 (44.4% women) participants with T2DM were analysed in the first (2009-2012), second (2014-2017) and third (2018-2021) surveys. Approximately half of the participants were not controlled by FPG. Using subjective data, over 90% (first survey) and 75% (second survey) of participants reported moderate and vigorous PA >150 min/week. After multivariable adjustment, no differences were found regarding all types of self-reported PA levels between controlled and uncontrolled participants. Objective assessment of PA led to considerable differences according to the software used: 90% and 20% of participants with moderate and vigorous PA >150 min/week, respectively. After multivariable adjustment, no differences were found for all PA levels between controlled and uncontrolled participants, irrespective of the analytical procedure used. Using glycated haemoglobin, almost two-thirds of participants were considered as uncontrolled, and no differences were found for objectively assessed PA between controlled and uncontrolled participants. 

46 52 Conclusions: in this population-based study, PA levels were not associated with a better
 47 48 53 control of T2DM.

50 54 Abstract word count: 250
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55 Keywords: physical activity; diabetes; control; epidemiology

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#### **Key messages**

#### What is already known on this topic

Adequate levels of physical activity help prevent type 2 diabetes and facilitate its management.

#### What this study adds

- In people treated for diabetes, physical activity levels did not differ between people with controlled
- and uncontrolled diabetes.

#### How this study might affect research, practice or policy

<text> Practitioners should motivate their patients with diabetes to exercise and not to rely solely on

#### medications.

Diabetes Mellitus affects 537 million adults in the world, 90% of whom by Type 2
Mellitus Diabetes (T2DM), and it is predicted that this number will increase until 783 million
for 2045. Diabetes has also a financial cost estimated at USD 966 billion dollars, representing
9% of total adult health spending. [1]

Besides quitting smoking and adopting a healthy diet, physical activity is recommended in all T2DM patients to improve their glycaemic control, insulin action, lipid levels and blood pressure [2], thus reducing the risk of cardiovascular disease. Simple activity such as walking 30 minutes per day can promote weight loss and improve glycaemic control [3]. More structured exercise programs are more effective to reduce insulin resistance in T2DM [4]. The exercise programs can be focused on aerobic training, resistance training or combined training, leading to significant improvements in HbA1c levels [5]. Still, it has been reported that patients with T2DM seldom adhere to the recommended amounts of physical activity. Indeed, barriers can affect the adhesion to recommended physical activity such as old age, female sex, lack of motivation, feeling of obligation, depression, and fatigue [6]. For instance, in the EUROASPIRE IV and V studies, over half of patients with CVD and self-reported diabetes did not intend to do regular planned physical activity, and only one quarter (26%) did it [7]. 

In Switzerland, it was estimated that, in 2021, 389'600 people aged between 20 and 79 years lived with diabetes, and 1'249'700 were affected by impaired glucose tolerance, the health costs amounting to \$4.9 billion [8]. Still, the level of physical activity among people with T2DM and its impact on T2DM control have never been assessed. 

Hence, we aimed to assess the effect of subjectively and objectively measured PA levels in subjects treated for T2DM according to diabetes control, using data from a population-based study. **BMJ** Open

### 91 MATERIALS AND METHODS

#### 92 Participants

The CoLaus PsyCoLaus study is a population-based prospective study assessing the clinical, biological, and genetic determinants of cardiovascular disease aged 35 to 75 years at baseline, living in the city of Lausanne, Switzerland [9]. In each survey, participants answered questionnaires, underwent a clinical examination and blood samples were drawn for analyses. Recruitment began in June 2003 and ended in May 2006. The first follow-up was performed between April 2009 and September 2012; the second follow-up was performed between May 2014 and April 2017, and the third follow-up was performed between April 2018 and May 2021. For more details, see www.colaus-psycolaus.ch.

#### 101 Self-reported physical activity

Subjective physical activity was assessed using the Physical Activity Frequency Questionnaire (PAFQ). This self-reported questionnaire has been validated in the population of Geneva, Switzerland, and assesses the type and duration of 70 kinds of (non)professional activities and sports during the previous week. Sedentary status was defined as spending more than 90% of the daily energy in activities below moderate- and high-intensity (defined as requiring at least 4 times the basal metabolic rate, BMR) [10]. BMR multiples are close to Metabolic Equivalent of Task (MET) multiples, although MET multiples do not consider participant sex, age or height. 

For the purpose of this study, each type of activity was categorized into sedentary behaviour (SB, <2 metabolic equivalent of tasks - METs), light physical activity (LPA, 2 to <3 METs), moderate physical activity (MPA, 3-6 METs) and vigorous physical activity (VPA, >6 METs) according to the compendium of physical activities [11]. Total PA was defined as the sum of LPA, MPA and VPA. For each item of the PAFQ, the time spent per week was computed as average hours per day multiplied by the number of days performing the activity. For each item category (i.e., corresponding to SB, LPA, MPA or VPA), the times were summed up and divided by 7 to estimate an average daily time. 

56 118

## 18 Accelerometry-assessed physical activity

57<br/>58119Physical activity was objectively assessed using a wrist-worn triaxial accelerometer59<br/>60120(GENEActiv, Activinsights Ltd, United Kingdom, www.activinsights.com). These devices are the

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same that have been used in the UK biobank study [12], weight 16 g, and allow continuous
monitoring of physical activity for a maximum of 45 days. The devices were pre-programmed
with a 50 Hz sampling frequency and subsequently attached to the participants' right wrist.
Participants were requested to wear the device continuously for 14 days in their free-living
conditions.

Raw accelerometry data were downloaded using the GENEActiv software version 2.9 (GENEActiv, Activinsights Ltd, United Kingdom) and transformed into 1-minute epoch files. Data were analysed using the GENEActiv Excel macro file 'General physical activity' version 1.9, which had been previously validated [13]. A valid day was defined as  $\geq 10$  h (i.e., 600 minepoch) and  $\geq 8$  h (i.e., 480 min-epoch) of diurnal wear-time on weekdays and weekend days, respectively. The Excel macro file can be provided upon request.

A second analysis was performed on the raw accelerometry data using the R-package GGIR version 1.5–9 (http://cran.r-project.org) [14] with the thresholds defined by [15], i.e. an acceleration between 85 and 180 milli-g to define light PA, between 181 and 437 milli-g to define moderate PA, and >437 milli-g to define vigorous PA. The code used to analyse the data is provided in **Annex 1**.

Participants were considered as complying with the recommendations if the weekly and mount of MPA and VPA exceeded 150 minutes.

8 139 Diabetes assessment

Participants were considered as presenting with diabetes if they reported taking any antidiabetic drug. Diabetes control was defined as a fasting plasma glucose <7 mmol/L; a second analysis was conducted using diabetes control defined as a glycated haemoglobin <6.5% (48 mmol/mol).

Blood was drawn in the fasting state and biological assays were performed by the CHUV Clinical Laboratory on fresh blood samples within 2 hours of blood collection. The following analytical procedures (with maximum inter and intra-batch CVs) were used: glucose by glucose hexokinase (1.6%-0.8%). In the second and third follow-ups, glycated haemoglobin levels were also measured by high performance liquid chromatography (HPCL) using Bio-Rad, D-10TM system, with measurement range 3.8% (18 mmol/mol) to 18.5% (179 mmol/mol). 

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## 150 Eligibility and exclusion criteria

151 All participants reporting being treated for diabetes were eligible for the study. 152 Participants were excluded if they lacked physical activity data.

#### 153 Covariates

Participants were queried regarding their personal and family history of cardiovascular
risk factors, medical treatment, and socio-economic status. Educational level was categorized
into low (mandatory or apprenticeship), medium (high school) and high (university). Smoking
status was categorized into never, former, and current.

Body weight and height were measured with participants barefoot and in light indoor clothes. Body weight was measured in kilograms to the nearest 100 g using a Seca<sup>®</sup> scale (Hamburg, Germany). Height was measured to the nearest 5 mm using a Seca<sup>®</sup> (Hamburg, Germany) height gauge. Body mass index (BMI) was computed and categorized into normal (<25 kg/m<sup>2</sup>), overweight ( $\geq$ 25 and <30 kg/m<sup>2</sup>) and obese ( $\geq$ 30 kg/m<sup>2</sup>).

## 163 Statistical analysis

Statistical analyses were performed separately for each study period using Stata version 16.0 for windows (Stata Corp, College Station, Texas, USA). Descriptive results were expressed as number of participants (percentage) for categorical variables and as average standard deviation or median and [interguartile range] for continuous variables. Bivariate analyses were performed using chi-square or Fisher's exact test for categorical variables and Student's t-test, analysis of variance (ANOVA) or Kruskal-Wallis nonparametric test for continuous variables. Multivariable analysis of continuous data was performed using ANOVA and results were expressed as adjusted mean±standard error of the mean (sem). Multivariable analysis of categorical data was performed using logistic regression and results were expressed as odds ratio (95% confidence interval). Multivariable analyses were conducted adjusting for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking status (never, former, current), educational level (low, medium, high). Statistical significance was assessed for a two-sided test with p<0.05.

## 55 177 Ethical statement 56

The institutional Ethics Committee of the University of Lausanne, which afterwards
 became the Ethics Commission of Canton Vaud (www.cer-vd.ch) approved the baseline

CoLaus study (reference 16/03). The approval was renewed for the first (reference 33/09), the second (reference 26/14) and the third (reference PB\_2018-00040) follow-ups. The approval for the entire CoLaus PsyCoLaus study was confirmed in 2021 (reference PB\_2018-00038, 239/09). The full decisions of the CER-VD can be obtained from the authors upon request. The study was performed in agreement with the Helsinki declaration and its former amendments, and in accordance with the applicable Swiss legislation (LRH 810.30). All participants gave their signed informed consent before entering the study.

#### **Results**

#### 188 Characteristics of participants

The selection procedure of the participants for the first, second and third follow-ups is summarized in **figure 1** and the characteristics of the participants according to adequate or inadequate control of diabetes stratified by survey are provided in **table 1**. Overall, one half of the participants treated for diabetes did not achieve adequate control. There were no consistent differences between controlled and uncontrolled participants, except that in the second follow-up, controlled participants were older and more frequently smokers.

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<b>able 1</b> : characteristic tudy, Lausanne, Swit	cs of participants zerland.	according to	diabetes (	control as per fa	asting plasma į	glucose, s	3-078909 surv tratitions on 21 Oc	ey, CoLaus Ps	syColau
	First sur	vey (2009-2012)		Second s	survey (2014-201	7)	ឲ្ល ក្លូ ថ្លី Third su	rvey (2018-2021	L)
	Not controlled	Controlled	p-value	Not controlled	Controlled	p-value	Not cantrolled	Controlled	p-valu
Sample size	121	74		97	102		ner ate	72	
Women (%)	37 (30.6)	22 (29.7)	1.000	28 (28.9)	32 (31.4)	0.758		35 (48.6)	0.330
Age (years)	65.1 ± 8.8	65.9 ± 8.4	0.519	66.6 ± 8.7	69.5 ± 8.8	0.020		68.1 ± 8.7	0.652
Swiss born (%)	85 (70.3)	43 (58.1)	0.090	59 (60.8)	67 (65.7)	0.556	a \$69.6)	42 (58.3)	0.175
Education (%)			0.212			0.589	ade		1.000
High	11 (9.1)	13 (17.6)		12 (12.4)	12 (11.9)			8 (11.1)	
Middle	29 (24.0)	18 (24.3)		24 (24.7)	19 (18.8)			17 (23.6)	
Low	81 (66.9)	43 (58.1)		61 (62.9)	70 (69.3)		<b>Ξ. <u>8</u> 3</b> 65.8)	47 (65.3)	
BMI (kg/m²)	30.5 ± 5.6	29.4 ± 4.1	0.161	30.5 ± 4.9	30.6 ± 5.1	0.924	<b>£</b> 9:8 <mark>2</mark> 4.6	29.0 ± 5.6	0.378
BMI categories (%)			0.711			1.000	Alt		0.319
Normal	17 (14.1)	10 (13.5)		11 (11.5)	12 (11.8)		a.11 <mark>8</mark> 13.9)	15 (20.8)	
Overweight	50 (41.3)	35 (47.3)		37 (38.5)	39 (38.2)		<b>j</b> 33 41.8)	33 (45.8)	
Obese	54 (44.6)	29 (39.2)		48 (50.0)	51 (50.0)		ັ <u>ຊ</u> 35 <u>3</u> 44.3)	24 (33.3)	
Smoking categories (%)			0.770			0.022	nd s		0.950
Never	37 (30.6)	25 (33.8)		26 (26.8)	39 (38.2)		29 <b>7</b> 36.7)	28 (38.9)	
Former	65 (53.7)	40 (54.1)		57 (58.8)	40 (39.2)		a 38 (48.1)	34 (47.2)	
Current	19 (15.7)	9 (12.2)		14 (14.4)	23 (22.6)		<b>6</b> 12 <b>€</b> 15.2)	10 (13.9)	
Hypertension (%)	99 (81.8)	55 (74.3)	0.277	76 (78.4)	80 (78.4)	1.000	67 (84.8)	57 (79.2)	0.401
Hypolipidemic ttt (%)	67 (55.4)	51 (68.9)	0.071				), 2( )log		
History of CVD (%)	18 (14.9)	12 (16.2)	0.839	18 (18.6)	20 (19.6)	0.859	<b>6</b> 16 <b>6</b> 20.3)	13 (18.1)	0.837

BMI, body mass index; CVD, cardiovascular disease. Results expressed as mean ± standard deviation for continuous vaiiables or as number of participants 

(percentage) for categorical variables. Statistical analysis by student's t-test or chi-square test.

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#### 200 Physical activity levels according to diabetes control as per fasting plasma

#### 201 glucose

The bivariate analysis of reported PA levels between controlled and uncontrolled participants for the first and the second follow-ups are presented in **supplementary table 1**. Overall, over 90% and 75% of participants were compliant with the 150 min/week of MPA+VPA. Participants spent half of their time in SB and very little in VPA. No differences in or as PA (in absolute time or as percentage of day) were found between controlled and uncontrolled participants, and similar findings were obtained after multivariable adjustment (table 2). 

				ٽ <u>ر</u>		
First s	urvey (2009-2012)		Secord survey (2014-2017)			
Not controlled	Controlled	p-value	Not controlled	. use	Controlled	p-value
121	74		52	seig s rel	48	
				2024. Inem lated		
527 ± 15	542 ± 19	0.543	525 ± 25	ent S	556 ± 26	0.395
197 ± 10	166 ± 13	0.056	204 ± 16	nloa	176 ± 16	0.237
186 ± 11	191 ± 15	0.819	181 ± 17	nded nd da	185 ± 18	0.864
32 ± 8	46 ± 10	0.250	43 ± 10	(ABE	26 ± 11	0.262
1 (ref)	NC		1 (ref)	ining	85 (0.35 - 2.09)	0.731 §
				, Al	1	
56 ± 1.5	57.3 ± 2	0.608	54.8 ± 2.4	train	58.8 ± 2.5	0.257
20.9 ± 1	17.7 ± 1.3	0.057	21.4 ± 1.6	ing, a	18.8 ± 1.7	0.275
19.7 ± 1.2	20.2 ± 1.5	0.798	19.3 ± 1.9	and s	19.6 ± 1.9	0.291
$3.4 \pm 0.8$	4.8 ± 1	0.260	4.6 ± 1	nv or simila	2.8 ± 1.1	0.257
	First s Not controlled 121 $527 \pm 15$ $197 \pm 10$ $186 \pm 11$ $32 \pm 8$ 1 (ref) $56 \pm 1.5$ $20.9 \pm 1$ $19.7 \pm 1.2$ $3.4 \pm 0.8$	First survey (2009-2012)Not controlledControlled12174 $527 \pm 15$ $542 \pm 19$ $197 \pm 10$ $166 \pm 13$ $186 \pm 11$ $191 \pm 15$ $32 \pm 8$ $46 \pm 10$ $1 (ref)$ NC $56 \pm 1.5$ $57.3 \pm 2$ $20.9 \pm 1$ $17.7 \pm 1.3$ $19.7 \pm 1.2$ $20.2 \pm 1.5$ $3.4 \pm 0.8$ $4.8 \pm 1$	First survey (2009-2012)Not controlledControlledp-value12174 $527 \pm 15$ $542 \pm 19$ $0.543$ $197 \pm 10$ $166 \pm 13$ $0.056$ $186 \pm 11$ $191 \pm 15$ $0.819$ $32 \pm 8$ $46 \pm 10$ $0.250$ $1 (ref)$ NC $7.3 \pm 2$ $56 \pm 1.5$ $57.3 \pm 2$ $0.608$ $20.9 \pm 1$ $17.7 \pm 1.3$ $0.057$ $19.7 \pm 1.2$ $20.2 \pm 1.5$ $0.798$ $3.4 \pm 0.8$ $4.8 \pm 1$ $0.260$	First survey (2009-2012)SectorNot controlledControlledp-valueNot controlled1217452 $527 \pm 15$ $542 \pm 19$ $0.543$ $525 \pm 25$ $197 \pm 10$ $166 \pm 13$ $0.056$ $204 \pm 16$ $186 \pm 11$ $191 \pm 15$ $0.819$ $181 \pm 17$ $32 \pm 8$ $46 \pm 10$ $0.250$ $43 \pm 10$ $1 (ref)$ NC $1 (ref)$ $56 \pm 1.5$ $57.3 \pm 2$ $0.608$ $54.8 \pm 2.4$ $20.9 \pm 1$ $17.7 \pm 1.3$ $0.057$ $21.4 \pm 1.6$ $19.7 \pm 1.2$ $20.2 \pm 1.5$ $0.798$ $19.3 \pm 1.9$ $3.4 \pm 0.8$ $4.8 \pm 1$ $0.260$ $4.6 \pm 1$	First survey (2009-2012)Second surveyNot controlledControlledp-valueNot controlledgrand for the survey1217452reigneement Superior Superior Controlled525 ± 25527 ± 15542 ± 190.543525 ± 25text and grand for the survey and grand for the	First survey (2009-2012)Secord survey (2014-2017)Not controlledControlledp-valueNot controlledGood survey (2014-2017)1217452 $add survey (2014-2017)$ Controlled527 ± 15542 ± 190.543525 ± 25 $bd survey (2014-2017)$ 527 ± 15542 ± 190.543525 ± 25 $bd survey (2014-2017)$ 197 ± 10166 ± 130.056204 ± 16 $176 \pm 16$ 186 ± 11191 ± 150.819181 ± 17 $185 \pm 18$ 32 ± 846 ± 100.25043 ± 10 $26 \pm 11$ 1 (ref)NC1 (ref) $1 (ref)$ $bd survey (2034-200)$ 56 ± 1.557.3 ± 20.60854.8 ± 2.4 $bd survey (2034-200)$ 56 ± 1.557.3 ± 20.60854.8 ± 2.4 $bd survey (2034-200)$ 20.9 ± 117.7 ± 1.30.05721.4 ± 1.6 $bd survey (2034-200)$ 19.7 ± 1.220.2 ± 1.50.79819.3 ± 1.9 $bd survey (2034-200)$ 3.4 ± 0.84.8 ± 10.2604.6 ± 1 $bd survey (2034-200)$

BMJ Open **Table 2**: multivariable analysis, self-reported physical activity by control group, stratified by survey, CoLaus | PsyColaugestudy, Lausanne, Switzerland. 

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for cont a solds ratio and as odds ratio and (95%) confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking status (never, former, current), educational level (low, medium, high). NC, not computable. § n=76 as several variables were dropped due to collinearity. Agence Bibliographique de l

were observed (table 3).

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The results of the bivariate analysis of the objectively assessed PA levels using the GENEActiv macro between controlled and uncontrolled participants for the second and third follow-ups are presented in supplementary table 2. Overall, over 90% of participants were compliant with the 150 min/week of MPA+VPA. Participants spent three quarters of their time in SB; conversely, they spent almost two hours per day on MPA. In the second survey, participants not controlled had higher levels and percentages of LPA and MPA, and lower level and percentage of SB. No difference was found between controlled and uncontrolled participants in the third survey. After multivariable adjustment, no significant differences

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ι survey. λ).

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<b>Fable 3</b> : multivariable analysis, objectively CoLaus PsyCoLaus study, Lausanne, Switz	y assessed physical erland.	activity by control gro	up as define	d using fasting pla	yright, inchaing fo	by surve
	Secor	nd survey (2014-2017)		Thi	<u>ှာ ဝ</u> irစ္စ် ရာမ္ပိုey (2018-2021)	
	Not controlled	Controlled	p-value	Not controlled	is be reig Controlled	p-value
Sample size	97	102		79	arem. 72	
Intensity of PA (min/day)					Dow to te	
Sedentary	609 ± 12	634 ± 11	0.131	601 ± 14	an 591 ± 15	0.634
Light	97 ± 4	86 ± 4	0.028	92 ± 4	nded 83±4	0.138
Moderate	122 ± 7	106 ± 7	0.124	122 ± 9	from 119±9	0.798
Vigorous	1 ± 1	1±1	0.684	1 ± 1	ning 1±1	0.476
At least 150 minutes MVPA per week	1 (ref)	0.94 (0.23 - 3.77)	0.925	1 (ref)	≥ 1945 (0.39 - 5.42)	0.576
Intensity of PA (% of daily time)					ujope train	
Sedentary	73.8 ± 1.1	77.1 ± 1.1	0.035	74.3 ± 1.2	ing, b 74.7 ± 1.3	0.812
Light	11.7 ± 0.4	$10.2 \pm 0.4$	0.011	11.1 ± 0.4	and 6 10.3 ± 0.4	0.280
Moderate	$14.4 \pm 0.8$	12.5 ± 0.8	0.105	14.5 ± 1.1	similar or 14.7 ± 1.1	0.897
Vigorous	$0.2 \pm 0.1$	$0.1 \pm 0.1$	0.679	$0.1 \pm 0.1$	Tte Un 0.2 ± 0.1	0.232

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing used so that are the sem for containing used confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking states (never, former, current), educational level (low, medium, high). Physical activity data assessed using the GENEActiv macro file 'General physical activity' version 1.9. 

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The results of the bivariate analysis of the objectively assessed PA levels using the R-package GGIR between controlled and uncontrolled participants for the second and the third follow-ups are presented in supplementary table 3. Overall, less than 25% of participants were compliant with the 150 min/week of MPA+VPA. Participants spent approximately one-quarter of an hour per day on MPA, and 90% of their time in SB. In the second survey, participants not controlled had higher levels and percentages of LPA and MPA, and lower level and percentage of SB. After multivariable adjustment, no significant differences were observed (supplementary table 4). 

#### Physical activity levels according to diabetes control as per glycated

#### haemoglobin

The results of the bivariate analysis of the objectively assessed PA levels using the GENEActiv macro between controlled and uncontrolled participants for the second and the third follow-ups are presented in **supplementary table 5**. Almost two-thirds of participants were considered as uncontrolled. No differences were found between controlled and uncontrolled participants in bivariate and multivariable analyses (table 4). 

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<b>Table 4</b> : multivariable analysis, objective CoLaus PsyCoLaus study, Lausanne, Switz	ly assessed physica zerland.	l activity by control gr	oup as defin	ed by glycated hae	ht, inchogo ending for	by survey,
	Secor	nd survey (2014-2017)		Thi	ir <mark>ភ្លឺ                                    </mark>	
	Not controlled	Controlled	p-value	Not controlled	Controlled	p-valu
Sample size	123	76		95	100224. 56	
Intensity of PA (min/day)					Dow 9nt S	
Sedentary	613 ± 10	636 ± 13	0.172	599 ± 13	anger 592 ± 17	0.736
Light	94 ± 3	87 ± 4	0.216	89 ± 4	ided 85±5	0.543
Moderate	118±6	106 ± 8	0.253	123 ± 8	(ADM 118±10	0.725
Vigorous	1 ± 1	1±1	0.978	1 ± 1	ning. 1±1	0.445
At least 150 minutes MVPA per week	1 (ref)	1.54 (0.41 - 5.79)	0.525	1 (ref)	2 11 (0.29 - 4.33	) 0.879
Intensity of PA (% of daily time)					jope raini	
Sedentary	74.6 ± 1.0	76.9 ± 1.2	0.143	74.4 ± 1.1	ng, b 74.8 ± 1.5	0.821
Light	11.3 ± 0.3	$10.4 \pm 0.4$	0.108	10.8 ± 0.4	nd g 10.5 ± 0.5	0.798
Moderate	14.0 ± 0.7	12.6 ± 0.9	0.225	14.7 ± 0.9	imila on 14.5 ± 1.2	0.884
Vigorous	$0.1 \pm 0.1$	$0.1 \pm 0.1$	0.925	$0.1 \pm 0.1$	tect une 0.2 ± 0.1	0.394

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing sources and as odds ratio and (95%) confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking states (never, former, current), educational level (low, medium, high). Physical activity data assessed using the GENEActiv macro file 'General physical activity' verition 1.9. 

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The results of the bivariate and multivariable analysis of the objectively assessed PA levels using the R-package GGIR between controlled and uncontrolled participants for the second and the third follow-ups are presented in supplementary table 6 (bivariate) and supplementary table 7 (multivariable). Almost two-thirds of participants were considered as uncontrolled. No differences were found between controlled and uncontrolled participants in bivariate and multivariable analyses, 

#### DISCUSSION

Our results show over half of participants treated for diabetes are not controlled. They also show that neither self-reported nor objectively assessed PA levels differ according to diabetes control.

**Characteristics of participants** 

Overall, participants with controlled T2DM represented less than half of the participants in each of the three follow-ups. These values are lower than reported in most European countries [16 17]. The reasons of such a low control are not easily identifiable: no differences were found between controlled and uncontrolled participants for almost all covariates analysed, and a previous study showed no differences in dietary intakes [18]. Hence, the factors associated to T2DM control may be a lesser effective health care or differences in PA levels, which will be detailed in the next section. Overall, our results indicate that over half of treated diabetics does not achieve adequate control in this Swiss population-based sample.

#### Physical activity levels according to diabetes control

PA is a cost-saving treatment [19 20]. Patients with T2DM who regularly participate to aerobic exercises activities have a better control of their disease [21]. According to Swiss and international guidelines, it is recommended to have 150 min/week moderate to vigorous PA [2]. 

In our study, participants with T2DM reported over 150 minutes per day of MPA. Those findings suggest that most participants with T2DM comply with PA recommendations, although a reporting bias cannot be excluded. Conversely, the results of the objectively assessed PA differed considerably according to the analytical method applied. According to 

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the GENEActiv macro, almost all participants treated for T2DM were compliant with the
current PA recommendations, while according to the R-package GGIR this percentage was less
than 25%. Those differences between analytical methods have been reported previously [22]
and raise the importance of standardization of PA accelerometry measurements [23].

After multivariable adjustment, no differences were found between controlled and uncontrolled participants regarding all PA levels, either as time or as % of day. Our findings agree with a study conducted in Poland, where no differences in both subjectively and objectively assessed PA levels were found between controlled and uncontrolled participants [24]. Conversely, our findings do not replicate those of two other studies, which showed significant improvement in glycaemic control in participants with T2DM when regular PA was part of a healthy lifestyle [25 26]. Possible explanations include the methods used to categorize participants. For instance, both studies used self-filled questionnaire to categorize participants into active and inactive, while ours used both subjective and objective PA assessment. It is likely that the relatively small sample size of our study led to a low statistical power, and we cannot exclude an indication bias, participants with uncontrolled T2DM being recommended more frequently to exercise than those who are controlled.

Female sex, older age, comorbidities such as obesity and depression, lack of motivation, and social influence have been suggested to decrease adherence to PA [27]. It would thus be useful to consider these barriers in subjects with T2DM when prescribing regular PA [6] and considering routine activities as domestic chores to increase PA [28].

42 300 Strengths and limitations
 43

This study used both subjectively and objectively assessed PA. It used two different software to analyse PA and two different criteria (fasting plasma glucose and glycated haemoglobin) to define T2DM. The results were replicated in two time points and a population-based sample was used.

This study also has some limitations. First, the study was conducted in a single location, and results might not be extrapolated to other settings, although similar findings were obtained elsewhere [24]. Second, a possible selection bias might have occurred, more motivated participants accepting to wear the accelerometer. Hence, it is likely that the amounts of PA might be overestimated, but not the comparisons between controlled and 

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uncontrolled participants. Finally, the amounts of light, moderate and vigorous PA differed
considerably according to the analytical procedure applied. This issue has already been
discussed [22] and recommendations have been issued [22 29]. Further, the results of the
comparison between controlled and uncontrolled participants were identical irrespective of
the analytical procedure applied.

#### <sup>3</sup> 315 **Conclusion**

In this population-based study focusing on participants treated for T2DM, no differences were found between controlled and uncontrolled T2DM regarding self-reported evels. or objectively assessed PA levels. 

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## **CREDIT AUTHOR STATEMENT**

Gaël Vonlanthen: investigation; formal analysis, visualisation; writing - original draft. Pedro Marques-Vidal: conceptualization; data curation; formal analysis; writing - review & editing; supervision. Pedro Marques-Vidal had full access to the data and is the guarantor of the study.

### **CONFLICT OF INTEREST**

- The authors report no conflict of interest.
- 327 FUNDING

The CoLaus | PsyCoLaus study was supported by research grants from GlaxoSmithKline, the Faculty of Biology and Medicine of Lausanne, the Swiss National Science Foundation (grants 3200B0–105993, 3200B0-118308, 33CSCO-122661, 33CS30-139468, 33CS30-148401, 33CS30\_177535 and 3247730\_204523) and the Swiss Personalized Health Network (project: Swiss Ageing Citizen Reference).

## **DATA AVAILABILITY**

The CoLaus PsyCoLaus cohort data used in this study cannot be fully shared as they contain potentially sensitive patient information. As discussed with the competent authority, the Research Ethic Committee of the Canton of Vaud, transferring or directly sharing this data would be a violation of the Swiss legislation aiming to protect the personal rights of participants. Non-identifiable, individual-level data are available for interested researchers, who meet the criteria for access to confidential data sharing, from the CoLaus Datacenter (CHUV, Lausanne, Switzerland). Instructions for gaining access to the CoLaus data used in this study are available at https://www.colaus-psycolaus.ch/professionals/how-to-collaborate/. 

342 PATIENT AND PUBLIC INVOLVEMENT

343 It was not possible to involve patients or the public in the design, or conduct, or344 reporting, or dissemination plans of our research.

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4	441	FIGURE LEGENDS
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6 7	442	Figure 1: selection procedure for the first, second and third follow-ups, CoLaus PsyColaus
8	443	study, Lausanne, Switzerland.
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 Supplementary information
 Supplementary table 1: bivariate analysis, self-reported physical activity by diabetes control group as defined by festing plasma glucose, stratified by survey,

 CoLaus |PsyCoLaus study, Lausanne, Switzerland.
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CoLaus | PsyCoLaus study, Lausanne, Switzerland.

	First s	urvey (2009-2012)		Seconမ္ဘိ ရွှေဖြွှဲဖွဲ့vey (2014-2017)			
	Not controlled	Controlled	p-value	Not controlled ह	Controlled	p-value	
Sample size	121	74		52 <b>b</b>	48 48		
Intensity of PA (min/day)				and	bade		
Sedentary	522 [394 - 660]	557 [449 - 651]	0.379	555 [405 - 665] a	<b>5</b> 32 [469 - 648]	0.637	
Light	185 [107 - 272]	156 [109 - 243]	0.128	168 [125 - 249]	57 [123 - 242]	0.567	
Moderate	164 [95 - 249]	155 [107 - 265]	0.862	يق. • 143 [105 - 246]	<b>5</b> 61 [104 - 221]	0.992	
Vigorous	0.7 [0 - 4]	0.8 [0 - 4.5]	0.995	18 [0 - 46] <b>fa</b>	<b>a</b> 15 [0 - 55]	0.997	
At least 150 minutes MVPA per week	118 (97.5)	73 (98.7)	ş	51 (78.5) <u>ni</u>	45 (76.3)	0.270	
Intensity of PA (% of daily time)				and	mj.co		
Sedentary	57.2 [42.4 - 68.8]	59.4 [46.8 - 68.4]	0.418	60.1 [44.6 - 68.0]	58.0 [48.3 - 68.0]	0.551	
Light	19.3 [11.2 - 29.7]	16.6 [12.0 - 24.5]	0.108	18.5 [13.8 - 26.7]	э́ 1 <del>2</del> .7 [12.8 - 26.6]	0.801	
Moderate	17.2 [10.7 - 25.8]	16.2 [11.2 - 26.9]	0.823	15.0 [10.3 - 26.8]	16.7 [11.4 - 24.2]	0.866	
Vigorous	6.0 [0 - 37.0]	6.0 [0 - 39.0]	0.980	1.9 [0 - 5.2] <b>g</b>	<u>,</u> 201.4 [0 - 6.0]	0.963	

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] to continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous v griables and chi-square or Fisher's exact test (§) for categorical variables. Bibliographique de l

Supplementary table 2: bivariate analysis, c	bjectively assessed	BMJ Open physical activity by di	abetes conti	rol group as defined	y fasting plasma glu	icose, stratified b
Survey, Colaus Psycolaus Study, Lausanne,	Switzerland.	survey (2014-2017)		ig for Thirding	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
	Not controlled	Controlled	p-value	Not controlle	S Controlled	p-value
Sample size	97	102		79 deme	72	
Intensity of PA (min/day)				o tex		
Sedentary	624 [522 - 691]	640 [561 - 734]	0.061	625 [515 - 69 <b>3</b>	588 [503 - 690]	0.341
Light	92 [69 - 124]	83 [58 - 111]	0.024	87 [65 - 115	83 [68 - 102]	0.378
Moderate	108 [65 - 165]	91 [54 - 134]	0.057		111 [60 - 160]	0.780
Vigorous	0 [0 - 1]	0 [0 - 1]	0.021	0 [0 - 2] g	0 [0 - 2]	0.683
At least 150 minutes MVPA per week (%)	93 (95.9)	94 (92.2)	0.271	71 (89.9) A tr	67 (93.1)	0.486
Intensity of PA (% of daily time)				aining		
Sedentary	74.7 [67.0 - 82.6]	79.2 [72.1 - 85.1]	0.011	بو [68.1 - 84	.74.5 [66.7 - 82.3]	0.587
Light	11.1 [9.1 - 14.1]	9.8 [7.5 - 13.0]	0.008	11 [8.0 - 13.19]	10.7 [8.4 - 12.9]	0.631
Moderate	12.5 [8.3 - 20.0]	10.3 [7.3 - 16.4]	0.039	14.1 [6.9 - 18. <b>9</b> ]	<b>1</b> 4.0 [8.4 - 18.9]	0.479
Vigorous	0.1 [0 - 0.2]	0 [0 - 0.1]	0.021	0 [0 - 0.2]	0 [0 - 0.2]	0.582

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] for continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous variables and chi-square or Fisher's exact test (§) for categorical variables. Physical activity data assessed using the GENEActiv macro file 'General physical activity' version 1.9.

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Supplementary table 3: bivariate analysis survey, CoLaus PsyCoLaus study. Lausani	s, objectively assesse ne, Switzerland.	ed physical activity by	diabetes c	ontrol group as defied	ed <b>§</b> y fasting plasma : <b>9</b>	glucose, stratified
	Second	l survey (2014-2017)		ୁର୍ ବୁ Thiroହি	. 2 	
	Not controlled	Controlled	p-value	ស Not controlled គ្គ	Ser 20 Controlled	p-value
Sample size	95	100		31 <b>d</b>	1000 1000 1000 1000 1000 1000 1000 100	
Intensity of PA (min/day)				io tex	nt Su	
Sedentary	750 [708 - 811]	770 [722 - 822]	0.123	768 [725 - 809] ar	10 00 00 00 00 00 00 00 00 00 00 00 00 0	0.591
Light	72 [43 - 107]	60 [35 - 89]	0.076	81 [43 - 106] at	ີ່ຊີ 66 [40 - 105]	0.198
Moderate	11 [6 - 22]	9 [3 - 16]	0.039	13 [6 - 22]	9 [6 - 19]	0.239
Vigorous	1 [0 - 1]	0 [0 - 1]	0.041	1 [0 - 2] g	• <b>0</b> [0 - 1]	0.080
At least 150 minutes MVPA per week	19 (20.0)	13 (13.0)	0.187	8 (25.8) Al tr	6 (22.2)	0.750
Intensity of PA (% of daily time)				ainin	pen.	
Sedentary	90.2 [85 - 94.1]	92.1 [87.8 - 95.1]	0.057	ي و[89.1 [85.5 - 94.0] 89.1	9.6 [86.6 - 95.0]	0.233
Light	8.2 [5.3 - 12.2]	6.8 [4.3 - 10.5]	0.062	9.1 [5.4 - 12.3] 🕯		0.252
Moderate	1.3 [0.7 - 2.4]	1.1 [0.4 - 1.8]	0.032	1.6 [0.7 - 2.4] ar	<b>9</b> 1.0 [0.7 - 2.2]	0.239
Vigorous	0.1 [0 - 0.2]	0 [0 - 0.1]	0.033	0.1 [0 - 0.2]	0 [0 - 0.1]	0.072

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile rame] br continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous **x**ariables and chi-square for categorical Agence Bibliographique de l variables. Physical activity data assessed using the R-package GGIR version 1.5–9.

<b>upplementary table 4</b> : multivariable an	alysis, objectively as	BMJ Oper sessed physical activit	י y by control:	group as defined b	l by copyright, included	ing plasma gluco	se, stratified
urvey, CoLaus PsyCoLaus study, Lausan	ne, Switzerland. Second	d survey (2014-2017)		Thirc	ing for use	5 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
	Not controlled	Controlled	p-value	Not controlled	iseign	Controlled	p-value
Sample size	95	100		31	iteme	27	
Intensity of PA (min/day)					o tex		
Sedentary	761 ± 7	769 ± 7	0.403	756 ± 14	iperio t anc	770 ± 15	0.527
Light	78 ± 4	69 ± 4	0.184	85 ± 9	eur (/ data	71±9	0.317
Moderate	15 ± 1	13 ± 1	0.509	18 ± 3	ABES min	15 ± 3	0.528
Vigorous	1 ± 1	1 ± 1	0.394	1±1 g	ing.	1±1	0.370
At least 150 minutes MVPA per week	1 (ref)	0.85 (0.34 - 2.14)	0.727	1 (ref)	Altra	39 (0.07 - 2.07)	0.268
Intensity of PA (% of daily time)					inin		
Sedentary	89.3 ± 0.6	90.4 ± 0.6	0.212	88.2 ± 1.3	g, an	. 90.0 ± 1.3	0.353
Light	8.9 ± 0.5	8.0 ± 0.5	0.177	9.6 ± 0.9	d sin	8.2 ± 1.0	0.316
Moderate	$1.7 \pm 0.1$	$1.5 \pm 0.1$	0.501	2.0 ± 0.3	ullar i	1.7 ± 0.4	0.581
Vigorous	$0.2 \pm 0.1$	$0.1 \pm 0.1$	0.432	$0.2 \pm 0.1$	lechr	0.1 ± 0.1	0.395

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing with some and as odds ratio and (95% confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking stat  $\hat{\mathbf{B}}$ s (never, former, current), educational ce Bibliographique de l level (low, medium, high). Physical activity data assessed using the R-package GGIR version 1.5–9.

Supplementary table 5: bivariate analysis, o	bjectively assessed p	BMJ Open hysical activity by di	abetes contr	T by copyright, inged of group as defined	y glycated haemoglo	obin, stratified
urvey, CoLaus PsyCoLaus study, Lausanne,	Switzerland.	survey (2014-2017)		iing for UBen TBen	y 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
	Not controlled	Controlled	p-value	Not controlletion	Controlled	p-value
Sample size	123	76		95 dt e	56	
Intensity of PA (min/day)				o tex		
Sedentary	626 [532 - 697]	638 [569 - 731]	0.151	600 [509 - 69 <sup>9</sup> ]	603 [520 - 687]	0.742
Light	89 [65 - 121]	81 [59 - 110]	0.113	90 [63 - 112 <b>6</b>	82 [70 - 100]	0.455
Moderate	106 [62 - 162]	89 [54 - 134]	0.140	123 [63 - 16 <b>6] m</b>	102 [53 - 151]	0.552
Vigorous	0 [0 - 1]	0 [0 - 1]	0.139	0 [0 - 2] <b>u</b>	0 [0 - 2]	0.843
At least 150 minutes MVPA per week (%)	116 (94.3)	71 (93.4)	0.798	87 (91.6) Ar	51 (91.1)	0.914
Intensity of PA (% of daily time)				aining		
Sedentary	75.0 [68.2 - 83.1]	79.0 [72.0 - 85.2]	0.082	73.9 [66.3 - 83	75.5 [68.4 - 82.3]	0.726
Light	11.0 [8.9 - 13.7]	9.9 [7.1 - 13.2]	0.074	11.2 [8.0 - 13 <b>थ्र</b> ]	10.1 [8.5 - 12.6]	0.520
Moderate	12.5 [7.9 - 19.6]	10.3 [7.2 - 16.7]	0.106	14.6 [7.6 - 19	12.3 [7.6 - 17.7]	0.540
Vigorous	0 [0 - 0.2]	0 [0 - 0.1]	0.144	0 [0 - 0.2] E	0 [0 - 0.2]	0.777

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] for continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous ariables and chi-square for categorical gence Bibliographique de l variables. Physical activity data assessed using the GENEActiv macro file 'General physical activity' version 1.9.

BMJ Open Supplementary table 6: bivariate analysis, objectively assessed physical activity by diabetes control group as defined survey, CoLaus   PsyCoLaus study, Lausanne, Switzerland.							
	Second survey (2014-2017)			 Tစ္စ်ာက္ခဋ္ဌိurvey (2018-2021)			
	Not controlled	Controlled	p-value	Not controll	Controlled	p-value	
Sample size	119	76		38 dt	20		
Intensity of PA (min/day)				o tex			
Sedentary	752 [719 - 812]	770 [722 - 827]	0.210	764 [727 - 80%]	742 [706 - 819]	0.612	
Light	69 [40 - 105]	60 [35 - 85]	0.146	77 [41 - 106	68 [45 - 97]	0.935	
Moderate	10 [5 - 19]	9 [4 - 17]	0.344	13 [6 - 22] B	10 [7 - 17]	0.731	
Vigorous	1 [0 - 1]	0 [0 - 1]	0.317	1 [0 - 2] g	0 [0 - 1]	0.185	
At least 150 minutes MVPA per week (%)	20 (16.8)	12 (15.8)	0.852	10 (26.3) A	4 (20.0)	0.593	
Intensity of PA (% of daily time)				ainin			
Sedentary	90.4 [85.5 - 94.3]	92.1 [87.6 - 95.1]	0.172	وم 89.6 [85.5 - 94ي1]	91.3 [87.1 - 93.5]	0.806	
Light	7.9 [5.1 - 12.1]	6.9 [4.3 - 10.1]	0.116	8.6 [5.0 - 12. <b>g</b> ]	7.6 [5.4 - 11.0]	0.909	
Moderate	1.2 [0.6 - 2.2]	1.1 [0.4 - 2.0]	0.324	1.5 [0.7 - 2.44]	1.1 [0.8 - 2.0]	0.659	
Vigorous	0.1 [0 - 0.2]	0 [0 - 0.2]	0.113	0.1 [0 - 0.2]	0.1 [0 - 0.1]	0.191	

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] for continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous **x**ariables and chi-square for categorical Agence Bibliographique de l variables. Physical activity data assessed using the R-package GGIR version 1.5–9.

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Supplementary table 7: multivariable and	alysis, objectively as	, in 89 grated haemo gradin 9	haemoglobin, stratified			
survey, Colaus Psycolaus study, Lausani	Second	l survey (2014-2017)		Thirc	رة أم التي مع التي مع	)21)
	Not controlled	Controlled	p-value	Not controlled	s seigr 2 Controlled	p-value
Sample size	119	76		38	1002 1002 1002 1002 1002 1002 1002 1002	
Intensity of PA (min/day)					Down nt Sc	
Sedentary	761 ± 6	770 ± 8	0.353	766 ± 12	tiperio 756 ± 17	0.664
Light	76 ± 4	68 ± 5	0.221	76 ± 8	date 84 ± 11	0.570
Moderate	13 ± 1	15 ± 1	0.494	16 ± 3		0.614
Vigorous	1 ± 1	1±1	0.974	1±1 9	ing. 1±1	0.238
At least 150 minutes MVPA per week	1 (ref)	1.31 (0.53 - 3.28)	0.560	1 (ref)	A tr 062 (0.11 - 3.	42) 0.586
Intensity of PA (% of daily time)					pen.	
Sedentary	89.5 ± 0.5	90.3 ± 0.7	0.392	89.4 ± 1.1	an 88.3±1.6	0.571
Light	$8.8 \pm 0.4$	7.9 ± 0.5	0.199	8.6 ± 0.8	<b>d sin</b> 9.5 ± 1.2	0.554
Moderate	$1.5 \pm 0.1$	1.7 ± 0.2	0.484	1.8 ± 0.3	n 2.1 ± 0.4	0.580
Vigorous	$0.1 \pm 0.1$	$0.1 \pm 0.1$	0.982	$0.2 \pm 0.1$	$\frac{1}{100}$ $\frac{1}{100}$ $0.1 \pm 0.1$	0.228

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing with the set of the se confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking stat  $\hat{\mathbf{B}}$ s (never, former, current), educational ce Bibliographique de l level (low, medium, high). Physical activity data assessed using the R-package GGIR version 1.5–9.

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#### ASSOCIATION BETWEEN PHYSICAL ACTIVITY AND DIABETES CONTROL: MULTIPLE CROSS-SECTIONAL STUDIES AND A PROSPECTIVE STUDY IN A POPULATION-BASED, SWISS COHORT

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Keywords:	General diabetes < DIABETES & ENDOCRINOLOGY, PREVENTIVE MEDICINE, EPIDEMIOLOGIC STUDIES




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1 2		
3	1	Association between physical activity and diabetes control: multiple cross-sectional studie
5	2	AND A PROSPECTIVE STUDY IN A POPULATION-BASED, SWISS COHORT
6 7	3	Running title: Physical activity and diabetes in Switzerland
8 9	4	Gaël Vonlanthen, student; Pedro Marques-Vidal, MD, PhD, FESC
10	5	Department of medicine, Internal medicine, Lausanne University Hospital and University of
12	6	Lausanne, 46 rue du Bugnon, 1011 Lausanne, Switzerland
13 14	7	
15 16	8	Authors' emails:
17	9	Gaël Vonlanthen: Gael.Vonlanthen@unil.ch
18 19	10	Pedro Marques-Vidal: Pedro-Manuel.Marques-Vidal@chuv.ch
20 21	11	
22	12	Authors' ORCIDs:
23 24	13	Gaël Vonlanthen: none
25 26	14	Pedro Marques-Vidal: 0000-0002-4548-8500
27 28	15	Address for correspondence and reprints
20 29	16	Pedro Marques-Vidal
30 31	17	Office BH10-642
32 33	18	Department of medicine, Internal medicine
34	19	Lausanne University Hospital
35 36	20	Rue du Bugnon 46
37 38	21	1011 Lausanne
39	22	Switzerland
40 41	23	Phone : +41 21 314 09 34
42 43	24	Fax : +41 21 314 09 55
44 45	25	Email : pedro.marquesvidal@gmail.com
46	26	
47 48	27	Word count: 5231 with references and tables
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# 30 ABSTRACT

Introduction: physical activity (PA) is recommended in type 2 diabetes mellitus (T2DM)
 patients to improve their glycaemic control. We aimed to assess PA levels among participants
 with controlled and uncontrolled T2DM.

Research design and methods: three cross-sectional analyses of a prospective cohort conducted in Lausanne, Switzerland. PA levels (sedentary, light, moderate and vigorous) were either self-reported via questionnaire (first and second survey) or objectively assessed using accelerometry (second and third survey). T2DM control was defined as glycaemia <7.0 mmol/L or glycated haemoglobin <6.5% (48 mmol/mol). 

Results: data from 195 (30.3% women), 199 (30.1% women) and 151 (44.4% women) participants with T2DM were analysed in the first (2009-2012), second (2014-2017) and third (2018-2021) surveys. Approximately half of the participants did not have controlled glycaemia. Using subjective data, over 90% (first survey) and 75% (second survey) of participants reported moderate and vigorous PA >150 min/week. After multivariable adjustment, no differences were found regarding all types of self-reported PA levels between controlled and uncontrolled participants. Objective assessment of PA led to considerable differences according to the software used: 90% and 20% of participants with moderate and vigorous PA >150 min/week, respectively. After multivariable adjustment, no differences were found for all PA levels between controlled and uncontrolled participants, irrespective of the analytical procedure used. Using glycated haemoglobin, almost two-thirds of participants were considered as uncontrolled, and no differences were found for objectively assessed PA between controlled and uncontrolled participants. 

- 46 52 Conclusions: no differences in PA levels were found between participants with controlled and
   47 53 uncontrolled T2DM.
- 50 54 Abstract word count: 250
   51
  - 55 Keywords: physical activity; diabetes; control; epidemiology

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# STRENGTHS AND LIMITATIONS OF THIS STUDY

- Physical activity levels were assessed using accelerometer.
- Diabetes control was assessed using both fasting plasma glucose and glycated haemoglobin. •
- Study was conducted in a single location; hence, generalizability might be an issue. •
- ad a single lk s exists as only Possible selection bias exists as only motivated participants accepted to wear the • accelerometer.

Diabetes mellitus affects 537 million adults in the world, 90% of whom have type 2
diabetes mellitus (T2DM). It is predicted that this number of people with diabetes will increase
to 783 million by 2045. Diabetes also has a financial cost estimated at USD 966 billion dollars,
representing 9% of total adult health spending. [1]

Besides guitting smoking and adopting a healthy diet, physical activity (PA) is recommended in all patients with T2DM to improve their glycaemic control, insulin action, lipid levels and blood pressure [2], thus reducing the risk of cardiovascular disease. Simple activity such as walking 30 minutes per day can promote weight loss and improve glycaemic control [3]. More structured exercise programs are more effective to reduce insulin resistance in T2DM [4]. Exercise programs can be focused on aerobic, resistance or combined training, leading to significant improvements in HbA1c levels [5]. Still, it has been reported that patients with T2DM seldom adhere to the recommended amounts of PA. Indeed, barriers such as old age, female sex, lack of motivation, feeling of obligation, depression, and fatigue, can affect adhesion to recommended PA [6]. For instance, in the EUROASPIRE IV and V studies, over half of patients with cardiovascular disease (CVD) and self-reported diabetes did not intend to do regular planned PA, and only one quarter (26%) did [7]. 

In Switzerland, it was estimated that, in 2021, 389,600 people aged between 20 and 79 years lived with diabetes, and 1,249,700 were affected by impaired glucose tolerance, with health costs amounting to \$4.9 billion [8]. Still, the level of PA among people with T2DM and its impact on T2DM control have never been assessed. 

Hence, we aimed to assess the effect of subjectively and objectively measured PA levels in subjects treated for T2DM according to diabetes control, using data from a population-based study. **BMJ** Open

# 88 MATERIALS AND METHODS

# 89 Participants

The CoLaus PsyCoLaus study is a population-based prospective study assessing the clinical, biological, and genetic determinants of cardiovascular disease aged 35 to 75 years at baseline, living in the city of Lausanne, Switzerland [9]. In each survey, participants answered questionnaires, underwent a clinical examination and blood samples were drawn for analyses. Recruitment began in June 2003 and ended in May 2006. The first follow-up was performed between April 2009 and September 2012; the second follow-up was performed between May 2014 and April 2017, and the third follow-up was performed between April 2018 and May 2021. For more details, see www.colaus-psycolaus.ch. 

# 

# Self-reported physical activity

Subjective PA was assessed using the Physical Activity Frequency Questionnaire (PAFQ). This self-reported questionnaire has been validated in the population of Geneva, Switzerland, and assesses the type and duration of 70 kinds of (non)professional activities and sports during the previous week. Sedentary status was defined as spending more than 90% of daily energy in activities below moderate- and high-intensity (defined as requiring at least 4 times the basal metabolic rate, BMR) [10]. BMR multiples are close to Metabolic Equivalent of Task (MET) multiples, although MET multiples do not consider participant sex, age, or height. 

For the purpose of this study, each type of activity was categorized into sedentary behaviour (SB, <2 metabolic equivalent of tasks - METs), light physical activity (LPA, 2 to <3 METs), moderate physical activity (MPA, 3-6 METs) and vigorous physical activity (VPA, >6 METs) according to the compendium of physical activities [11]. Total PA was defined as the sum of LPA, MPA and VPA. For each item of the PAFQ, the time spent per week was computed as average hours per day multiplied by the number of days when the activity was performed. For each item category (i.e., corresponding to SB, LPA, MPA or VPA), the times were summed up and divided by 7 to estimate an average daily time. 

We chose to include sedentary behaviour in the analysis as we have previously shown
 that it is associated with an increased risk of developing T2DM [12].

1 2		
2 3 4	116	Accelerometry-assessed physical activity
5	117	Physical activity was objectively assessed using a wrist-worn triaxial accelerometer
7	118	(GENEActiv, Activinsights Ltd, United Kingdom, www.activinsights.com). These devices are the
8 9	119	same that have been used in the UK biobank study [13], weigh 16 g, and allow continuous
10 11	120	monitoring of PA for a maximum of 45 days. The devices were pre-programmed with a 50 Hz
12 13	121	sampling frequency and subsequently attached to the participants' right wrist. Participants
14 15	122	were requested to wear the device continuously for 14 days in their free-living conditions.
16 17	123	Raw accelerometry data were downloaded using the GENEActiv software version 2.9
18 19	124	(GENEActiv, Activinsights Ltd, United Kingdom) and transformed into 1-minute epoch files.
20 21	125	Data were analysed using the GENEActiv Excel macro file 'General physical activity' version
22	126	1.9, which had been previously validated [14]. A valid day was defined as ≥10 h (i.e., 600 min-
23	127	epoch) and $\geq$ 8 h (i.e., 480 min-epoch) of diurnal wear-time on weekdays and weekend days,
25 26 27	128	respectively. The Excel macro file can be provided upon request.
28 20	129	A second analysis was performed on the raw accelerometry data using the R-package
30	130	GGIR version 1.5–9 (http://cran.r-project.org) [15] with the thresholds defined by [16], i.e. an
31 32	131	acceleration between 85 and 180 milli-g to define light PA, between 181 and 437 milli-g to
33 34	132	define moderate PA, and >437 milli-g to define vigorous PA. The code used to analyse the data
35 36 27	133	is provided in Annex 1.
38	134	Participants were considered as complying with the recommendations if the weekly
39 40	135	amount of MPA and VPA exceeded 150 minutes, as per European Society of Cardiology/
41 42	136	European Association for the Study of Diabetes (ESC/EASD) guidelines [2].
43 44	137	Diabetes assessment
45 46	138	Participants were considered as presenting with treated diabetes if they reported
47 48	139	taking any antidiabetic drug. Diabetes control was defined as a fasting plasma glucose <7
49 50	140	mmol/L; a second analysis was conducted using diabetes control defined as a glycated
51 52	141	haemoglobin <6.5% (48 mmol/mol).
53 54	142	Blood was drawn in the fasting state and biological assays were performed by the
55 56	143	Centre Hospitalier Universitaire Vaudois Clinical Laboratory on fresh blood samples within 2
57 58	144	hours of blood collection. The following analytical procedures (with maximum inter and intra-
59 60	145	batch CVs) were used: glucose by glucose hexokinase (1.6%-0.8%). In the second and third

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follow-ups, glycated haemoglobin levels were also measured by high performance liquid
 follow-ups, glycated haemoglobin levels were also measured by high performance liquid
 chromatography (HPCL) using Bio-Rad, D-10TM system, with measurement range 3.8% (18
 mmol/mol) to 18.5% (179 mmol/mol).

9 149 Eligibility and exclusion criteria
 10

All participants reporting being treated for diabetes were eligible for the study.
 All participants reporting being treated for diabetes were eligible for the study.
 Participants were excluded if they lacked PA data.

# 15 152 Covariates 16

Participants were queried regarding their personal and family history of cardiovascular risk factors, medical treatment, and socio-economic status. Educational level was categorized into low (mandatory or apprenticeship), medium (high school) and high (university). Smoking status was categorized into never, former, and current. 

Body weight and height were measured with participants barefoot and in light indoor clothes. Body weight was measured in kilograms to the nearest 100 g using a Seca<sup>®</sup> scale (Hamburg, Germany). Height was measured to the nearest 5 mm using a Seca<sup>®</sup> (Hamburg, Germany) height gauge. Body mass index (BMI) was computed and categorized into normal (<25 kg/m<sup>2</sup>), overweight ( $\geq$ 25 and <30 kg/m<sup>2</sup>) and obese ( $\geq$ 30 kg/m<sup>2</sup>). 

Blood pressure was measured using an Omron<sup>®</sup> HEM-907 automated oscillometric sphygmomanometer after at least a 10-minute rest in a seated position, and the average of the last two measurements was used. Hypertension was defined by a SBP  $\ge$  140 mm Hg or a DBP  $\ge$  90 mm Hg or presence of antihypertensive drug treatment.

43 166 **Patient and Public Involvement** 

It was not possible to involve patients or the public in the design, or conduct, or reporting, or
 dissemination plans of our research.

49 169 **Statistical analysis** 

Statistical analyses were performed separately for each study period using Stata version 18.0 for windows (Stata Corp, College Station, Texas, USA). Descriptive results were expressed as number of participants (percentage) for categorical variables and as average standard deviation or median and [interquartile range] for continuous variables. Bivariate analyses were performed using chi-square or Fisher's exact test for categorical variables and Student's t-test, analysis of variance (ANOVA) or Kruskal-Wallis nonparametric test for 

Page 9 of 30

176 continuous variables. Multivariable analysis of continuous data was performed using ANOVA
177 and results were expressed as adjusted mean±standard error of the mean (sem). Multivariable
178 analysis of categorical data was performed using logistic regression and results were
179 expressed as odds ratio (95% confidence interval). Multivariable analyses were conducted
180 adjusting for sex (male, female), age (continuous), BMI categories (normal, overweight,
181 obese), smoking status (never, former, current), educational level (low, medium, high).
182 Statistical significance was assessed for a two-sided test with p<0.05.</li>

**RESULTS** 

# 184 Characteristics of participants

The selection procedure of the participants for the first, second and third follow-ups is summarized in **figure 1** and the characteristics of the participants according to adequate or inadequate control of diabetes stratified by survey are provided in **supplementary table 1**. Overall, one half of the participants treated for diabetes did not achieve adequate control. There were no consistent differences between controlled and uncontrolled participants, except that in the second follow-up, controlled participants were older and more frequently smokers.

# 5 192 Sedentary behaviour and physical activity levels according to diabetes control

**as per fasting plasma glucose** 

The bivariate analysis of reported PA levels between controlled and uncontrolled participants for the first and the second follow-ups are presented in **supplementary table 2**. Overall, over 90% and 75% of participants were compliant with the 150 min/week of MPA+VPA in the first and second surveys, respectively. Participants spent half of their time in SB and very little in VPA. No differences in PA (in absolute time or as percentage of day) were found between controlled and uncontrolled participants, and similar findings were obtained after multivariable adjustment (**table 1**).

					ing				
	First s	urvey (2009-2012)		Second survey (2014-2017)					
	Not controlled	Controlled	p-value	Not controlled	. use	Controlled	p-value		
Sample size	121	74		52	ber 2 seig s rel	48			
Intensity of PA (min/day)					2024. Inem lated				
Sedentary	527 ± 15	542 ± 19	0.543	525 ± 25	ent s	556 ± 26	0.395		
Light	197 ± 10	166 ± 13	0.056	204 ± 16	vnloa Supe ext ai	176 ± 16	0.237		
Moderate	186 ± 11	191 ± 15	0.819	181 ± 17	nded nd da	185 ± 18	0.864		
Vigorous	32 ± 8	46 ± 10	0.250	43 ± 10	(ABI	26 ± 11	0.262		
At least 150 minutes MVPA per week	1 (ref)	NC		1 (ref)	ining	85 (0.35 - 2.09)	0.731 §		
Intensity of PA (% of daily time)					g, Al				
Sedentary	56 ± 1.5	57.3 ± 2	0.608	54.8 ± 2.4	njope	58.8 ± 2.5	0.257		
Light	20.9 ± 1	17.7 ± 1.3	0.057	21.4 ± 1.6	ing,	18.8 ± 1.7	0.275		
Moderate	19.7 ± 1.2	20.2 ± 1.5	0.798	19.3 ± 1.9	nj.co	19.6 ± 1.9	0.291		
Vigorous	3.4 ± 0.8	4.8 ± 1	0.260	4.6 ± 1	simil	2.8 ± 1.1	0.257		
					പാ				

BMJ Open **Table 1**: multivariable analysis, self-reported physical activity by control group, stratified by survey, CoLaus | PsyColaugestudy, Lausanne, Switzerland. 

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for cont in cont in the sem for contains the sem for conta confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking status (never, former, current), educational at Agence Bibliographique de l level (low, medium, high). NC, not computable. § n=76 as several variables were dropped due to collinearity. 

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The results of the bivariate analysis of the objectively assessed PA levels using the GENEActiv macro between controlled and uncontrolled participants for the second and third follow-ups are presented in supplementary table 3. Overall, over 90% of participants were compliant with the 150 min/week of MPA+VPA. Participants spent three quarters of their time in SB; conversely, they spent almost two hours per day on MPA. In the second survey, uncontrolled participants had higher levels and percentages of LPA and MPA, and a lower level ι th. and percentage of SB. In the third survey, no difference was found between controlled and uncontrolled participants . After multivariable adjustment, no significant differences were observed (table 2). 

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<b>Table 2</b> : multivariable analysis, objectiv CoLaus   PsyCoLaus study, Lausanne, Sw	vely assessed physical vitzerland.	activity by control gro	oup as define	d using fasting plas	right, increase, stratified bigging goucose, stratified on	by surve
	Secor	nd survey (2014-2017)		Thir	ရှိ ရှာမ္ဘာဗေ (2018-2021)	
	Not controlled	Controlled	p-value	Not controlled	is be religion Controlled	p-value
Sample size	97	102		79	ated 72	
Intensity of PA (min/day)					Dow to te	
Sedentary	609 ± 12	634 ± 11	0.131	601 ± 14	supposed 591±15	0.634
Light	97 ± 4	86 ± 4	0.028	92 ± 4	nded 83±4	0.138
Moderate	122 ± 7	106 ± 7	0.124	122 ± 9	ata (Arian 119±9	0.798
Vigorous	1 ± 1	1±1	0.684	1±1		0.476
At least 150 minutes MVPA per week	1 (ref)	0.94 (0.23 - 3.77)	0.925	1 (ref)	<b>2 2</b> 45 (0.39 - 5.42)	0.576
Intensity of PA (% of daily time)					njope train	
Sedentary	73.8 ± 1.1	77.1 ± 1.1	0.035	74.3 ± 1.2	<b>n</b> <b>b</b> 74.7 ± 1.3	0.812
Light	11.7 ± 0.4	$10.2 \pm 0.4$	0.011	11.1 ± 0.4	and $\frac{2}{6}$ 10.3 ± 0.4	0.280
Moderate	14.4 ± 0.8	12.5 ± 0.8	0.105	14.5 ± 1.1	si <b>e</b> 14.7 ± 1.1	0.897
Vigorous	$0.2 \pm 0.1$	$0.1 \pm 0.1$	0.679	0.1 ± 0.1	ar 5 fg ur 0.2±0.1	0.232

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing variables and as odds ratio and (95%) confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables ang by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking statis (never, former, current), educational level (low, medium, high). Physical activity data assessed using the GENEActiv macro file 'General physical activity' verition 1.9. 

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Supplementary table 4 shows the bivariate analysis between controlled and uncontrolled participants of follow-ups 2 and 3, for objectively assessed PA, using the R-package GGIR . Overall, less than 25% of participants were compliant with the 150 min/week of MPA+VPA. Participants spent approximately one-quarter of an hour per day in MPA, and 90% of their time in SB. In the second survey, uncontrolled participants had higher levels and percentages of LPA and MPA, and a lower level and percentage of SB. After multivariable adjustment, no significant differences were observed (supplementary table 5). 

### Sedentary behaviour and physical activity levels according to diabetes control as per glycated haemoglobin

The results of the bivariate analysis of the objectively assessed PA levels using the GENEActiv macro between controlled and uncontrolled participants for the second and the third follow-ups are presented in **supplementary table 6**. Almost two-thirds of participants were considered as uncontrolled. No differences were found between controlled and uncontrolled participants in bivariate and multivariable analyses (table 3).

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<b>Table 3</b> : multivariable analysis, objectiv	vely assessed physical	l activity by control gr	oup as defin	ed by glycated hae	oggobin, stratified by	/ survey,
CoLaus   PsyCoLaus study, Lausanne, Sw	itzerland.	d survey (2014-2017)			5 2 0 	
	Not controlled	Controlled	p-value	Not controlled		p-value
Sample size	123	76		95 6	<b>nem</b> 56	
Intensity of PA (min/day)				101	ent s	
Sedentary	613 ± 10	636 ± 13	0.172	599 ± 13	upen 592 ± 17	0.736
Light	94 ± 3	87 ± 4	0.216	89 ± 4	ded 85±5	0.543
Moderate	118 ± 6	106 ± 8	0.253	123 ± 8	AB 118 ± 10	0.725
Vigorous	1 ± 1	1±1	0.978	1±1		0.445
At least 150 minutes MVPA per week	1 (ref)	1.54 (0.41 - 5.79)	0.525	1 (ref)	<b>1 1</b> (0.29 - 4.33)	0.879
Intensity of PA (% of daily time)					jope	
Sedentary	74.6 ± 1.0	76.9 ± 1.2	0.143	74.4 ± 1.1	<b>74.8 ± 1.5</b>	0.821
Light	$11.3 \pm 0.3$	$10.4 \pm 0.4$	0.108	10.8 ± 0.4	8 10.5 ± 0.5	0.798
Moderate	$14.0 \pm 0.7$	12.6 ± 0.9	0.225	14.7 ± 0.9	<b>e</b> 14.5 ± 1.2	0.884
Vigorous	$0.1 \pm 0.1$	$0.1 \pm 0.1$	0.925	0.1 ± 0.1	un 0.2 ± 0.1	0.394

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for congous variables and as odds ratio and (95% confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking states (never, former, current), educational level (low, medium, high). Physical activity data assessed using the GENEActiv macro file 'General physical activity' version 1.9. 

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The results of the bivariate and multivariable analysis of the objectively assessed PA levels using the R-package GGIR between controlled and uncontrolled participants for the second and the third follow-ups are presented in **supplementary table 7** (bivariate) and **supplementary table 8** (multivariable). Almost two-thirds of participants were considered as uncontrolled. No differences were found between controlled and uncontrolled participants in bivariate and multivariable analyses,

# **DISCUSSION**

Our results show that over half of participants treated for type 2 diabetes are not controlled. They also show that neither self-reported nor objectively assessed PA levels differ according to diabetes control.

<sup>4</sup> 251 **Characteristics of participants** 

Overall, participants with controlled T2DM represented less than half of the participants in each of the three follow-ups. These values are lower than those reported in most European countries [17 18]. The reasons for such a low control are not easily identifiable: no differences were found between controlled and uncontrolled participants for almost all covariates analysed, and a previous study showed no differences in dietary intakes [19]. Hence, the factors associated to T2DM control may be a less effective health care or differences in PA levels, which will be detailed in the next section. Overall, our results indicate that over half of treated diabetics do not achieve adequate control in this Swiss population-based sample.

261 Sedentary behaviour and physical activity levels according to diabetes control

PA is a cost-saving treatment [20 21]. Patients with T2DM who regularly participate in aerobic exercise have a better control of their disease [22]. According to Swiss and international guidelines, it is recommended to spend 150 min/week doing moderate to vigorous PA [23].

In our study, participants with T2DM reported over 150 minutes per day of MPA. Our
 findings suggest that most participants with T2DM comply with PA recommendations,
 although a reporting bias cannot be excluded. Conversely, the results of the objectively
 assessed PA differed considerably according to the analytical method applied. According to

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the GENEActiv macro, almost all participants treated for T2DM were compliant with current
PA recommendations, while according to the R-package GGIR this percentage was less than
25%. These differences between analytical methods have been reported previously [24] and
raise the importance of standardization of PA accelerometry measurements [25].

After multivariable adjustment, no differences were found between controlled and uncontrolled participants regarding all PA levels, either as absolute time or as % of day. Our findings agree with a study conducted in Poland, where no differences in both subjectively and objectively assessed PA levels were found between controlled and uncontrolled participants [26]. Conversely, our findings do not replicate those of two other studies, which showed significant improvement in glycaemic control in participants with T2DM when regular PA was part of a healthy lifestyle [27 28]. Possible explanations include the methods used to categorize participants. For instance, both studies used self-filled questionnaire to categorize participants into active and inactive, while ours used both subjective and objective PA assessment. It is likely that the relatively small sample size of our study led to a low statistical power, and we cannot exclude an indication bias, participants with uncontrolled T2DM being recommended more frequently to exercise than those who are controlled.

Female sex, older age, comorbidities such as obesity and depression, lack of motivation, and social influence have been suggested to decrease adherence to PA [29]. It would thus be useful to consider these barriers in subjects with T2DM when prescribing regular PA [6] and consider routine activities as domestic chores to increase PA [30].

290 Strengths and limitations

The major strengths of this study is the use of both subjectively and objectively assessed PA. It used two different software to analyse PA and two different criteria (fasting plasma glucose and glycated haemoglobin) to define T2DM. The results were replicated in two time points and a population-based sample was used.

This study also has some limitations. First, the study was conducted in a single location, and results might not be extrapolated to other settings, although similar findings were obtained elsewhere [26]. Second, a possible selection bias might have occurred, as more motivated participants may accept o wear the accelerometer more easily. Hence, it is likely that the amounts of PA might be overestimated, but not the comparisons between controlled 

and uncontrolled participants. Finally, the amounts of light, moderate and vigorous PA differed considerably according to the analytical procedure applied. This issue has already been discussed [24] and recommendations have been issued [24 31]. Further, the results between controlled and uncontrolled participants were identical irrespective of the analytical procedure applied.
Conclusion
In this population-based study focusing on participants treated for T2DM, no differences were found between controlled and uncontrolled T2DM regarding self-reported or objectively assessed PA levels.

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# **CONTRIBUTORY STATEMENT**

Gaël Vonlanthen: investigation; formal analysis, visualisation; writing - original draft. Pedro Marques-Vidal: conceptualization; data curation; formal analysis; writing - review & editing; supervision. Pedro Marques-Vidal had full access to the data and is the guarantor of the study.

# **COMPETING INTERESTS**

- The authors report no conflict of interest.
- 317 FUNDING

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**DATA SHARING STATEMENT** 

The CoLaus PsyCoLaus cohort data used in this study cannot be fully shared as they contain potentially sensitive patient information. As discussed with the competent authority, the Research Ethic Committee of the Canton of Vaud, transferring or directly sharing this data would be a violation of the Swiss legislation aiming to protect the personal rights of participants. Non-identifiable, individual-level data are available for interested researchers, who meet the criteria for access to confidential data sharing, from the CoLaus Datacenter (CHUV, Lausanne, Switzerland). Instructions for gaining access to the CoLaus data used in this study are available at https://www.colaus-psycolaus.ch/professionals/how-to-collaborate/. 

332 ETHICAL STATEMENT

54<br/>55333The institutional Ethics Committee of the University of Lausanne, which afterwards55<br/>56<br/>57334became the Ethics Commission of Canton Vaud (www.cer-vd.ch) approved the baseline57<br/>58<br/>58<br/>60335CoLaus study (reference 16/03). The approval was renewed for the first (reference 33/09), the<br/>second (reference 26/14) and the third (reference PB\_2018-00040) follow-ups. The approval

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3 4	337	for the entire CoLaus PsyCoLaus study was confirmed in 2021 (reference PB_2018-00038,
5	338	239/09). The full decisions of the CER-VD can be obtained from the authors upon request. The
7	339	study was performed in agreement with the Helsinki declaration and its former amendments,
8 9	340	and in accordance with the applicable Swiss legislation (LRH 810.30). All participants gave their
10 11	341	signed informed consent before entering the study.
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# 439 **FIGURE LEGENDS**

440 **Figure 1**: selection procedure for the first, second and third follow-ups, CoLaus|PsyColaus

441 study, Lausanne, Switzerland.

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 Supplementary information
 Table 1: characteristics of participants according to diabetes control as per fasting plasma glucose, stratticed by survey, CoLaus | PsyColaus

 study Lausanne Switzerland
 Supplementary information

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study, Lausanne, Switzerland.

	First sur	vey (2009-2012)		Second survey (2014-2017)			ဆို ခြံ လြိုThird survey (2018-2021)			
	Not controlled	Controlled	p-value	Not controlled	Controlled	p-value	Notecantrolled	Controlled	p-value	
Sample size	121	74		97	102		b te	72		
Women (%)	37 (30.6)	22 (29.7)	1.000	28 (28.9)	32 (31.4)	0.758	¥ \$2	35 (48.6)	0.330	
Age (years)	65.1 ± 8.8	65.9 ± 8.4	0.519	66.6 ± 8.7	69.5 ± 8.8	0.020		68.1 ± 8.7	0.652	
Swiss born (%)	85 (70.3)	43 (58.1)	0.090	59 (60.8)	67 (65.7)	0.556	<b>ရွ</b> 55 <b>(</b> 69.6)	42 (58.3)	0.175	
Education (%)			0.212			0.589	ron (AB		1.000	
High	11 (9.1)	13 (17.6)		12 (12.4)	12 (11.9)		<b>ni (2)</b> (11.4)	8 (11.1)		
Middle	29 (24.0)	18 (24.3)		24 (24.7)	19 (18.8)		ب <b>ق</b> 18 <mark>9</mark> 22.8)	17 (23.6)		
Low	81 (66.9)	43 (58.1)		61 (62.9)	70 (69.3)		<b>≥</b> 52 <mark>3</mark> 65.8)	47 (65.3)		
BMI (kg/m <sup>2</sup> )	30.5 ± 5.6	29.4 ± 4.1	0.161	30.5 ± 4.9	30.6 ± 5.1	0.924	<b>រឺ</b> ម្មិ.8 <mark>ទ</mark> ្ធ 4.6	29.0 ± 5.6	0.378	
BMI categories (%)			0.711			1.000	nin en.		0.319	
Normal	17 (14.1)	10 (13.5)		11 (11.5)	12 (11.8)		ູ ລູ 11 <mark>3</mark> 13.9)	15 (20.8)		
Overweight	50 (41.3)	35 (47.3)		37 (38.5)	39 (38.2)		a 33 (41.8)	33 (45.8)		
Obese	54 (44.6)	29 (39.2)		48 (50.0)	51 (50.0)		<b>S</b> :35 <b>4</b> 44.3)	24 (33.3)		
Smoking categories (%)			0.770			0.022	vilar		0.950	
Never	37 (30.6)	25 (33.8)		26 (26.8)	39 (38.2)			28 (38.9)		
Former	65 (53.7)	40 (54.1)		57 (58.8)	40 (39.2)		38 <sup>0</sup> (48.1)	34 (47.2)		
Current	19 (15.7)	9 (12.2)		14 (14.4)	23 (22.6)		<b>8</b> 12 (15.2)	10 (13.9)		
Hypertension (%)	99 (81.8)	55 (74.3)	0.277	76 (78.4)	80 (78.4)	1.000	<b>G</b> 67 <b>K</b> 84.8)	57 (79.2)	0.401	
Hypolipidemic ttt (%)	67 (55.4)	51 (68.9)	0.071				s. stat			
History of CVD (%)	18 (14.9)	12 (16.2)	0.839	18 (18.6)	20 (19.6)	0.859	16 <b>4</b> 20.3)	13 (18.1)	0.837	

BMI, body mass index; CVD, cardiovascular disease; ttt, treatment. Results expressed as mean ± standard deviation for continuous variables or as number of participants (percentage) for categorical variables. Statistical analysis by student's t-test or chi-square test.

Supplementary table 2: bivariate analysis	s, self-reported physi	cal activity by diabet	es control g	roup as defined by	en-2023-078929 or	g plasma glucose	, stratified by surv
LOLAUS   PSyCOLAUS Study, Lausanne, Switz	First s	urvey (2009-2012)		تة or Secon		vey (2014-2017)	
	Not controlled	Controlled	p-value	Not controlled	oer 20 seign	Controlled	p-value
Sample size	121	74		52 <b>d</b>	)24. L	48	
Intensity of PA (min/day)				o tex	nt Su		
Sedentary	522 [394 - 660]	557 [449 - 651]	0.379	555 [405 - 665]	Iperio	32 [469 - 648]	0.637
Light	185 [107 - 272]	156 [109 - 243]	0.128	168 [125 - 249] a	edHr	57 [123 - 242]	0.567
Moderate	164 [95 - 249]	155 [107 - 265]	0.862	143 [105 - 246]		61 [104 - 221]	0.992
Vigorous	0.7 [0 - 4]	0.8 [0 - 4.5]	0.995	18 [0 - 46] 🤤		15 [0 - 55]	0.997
At least 150 minutes MVPA per week	118 (97.5)	73 (98.7)	ş	51 (78.5) A	bmjc	45 (76.3)	0.270
Intensity of PA (% of daily time)				ainin			
Sedentary	57.2 [42.4 - 68.8]	59.4 [46.8 - 68.4]	0.418	ي [60.1 [44.6 - 68.0]	billing.	3.0 [48.3 - 68.0]	0.551
Light	19.3 [11.2 - 29.7]	16.6 [12.0 - 24.5]	0.108	ຊ 18.5 [13.8 - 26.7]ອ		.7 [12.8 - 26.6]	0.801
Moderate	17.2 [10.7 - 25.8]	16.2 [11.2 - 26.9]	0.823	ា 15.0 [10.3 - 26.8]ឌុ	: 17	5.7 [11.4 - 24.2]	0.866
Vigorous	6.0 [0 - 37.0]	6.0 [0 - 39.0]	0.980	1.9 [0 - 5.2]	une	1.4 [0 - 6.0]	0.963

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] br continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous variables and chi-square or Fisher's exact Agence Bibliographique de l test (§) for categorical variables.

Supplementary table 3: bivariate analysis, c	bjectively assessed	BMJ Open ohysical activity by di	abetes conti	rol group as defined	y fasting plasma glu	icose, stratified by
survey, CoLaus PsyCoLaus study, Lausanne,	Switzerland.	survey (2014-2017)		ing for two dig This dig	5 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
	Not controlled	Controlled	p-value	Not controlle	Controlled	p-value
Sample size	97	102		79 deme	72	
Intensity of PA (min/day)				o tex		
Sedentary	624 [522 - 691]	640 [561 - 734]	0.061	625 [515 - 69 <b>3] e</b>	588 [503 - 690]	0.341
Light	92 [69 - 124]	83 [58 - 111]	0.024	87 [65 - 115]	83 [68 - 102]	0.378
Moderate	108 [65 - 165]	91 [54 - 134]	0.057	117 [56 - 161]	111 [60 - 160]	0.780
Vigorous	0 [0 - 1]	0 [0 - 1]	0.021	0 [0 - 2] g	0 [0 - 2]	0.683
At least 150 minutes MVPA per week (%)	93 (95.9)	94 (92.2)	0.271	71 (89.9) A	67 (93.1)	0.486
Intensity of PA (% of daily time)				aining		
Sedentary	74.7 [67.0 - 82.6]	79.2 [72.1 - 85.1]	0.011	ې [68.1 - 84ع)] 75.7	.74.5 [66.7 - 82.3]	0.587
Light	11.1 [9.1 - 14.1]	9.8 [7.5 - 13.0]	0.008	11 [8.0 - 13.1 <del>g</del>	10.7 [8.4 - 12.9]	0.631
Moderate	12.5 [8.3 - 20.0]	10.3 [7.3 - 16.4]	0.039	14.1 [6.9 - 18. <b>9</b> ]	<b>2</b> 14.0 [8.4 - 18.9]	0.479
Vigorous	0.1 [0 - 0.2]	0 [0 - 0.1]	0.021	0 [0 - 0.2]	0 [0 - 0.2]	0.582

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] br continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous variables and chi-square or Fisher's exact test (§) for categorical variables. Physical activity data assessed using the GENEActiv macro file 'General physical activ  $\mathbf{\hat{k}}$ y' version 1.9.

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		ВМЈ Орен	n	l by copyright, i	njopen-2023-07		
Supplementary table 4: bivariate analysis	s, objectively assesse	ed physical activity by	diabetes co	ح ontrol group as define في	ed <b>19</b> : <b>0</b>	y fasting plasma g	glucose, stratifie
survey, CoLaus PsyCoLaus study, Lausanr	ne, Switzerland.			ng for	n 21 0		
	Second	l survey (2014-2017)		Third	S S S S S S S S S S S S S S S S S S S	ey (2018-2021)	
	Not controlled	Controlled	p-value	Not controlled	seign	Controlled	p-value
Sample size	95	100		31	eme	27	
Intensity of PA (min/day)				o tex	nt Su		
Sedentary	750 [708 - 811]	770 [722 - 822]	0.123	768 [725 - 809]	Iperio	42 [706 - 821]	0.591
Light	72 [43 - 107]	60 [35 - 89]	0.076	81 [43 - 106] at	ed tr	66 [40 - 105]	0.198
Moderate	11 [6 - 22]	9 [3 - 16]	0.039	13 [6 - 22]	ABES	9 [6 - 19]	0.239
Vigorous	1 [0 - 1]	0 [0 - 1]	0.041	1 [0 - 2] 🤤	•) •)	0 [0 - 1]	0.080
At least 150 minutes MVPA per week	19 (20.0)	13 (13.0)	0.187	8 (25.8) Al tr	bmjo	6 (22.2)	0.750
Intensity of PA (% of daily time)					pen.		
Sedentary	90.2 [85 - 94.1]	92.1 [87.8 - 95.1]	0.057	ي و[89.1 [85.5 - 94.0] 89.1	bigi.	.6 [86.6 - 95.0]	0.233
Light	8.2 [5.3 - 12.2]	6.8 [4.3 - 10.5]	0.062	9.1 [5.4 - 12.3]		7.3 [4.4 - 11.1]	0.252
Moderate	1.3 [0.7 - 2.4]	1.1 [0.4 - 1.8]	0.032	1.6 [0.7 - 2.4] ar	on J	1.0 [0.7 - 2.2]	0.239
Vigorous	0.1 [0 - 0.2]	0 [0 - 0.1]	0.033	0.1 [0 - 0.2]	une	0 [0 - 0.1]	0.072

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] br continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous **x**ariables and chi-square for categorical Agence Bibliographique de l variables. Physical activity data assessed using the R-package GGIR version 1.5–9.

u <b>pplementary table 5</b> : multivariable an urvey, CoLaus PsyCoLaus study, Lausan	alysis, objectively as ne, Switzerland.	BMJ Oper sessed physical activit	ry by control	group as defined b	l by copyright, including fo	s s g ing plasma gluco	se, stratified
	Second	l survey (2014-2017)		Third		ey (2018-2021)	
	Not controlled	Controlled	p-value	Not controlled	seign s rela	S Controlled	p-value
Sample size	95	100		31	ted t	27	
Intensity of PA (min/day)					o tex		
Sedentary	761 ± 7	769 ± 7	0.403	756 ± 14	iperio t anc	770 ± 15	0.527
Light	78 ± 4	69 ± 4	0.184	85 ± 9	eur (/ data	71±9	0.317
Moderate	15 ± 1	13 ± 1	0.509	18 ± 3	ABES min	15 ± 3	0.528
Vigorous	1 ± 1	1 ± 1	0.394	1±1 9	s) ing.	1±1	0.370
At least 150 minutes MVPA per week	1 (ref)	0.85 (0.34 - 2.14)	0.727	1 (ref)	Altra	39 (0.07 - 2.07)	0.268
ntensity of PA (% of daily time)					ainin.		
Sedentary	89.3 ± 0.6	90.4 ± 0.6	0.212	88.2 ± 1.3	q. an	. 90.0 ± 1.3	0.353
Light	8.9 ± 0.5	8.0 ± 0.5	0.177	9.6 ± 0.9	d sin	8.2 ± 1.0	0.316
Moderate	$1.7 \pm 0.1$	$1.5 \pm 0.1$	0.501	2.0 ± 0.3	nilar	2 1.7 ± 0.4	0.581
Vigorous	$0.2 \pm 0.1$	$0.1 \pm 0.1$	0.432	$0.2 \pm 0.1$	lechr	0.1 ± 0.1	0.395

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing with some and as odds ratio and (95% confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking stat  $\hat{\mathbf{B}}$ s (never, former, current), educational ce Bibliographique de l level (low, medium, high). Physical activity data assessed using the R-package GGIR version 1.5-9.

Supplementary table 6: bivariate analysis, c	bjectively assessed p	BMJ Open ohysical activity by di	abetes contr	I by copyright, inced ol group as defined	y glycated haemoglo	obin, stratified
survey, CoLaus PsyCoLaus study, Lausanne,	Switzerland.	survey (2014-2017)		ing for Ungen Ting for Ungen	urvey (2018-2021)	
	Not controlled	Controlled	p-value	Not controll	Controlled	p-value
Sample size	123	76		95 <b>ed r</b>	56	
Intensity of PA (min/day)				o tex		
Sedentary	626 [532 - 697]	638 [569 - 731]	0.151	600 [509 - 69	603 [520 - 687]	0.742
Light	89 [65 - 121]	81 [59 - 110]	0.113	90 [63 - 112 <b>6</b>	82 [70 - 100]	0.455
Moderate	106 [62 - 162]	89 [54 - 134]	0.140	123 [63 - 168]	102 [53 - 151]	0.552
Vigorous	0 [0 - 1]	0 [0 - 1]	0.139	0 [0 - 2] 🤤	0 [0 - 2]	0.843
At least 150 minutes MVPA per week (%)	116 (94.3)	71 (93.4)	0.798	87 (91.6) <b>A</b>	51 (91.1)	0.914
Intensity of PA (% of daily time)				ainin		
Sedentary	75.0 [68.2 - 83.1]	79.0 [72.0 - 85.2]	0.082	73.9 [66.3 - 83 - 83 - 9]	75.5 [68.4 - 82.3]	0.726
Light	11.0 [8.9 - 13.7]	9.9 [7.1 - 13.2]	0.074	11.2 [8.0 - 13හූ]	10.1 [8.5 - 12.6]	0.520
Moderate	12.5 [7.9 - 19.6]	10.3 [7.2 - 16.7]	0.106	14.6 [7.6 - 19 <b>4</b> ]	12.3 [7.6 - 17.7]	0.540
Vigorous	0 [0 - 0.2]	0 [0 - 0.1]	0.144	0 [0 - 0.2] E	0 [0 - 0.2]	0.777

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] for continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous ariables and chi-square for categorical gence Bibliographique de l variables. Physical activity data assessed using the GENEActiv macro file 'General physical activity' version 1.9.

<b>upplementary table 7</b> : bivariate analysis, o urvey, CoLaus PsyCoLaus study, Lausanne,	bjectively assessed p Switzerland.	BMJ Open ohysical activity by dia	abetes contr	l by copyright, including fo ol group as defiduding fo	y glycated haemogle	obin, stratified l
	Second	l survey (2014-2017)		 gingit	o urvey (2018-2021)	
	Not controlled	Controlled	p-value	Not controll	Controlled	p-value
Sample size	119	76		38 dt	20	
Intensity of PA (min/day)				o tex		
Sedentary	752 [719 - 812]	770 [722 - 827]	0.210	764 [727 - 80%]	742 [706 - 819]	0.612
Light	69 [40 - 105]	60 [35 - 85]	0.146	77 [41 - 106]	68 [45 - 97]	0.935
Moderate	10 [5 - 19]	9 [4 - 17]	0.344	13 [6 - 22]	10 [7 - 17]	0.731
Vigorous	1 [0 - 1]	0 [0 - 1]	0.317	1 [0 - 2] g	0 [0 - 1]	0.185
At least 150 minutes MVPA per week (%)	20 (16.8)	12 (15.8)	0.852	10 (26.3) A	4 (20.0)	0.593
Intensity of PA (% of daily time)				ainin		
Sedentary	90.4 [85.5 - 94.3]	92.1 [87.6 - 95.1]	0.172	بو 89.6 [85.5 - 94ي1]	91.3 [87.1 - 93.5]	0.806
Light	7.9 [5.1 - 12.1]	6.9 [4.3 - 10.1]	0.116	8.6 [5.0 - 12. <b>g</b> ]	7.6 [5.4 - 11.0]	0.909
Moderate	1.2 [0.6 - 2.2]	1.1 [0.4 - 2.0]	0.324	1.5 [0.7 - 2.4 ]	1.1 [0.8 - 2.0]	0.659
Vigorous	0.1 [0 - 0.2]	0 [0 - 0.2]	0.113	0.1 [0 - 0.2]	0.1 [0 - 0.1]	0.191

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] br continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous **x**ariables and chi-square for categorical Agence Bibliographique de l variables. Physical activity data assessed using the R-package GGIR version 1.5–9.

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Supplementary table 8: multivariable and	alysis, objectively as	sessed physical activit	y by control	group as defined b	, inchudi	ated haemoglob	in, stratified
survey, CoLaus   PsyCoLaus study, Lausan	ne, Switzerland.	()			ng for u	2	
	Secon	d survey (2014-2017)	n valua	Thir Not controlled	Ses ru	ey (2018-2021)	n valua
Sample size		76	p-value		2024 ignen elateo		p-value
Sample size	119	70		38	nent d to t	20	
Sodentary	761 + 6	770 ± 9	0.252	766 ± 10	Supe	756 ± 17	0 664
Sedentary	761±6	770±8	0.353	766 ± 12	aded Prieur	/30 I 1/	0.004
Ligiti	70±4		0.221	76±8	(AB ata n	. 84 ± 11	0.570
	13 ± 1	15 ± 1	0.494	10 ± 3	http: http://www.escillar.com/ http://wwww.escillar.com/ http://www.escillar.com/ http://www.esc	18 ± 4	0.014
vigorous	1 ± 1	1±1	0.974	$1 \pm 1$	g, Al		0.238
At least 150 minutes MVPA per week	I (ref)	1.31 (0.53 - 3.28)	0.560	I (ret)	train	62 (0.11 - 3.42)	0.586
Intensity of PA (% of daily time)			10.		ing,		
Sedentary	89.5 ± 0.5	90.3 ± 0.7	0.392	89.4 ± 1.1	nj.co	. 88.3 ± 1.6	0.571
Light	8.8 ± 0.4	7.9 ± 0.5	0.199	8.6 ± 0.8	sim	9.5 ± 1.2	0.554
Moderate	$1.5 \pm 0.1$	$1.7 \pm 0.2$	0.484	$1.8 \pm 0.3$	on J iilar t	2.1 ± 0.4	0.580
Vigorous	$0.1 \pm 0.1$	$0.1 \pm 0.1$	0.982	$0.2 \pm 0.1$	une	$0.1 \pm 0.1$	0.228

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing was variables and as odds ratio and (95% confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking stat  $\hat{\mathbf{B}}$ s (never, former, current), educational ce Bibliographique de l level (low, medium, high). Physical activity data assessed using the R-package GGIR version 1.5–9.

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# ASSOCIATION BETWEEN PHYSICAL ACTIVITY AND DIABETES CONTROL: MULTIPLE CROSS-SECTIONAL STUDIES AND A PROSPECTIVE STUDY IN A POPULATION-BASED, SWISS COHORT

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Keywords:	General diabetes < DIABETES & ENDOCRINOLOGY, PREVENTIVE MEDICINE, EPIDEMIOLOGIC STUDIES				
Note: The following files were submitted by the author for peer review, but cannot be converted to PDF. You must view these files (e.g. movies) online.					

Annex 1.R

SCHOLARONE<sup>™</sup> Manuscripts



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# BMJ Open

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2		
3 4	1	Association between physical activity and diabetes control: multiple cross-sectional studies
5	2	AND A PROSPECTIVE STUDY IN A POPULATION-BASED, SWISS COHORT
6 7	3	Running title: Physical activity and diabetes in Switzerland
8 9	4	Gaël Vonlanthen, student; Pedro Marques-Vidal, MD, PhD, FESC
10 11	5	Department of medicine, Internal medicine, Lausanne University Hospital and University of
12	6	Lausanne, 46 rue du Bugnon, 1011 Lausanne, Switzerland
13 14	7	
15 16	8	Authors' emails:
17	9	Gaël Vonlanthen: Gael.Vonlanthen@unil.ch
18 19	10	Pedro Marques-Vidal: Pedro-Manuel.Marques-Vidal@chuv.ch
20 21	11	
22 23	12	Authors' ORCIDs:
23 24	13	Gaël Vonlanthen: none
25 26	14	Pedro Marques-Vidal: 0000-0002-4548-8500
27 28	15	Address for correspondence and reprints
29	16	Pedro Marques-Vidal
30 31	17	Office BH10-642
32 33	18	Department of medicine, Internal medicine
34	19	Lausanne University Hospital
35 36	20	Rue du Bugnon 46
37 38	21	1011 Lausanne
39	22	Switzerland
40 41	23	Phone : +41 21 314 09 34
42 43	24	Fax : +41 21 314 09 55
44	25	Email : pedro.marquesvidal@gmail.com
45 46	26	
47 48	27	Word count: 5231 with references and tables
49	28	Number of tables: 3Figures: 1References: 31
50 51		
52 53		
54		
55 56		

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# 30 ABSTRACT

Introduction: physical activity (PA) is recommended in type 2 diabetes mellitus (T2DM)
 patients to improve their glycaemic control. We aimed to assess PA levels among participants
 with controlled and uncontrolled T2DM.

Research design and methods: three cross-sectional analyses of a prospective cohort
 conducted in Lausanne, Switzerland. PA levels (sedentary, light, moderate and vigorous) were
 either self-reported via questionnaire (first and second survey) or objectively assessed using
 accelerometry (second and third survey). T2DM control was defined as glycaemia <7.0</li>
 mmol/L or glycated haemoglobin <6.5% (48 mmol/mol).</li>

Results: data from 195 (30.3% women), 199 (30.1% women) and 151 (44.4% women) participants with T2DM were analysed in the first (2009-2012), second (2014-2017) and third (2018-2021) surveys. Approximately half of the participants did not have controlled glycaemia. Using subjective data, over 90% (first survey) and 75% (second survey) of participants reported moderate and vigorous PA >150 min/week. After multivariable adjustment, no differences were found regarding all types of self-reported PA levels between controlled and uncontrolled participants. Objective assessment of PA led to considerable differences according to the software used: 90% and 20% of participants with moderate and vigorous PA >150 min/week, respectively. After multivariable adjustment, no differences were found for all PA levels between controlled and uncontrolled participants, irrespective of the analytical procedure used. Using glycated haemoglobin, almost two-thirds of participants were considered as uncontrolled, and no differences were found for objectively assessed PA between controlled and uncontrolled participants. 

- 6 52 Conclusions: no differences in PA levels were found between participants with controlled and
   7 53 uncontrolled T2DM.
- 54 Abstract word count: 250
  - 55 Keywords: physical activity; diabetes; control; epidemiology

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# STRENGTHS AND LIMITATIONS OF THIS STUDY

- Physical activity levels were assessed using accelerometer.
- Diabetes control was assessed using both fasting plasma glucose and glycated haemoglobin. •
- Study was conducted in a single location; hence, generalizability might be an issue. •
- ad a single k .s exists as only Possible selection bias exists as only motivated participants accepted to wear the • accelerometer.
Diabetes mellitus affects 537 million adults in the world, 90% of whom have type 2
diabetes mellitus (T2DM). It is predicted that this number of people with diabetes will increase
to 783 million by 2045. Diabetes also has a financial cost estimated at USD 966 billion dollars,
representing 9% of total adult health spending. [1]

Besides guitting smoking and adopting a healthy diet, physical activity (PA) is recommended in all patients with T2DM to improve their glycaemic control, insulin action, lipid levels and blood pressure [2], thus reducing the risk of cardiovascular disease. Simple activity such as walking 30 minutes per day can promote weight loss and improve glycaemic control [3]. More structured exercise programs are more effective to reduce insulin resistance in T2DM [4]. Exercise programs can be focused on aerobic, resistance or combined training, leading to significant improvements in HbA1c levels [5]. Still, it has been reported that patients with T2DM seldom adhere to the recommended amounts of PA. Indeed, barriers such as old age, female sex, lack of motivation, feeling of obligation, depression, and fatigue, can affect adhesion to recommended PA [6]. For instance, in the EUROASPIRE IV and V studies, over half of patients with cardiovascular disease (CVD) and self-reported diabetes did not intend to do regular planned PA, and only one quarter (26%) did [7]. 

In Switzerland, it was estimated that, in 2021, 389,600 people aged between 20 and 79 years lived with diabetes, and 1,249,700 were affected by impaired glucose tolerance, with health costs amounting to \$4.9 billion [8]. Still, the level of PA among people with T2DM and its impact on T2DM control have never been assessed. 

Hence, we aimed to assess the effect of subjectively and objectively measured PA levels in subjects treated for T2DM according to diabetes control, using data from a population-based study. **BMJ** Open

### 88 MATERIALS AND METHODS

### 89 Participants

The CoLaus PsyCoLaus study is a population-based prospective study assessing the clinical, biological, and genetic determinants of cardiovascular disease aged 35 to 75 years at baseline, living in the city of Lausanne, Switzerland [9]. In each survey, participants answered questionnaires, underwent a clinical examination and blood samples were drawn for analyses. Recruitment began in June 2003 and ended in May 2006. The first follow-up was performed between April 2009 and September 2012; the second follow-up was performed between May 2014 and April 2017, and the third follow-up was performed between April 2018 and May 2021. For more details, see www.colaus-psycolaus.ch. 

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### Self-reported physical activity

Subjective PA was assessed using the Physical Activity Frequency Questionnaire (PAFQ). This self-reported questionnaire has been validated in the population of Geneva, Switzerland, and assesses the type and duration of 70 kinds of (non)professional activities and sports during the previous week. Sedentary status was defined as spending more than 90% of daily energy in activities below moderate- and high-intensity (defined as requiring at least 4 times the basal metabolic rate, BMR) [10]. BMR multiples are close to Metabolic Equivalent of Task (MET) multiples, although MET multiples do not consider participant sex, age, or height. 

For the purpose of this study, each type of activity was categorized into sedentary behaviour (SB, <2 metabolic equivalent of tasks - METs), light physical activity (LPA, 2 to <3 METs), moderate physical activity (MPA, 3-6 METs) and vigorous physical activity (VPA, >6 METs) according to the compendium of physical activities [11]. Total PA was defined as the sum of LPA, MPA and VPA. For each item of the PAFQ, the time spent per week was computed as average hours per day multiplied by the number of days when the activity was performed. For each item category (i.e., corresponding to SB, LPA, MPA or VPA), the times were summed up and divided by 7 to estimate an average daily time. 

We chose to include sedentary behaviour in the analysis as we have previously shown
 that it is associated with an increased risk of developing T2DM [12].

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3 4	116	Accelerometry-assessed physical activity
5 6	117	Physical activity was objectively assessed using a wrist-worn triaxial accelerometer
7	118	(GENEActiv, Activinsights Ltd, United Kingdom, www.activinsights.com). These devices are the
8 9 10 11 12 13	119	same that have been used in the UK biobank study [13], weigh 16 g, and allow continuous
	120	monitoring of PA for a maximum of 45 days. The devices were pre-programmed with a 50 Hz
	121	sampling frequency and subsequently attached to the participants' right wrist. Participants
14 15	122	were requested to wear the device continuously for 14 days in their free-living conditions.
16 17	123	Raw accelerometry data were downloaded using the GENEActiv software version 2.9
18 19	124	(GENEActiv, Activinsights Ltd, United Kingdom) and transformed into 1-minute epoch files.
20 21	125	Data were analysed using the GENEActiv Excel macro file 'General physical activity' version
22 22	126	1.9, which had been previously validated [14]. A valid day was defined as ≥10 h (i.e., 600 min-
23	127	epoch) and $\geq$ 8 h (i.e., 480 min-epoch) of diurnal wear-time on weekdays and weekend days,
25 26 27	128	respectively. The Excel macro file can be provided upon request.
28 29 30	129	A second analysis was performed on the raw accelerometry data using the R-package
	130	GGIR version 1.5–9 (http://cran.r-project.org) [15] with the thresholds defined by [16], i.e. an
31 32	131	acceleration between 85 and 180 milli-g to define light PA, between 181 and 437 milli-g to
33 34	132	define moderate PA, and >437 milli-g to define vigorous PA. The code used to analyse the data
35 36	133	is provided in Annex 1.
37 38	134	Participants were considered as complying with the recommendations if the weekly
39 40	135	amount of MPA and VPA exceeded 150 minutes, as per European Society of Cardiology/
41 42	136	European Association for the Study of Diabetes (ESC/EASD) guidelines [2].
43 44	137	Diabetes assessment
45 46	138	Participants were asked whether they had been told they had diabetes and, if the
47 48	139	answer was positive, if they were taking any medication (including insulin) to treat their
49 50	140	diabetes. Participants were considered as presenting with treated diabetes if they reported
51 52	141	taking any antidiabetic drug. Diabetes control was defined as a fasting plasma glucose <7
53	142	mmol/L; a second analysis was conducted using diabetes control defined as a glycated
54 55 56	143	haemoglobin <6.5% (48 mmol/mol).
57 50	144	Blood was drawn in the fasting state and biological assays were performed by the
59 60	145	Centre Hospitalier Universitaire Vaudois Clinical Laboratory on fresh blood samples within 2
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hours of blood collection. The following analytical procedures (with maximum inter and intra-batch CVs) were used: glucose by glucose hexokinase (1.6%-0.8%). In the second and third follow-ups, glycated haemoglobin levels were also measured by high performance liquid chromatography (HPCL) using Bio-Rad, D-10TM system, with measurement range 3.8% (18 mmol/mol) to 18.5% (179 mmol/mol). 

# 151 Eligibility and exclusion criteria

All participants reporting being treated for diabetes were eligible for the study.Participants were excluded if they lacked PA data.

### **Covariates**

Participants were queried regarding their personal and family history of cardiovascular
risk factors, medical treatment, and socio-economic status. Educational level was categorized
into low (mandatory or apprenticeship), medium (high school) and high (university). Smoking
status was categorized into never, former, and current.

Body weight and height were measured with participants barefoot and in light indoor clothes. Body weight was measured in kilograms to the nearest 100 g using a Seca<sup>®</sup> scale (Hamburg, Germany). Height was measured to the nearest 5 mm using a Seca® (Hamburg, Germany) height gauge. Body mass index (BMI) was computed and categorized into normal (<25 kg/m<sup>2</sup>), overweight ( $\geq$ 25 and <30 kg/m<sup>2</sup>) and obese ( $\geq$ 30 kg/m<sup>2</sup>). 

Blood pressure was measured using an Omron<sup>®</sup> HEM-907 automated oscillometric sphygmomanometer after at least a 10-minute rest in a seated position, and the average of the last two measurements was used. Hypertension was defined by a SBP  $\geq$  140 mm Hg or a DBP  $\geq$  90 mm Hg or presence of antihypertensive drug treatment. 

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# **Patient and Public Involvement**

It was not possible to involve patients or the public in the design, or conduct, or
 reporting, or dissemination plans of our research.

53 171 **Statistical analysis** 

54<br/>55172Statistical analyses were performed separately for each study period using Stata56<br/>57173version 18.0 for windows (Stata Corp, College Station, Texas, USA). Descriptive results were58<br/>59174expressed as number of participants (percentage) for categorical variables and as average60175standard deviation or median and [interquartile range] for continuous variables. Bivariate

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analyses were performed using chi-square or Fisher's exact test for categorical variables and Student's t-test, analysis of variance (ANOVA) or Kruskal-Wallis nonparametric test for continuous variables. Multivariable analysis of continuous data was performed using ANOVA and results were expressed as adjusted mean±standard error of the mean (sem). Multivariable analysis of categorical data was performed using logistic regression and results were expressed as odds ratio (95% confidence interval). Multivariable analyses were conducted adjusting for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking status (never, former, current), educational level (low, medium, high). 

A sensitivity analysis was conducted using multivariable linear regression adjusting for the same covariates to assess the association between PA and fasting plasma glucose or glycated hemoglobin. Results were expressed as standardized beta coefficients. 

Statistical significance was assessed for a two-sided test with p<0.05.

#### RESULTS

#### **Characteristics of participants**

The selection procedure of the participants for the first, second and third follow-ups is summarized in **figure 1** and the characteristics of the participants according to adequate or inadequate control of diabetes stratified by survey are provided in **supplementary table 1**. Overall, one half of the participants treated for diabetes did not achieve adequate control. There were no consistent differences between controlled and uncontrolled participants, except that in the second follow-up, controlled participants were older and more frequently smokers.

Sedentary behaviour and physical activity levels according to diabetes control 

### as per fasting plasma glucose

The bivariate analysis of reported PA levels between controlled and uncontrolled participants for the first and the second follow-ups are presented in **supplementary table 2**. Overall, over 90% and 75% of participants were compliant with the 150 min/week of MPA+VPA in the first and second surveys, respectively. Participants spent half of their time in SB and very little in VPA. No differences in PA (in absolute time or as percentage of day) were found between controlled and uncontrolled participants, and similar findings were obtained after multivariable adjustment (table 1). 

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	First s	urvey (2009-2012)		Sec	orged suff	vey (2014-2017)	
	Not controlled	Controlled	p-value	Not controlled	r use	Controlled	p-value
Sample size	121	74		52	ber 2 s rel s rel	48	
ntensity of PA (min/day)					2024. Inem lated		
Sedentary	527 ± 15	542 ± 19	0.543	525 ± 25	ent S	556 ± 26	0.395
Light	197 ± 10	166 ± 13	0.056	204 ± 16	vnloa Supe ext ai	176 ± 16	0.237
Moderate	186 ± 11	191 ± 15	0.819	181 ± 17	nded nd da	185 ± 18	0.864
Vigorous	32 ± 8	46 ± 10	0.250	43 ± 10	(ABI	26 ± 11	0.262
At least 150 minutes MVPA per week	1 (ref)	NC		1 (ref)	ining	.85 (0.35 - 2.09)	0.731 §
Intensity of PA (% of daily time)					g, Al	1	
Sedentary	56 ± 1.5	57.3 ± 2	0.608	54.8 ± 2.4	njope train	58.8 ± 2.5	0.257
Light	20.9 ± 1	17.7 ± 1.3	0.057	21.4 ± 1.6	ing,	18.8 ± 1.7	0.275
Moderate	19.7 ± 1.2	20.2 ± 1.5	0.798	19.3 ± 1.9	nj.co and s	19.6 ± 1.9	0.291
Vigorous	3.4 ± 0.8	4.8 ± 1	0.260	4.6 ± 1	m/ o simil	2.8 ± 1.1	0.257
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BMJ Open **Table 1**: multivariable analysis, self-reported physical activity by control group, stratified by survey, CoLaus |PsyColausestudy, Lausanne, Switzerland. 

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for cont a solds variables and as odds ratio and (95%) confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking status (never, former, current), educational at Agence Bibliographique de l level (low, medium, high). NC, not computable. § n=76 as several variables were dropped due to collinearity. 

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The results of the bivariate analysis of the objectively assessed PA levels using the GENEActiv macro between controlled and uncontrolled participants for the second and third follow-ups are presented in supplementary table 3. Overall, over 90% of participants were compliant with the 150 min/week of MPA+VPA. Participants spent three quarters of their time in SB; conversely, they spent almost two hours per day on MPA. In the second survey, uncontrolled participants had higher levels and percentages of LPA and MPA, and a lower level i th. and percentage of SB. In the third survey, no difference was found between controlled and uncontrolled participants . After multivariable adjustment, no significant differences were observed (table 2). 

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<b>Table 2</b> : multivariable analysis, objectiv CoLaus PsyCoLaus study, Lausanne, Sw	ely assessed physical itzerland.	activity by control gro	oup as define	d using fasting plas	right, in characteristic bight on 21	d by surve
	Secon	nd survey (2014-2017)		Thir	<u>ဒို ရာ</u> မ္မှာey (2018-2021)	
	Not controlled	Controlled	p-value	Not controlled	រ៉េត្រ កម្មភ្លំ Controlled	p-valu
Sample size	97	102		79	atem 72	
Intensity of PA (min/day)					Dow to to	
Sedentary	609 ± 12	634 ± 11	0.131	601 ± 14	ave supposed in the second sec	0.634
Light	97 ± 4	86 ± 4	0.028	92 ± 4	nded 83±4	0.138
Moderate	122 ± 7	106 ± 7	0.124	122 ± 9	Ata m AB 119±9	0.798
Vigorous	1 ± 1	1±1	0.684	1 ± 1	ining 1±1	0.476
At least 150 minutes MVPA per week	1 (ref)	0.94 (0.23 - 3.77)	0.925	1 (ref)	<b>2</b> .45 (0.39 - 5.42)	0.576
Intensity of PA (% of daily time)					<b>njope</b> train	
Sedentary	73.8 ± 1.1	77.1 ± 1.1	0.035	74.3 ± 1.2	ng g 74.7 ± 1.3	0.812
Light	11.7 ± 0.4	$10.2 \pm 0.4$	0.011	11.1 ± 0.4	and $\frac{3}{6}$ 10.3 ± 0.4	0.280
Moderate	14.4 ± 0.8	12.5 ± 0.8	0.105	14.5 ± 1.1	Simil 0 14.7 ± 1.1	0.897
Vigorous	0.2 ± 0.1	$0.1 \pm 0.1$	0.679	0.1±0.1	ar <u>5</u> Er un 0.2 ± 0.1	0.232
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PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing variables and as odds ratio and (95%) confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables ang by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking statis (never, former, current), educational level (low, medium, high). Physical activity data assessed using the GENEActiv macro file 'General physical activity' verition 1.9. 

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3 4	226	Supplementary table 4 shows the bivariate analysis between controlled and
5 6	227	uncontrolled participants of follow-ups 2 and 3, for objectively assessed PA, using the R-
7	228	package GGIR . Overall, less than 25% of participants were compliant with the 150 min/week
8 9	229	of MPA+VPA. Participants spent approximately one-quarter of an hour per day in MPA, and
10 11	230	90% of their time in SB. In the second survey, uncontrolled participants had higher levels and
12 13	231	percentages of LPA and MPA, and a lower level and percentage of SB. After multivariable
14 15	232	adjustment, no significant differences were observed (supplementary table 5).

The results of the sensitivity analysis using multivariable linear regression are provided in supplementary tables 6 to 8. Besides a significant negative association between LPA and glucose levels in the second follow-up for PA assessed by the MACRO procedure, which was not confirmed in the third follow-up, no other association between PA levels and glucose levels was found. 

#### Sedentary behaviour and physical activity levels according to diabetes control as per glycated haemoglobin

The results of the bivariate analysis of the objectively assessed PA levels using the GENEActiv macro between controlled and uncontrolled participants for the second and the third follow-ups are presented in **supplementary table 9**. Almost two-thirds of participants were considered as uncontrolled. No differences were found between controlled and uncontrolled participants in bivariate and multivariable analyses (table 3).

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<b>Table 3</b> : multivariable analysis, objectiv CoLaus PsyCoLaus study, Lausanne, Sw	vely assessed physical itzerland.	activity by control gr	roup as defin	ed by glycated hae	yright, inceogo by right, inceogo bin, stratified b bin, stratified b bin, stratified b	oy survey,
	Secon	d survey (2014-2017)		Thi	ថ្មី កម្លី ឆ្នាំថ្មីey (2018-2021)	
	Not controlled	Controlled	p-value	Not controlled	s seig reiging Controlled	p-value
Sample size	123	76		95	ated 56	
Intensity of PA (min/day)					Dow to te	
Sedentary	613 ± 10	636 ± 13	0.172	599 ± 13	and solution and s	0.736
Light	94 ± 3	87 ± 4	0.216	89 ± 4	ded 85±5	0.543
Moderate	118 ± 6	106 ± 8	0.253	123 ± 8	a A a a a a a a a a a a a a a a a a a a	0.725
Vigorous	1 ± 1	1±1	0.978	1 ± 1	ining 1±1	0.445
At least 150 minutes MVPA per week	1 (ref)	1.54 (0.41 - 5.79)	0.525	1 (ref)	<b>A 1</b> (0.29 - 4.33)	0.879
Intensity of PA (% of daily time)					ljope	
Sedentary	74.6 ± 1.0	76.9 ± 1.2	0.143	74.4 ± 1.1	<b>ng</b> , <b>b</b> 74.8 ± 1.5	0.821
Light	11.3 ± 0.3	$10.4 \pm 0.4$	0.108	10.8 ± 0.4	and 6 10.5 ± 0.5	0.798
Moderate	$14.0 \pm 0.7$	12.6 ± 0.9	0.225	14.7 ± 0.9	similar or 14.5 ± 1.2	0.884
Vigorous	$0.1 \pm 0.1$	$0.1 \pm 0.1$	0.925	$0.1 \pm 0.1$	n 1 0.2 ± 0.1	0.394

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for congous variables and as odds ratio and (95% confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking states (never, former, current), educational level (low, medium, high). Physical activity data assessed using the GENEActiv macro file 'General physical activity' version 1.9. 

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The results of the bivariate and multivariable analysis of the objectively assessed PA levels using the R-package GGIR between controlled and uncontrolled participants for the second and the third follow-ups are presented in **supplementary table 10** (bivariate) and **supplementary table 11** (multivariable). Almost two-thirds of participants were considered as uncontrolled. No differences were found between controlled and uncontrolled participants in bivariate and multivariable analyses.

The results of the sensitivity analysis using multivariable linear regression are provided in **supplementary tables 12 and 13**. No significant association between PA levels and glycated hemoglobin was found.

### 260 **Discussion**

Our results show that over half of participants treated for type 2 diabetes are not controlled. They also show that neither self-reported nor objectively assessed PA levels differ according to diabetes control.

### 264 Characteristics of participants

Overall, participants with controlled T2DM represented less than half of the 65 66 participants in each of the three follow-ups. These values are lower than those reported in most European countries [17 18]. The reasons for such a low control are not easily identifiable: 67 68 no differences were found between controlled and uncontrolled participants for almost all covariates analysed, and a previous study showed no differences in dietary intakes [19]. 69 70 Hence, the factors associated to T2DM control may be a less effective health care or differences in PA levels, which will be detailed in the next section. Overall, our results indicate 71 that over half of treated diabetics do not achieve adequate control in this Swiss population-72 73 based sample.

### 274 Sedentary behaviour and physical activity levels according to diabetes control

PA is a cost-saving treatment [20 21]. Patients with T2DM who regularly participate in aerobic exercise have a better control of their disease [22]. According to Swiss and international guidelines, it is recommended to spend 150 min/week doing moderate to vigorous PA [23]. **BMJ** Open

In our study, participants with T2DM reported over 150 minutes per day of MPA. Our findings suggest that most participants with T2DM comply with PA recommendations, although a reporting bias cannot be excluded. Conversely, the results of the objectively assessed PA differed considerably according to the analytical method applied. According to the GENEActiv macro, almost all participants treated for T2DM were compliant with current PA recommendations, while according to the R-package GGIR this percentage was less than 25%. These differences between analytical methods have been reported previously [24] and raise the importance of standardization of PA accelerometry measurements [25]. 

After multivariable adjustment, no differences were found between controlled and uncontrolled participants regarding all PA levels, either as absolute time or as % of day. Our findings agree with a study conducted in Poland, where no differences in both subjectively and objectively assessed PA levels were found between controlled and uncontrolled participants [26]. Conversely, our findings do not replicate those of two other studies, which showed significant improvement in glycaemic control in participants with T2DM when regular PA was part of a healthy lifestyle [27 28]. Possible explanations include the methods used to categorize participants. For instance, both studies used self-filled questionnaire to categorize participants into active and inactive, while ours used both subjective and objective PA assessment. It is likely that the relatively small sample size of our study led to a low statistical power, and we cannot exclude an indication bias, participants with uncontrolled T2DM being recommended more frequently to exercise than those who are controlled. 

PA levels differed considerably according to the methodology used. The differences between reported and objectively assessed PA are known [29], and the differences in PA levels according to the software used to process the accelerometry data have also been detected previously [24]. Overall, our results indicate that the method to assess PA might considerably impact the associations between PA and cardiometabolic risk factors. Hence, care should be taken when comparing findings from studies that used different software to assess PA.

Female sex, older age, comorbidities such as obesity and depression, lack of motivation, and social influence have been suggested to decrease adherence to PA [30]. It would thus be useful to consider these barriers in subjects with T2DM when prescribing regular PA [6] and consider routine activities as domestic chores to increase PA [31]. 

### 309 Implications for clinical practice

Overall, our results suggest that people with diabetes exhibit the same PA behaviour irrespective of their fasting glucose or HbA1c levels. As PA is part of the management of T2DM [2], more emphasis should be put by clinicians to motivate their patients to be more active, different types of PA being effective [5]. Still, doctors might not have either the time or the knowledge [32] to adequately advise their patients regarding PA. Hence, postgraduate training regarding PA prescription is advised [33].

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### Strengths and limitations

The major strengths of this study is the use of both subjectively and objectively assessed PA. It used two different software to analyse PA and two different criteria (fasting plasma glucose and glycated haemoglobin) to define T2DM. The results were replicated in two time points and a population-based sample was used.

This study also has some limitations. First, the study was conducted in a single location, and results might not be extrapolated to other settings, although similar findings were obtained elsewhere [26]. Second, a possible selection bias might have occurred, as more motivated participants may accept to wear the accelerometer more easily. Hence, it is likely that the amounts of PA might be overestimated, but not the comparisons between controlled and uncontrolled participants. Third, the cross-sectional design of this study cannot address the question whether effective PA levels can efficiently help manage diabetes. Still, our results are similar to those reported elsewhere [34], and suggest that PA levels should be implemented among people with diabetes. Finally, the amounts of light, moderate and vigorous PA differed considerably according to the analytical procedure applied. This issue has already been discussed [24] and recommendations have been issued [24 35]. Further, the results between controlled and uncontrolled participants were identical irrespective of the analytical procedure applied. 

334 Conclusion

In this population-based study focusing on participants treated for T2DM, no
 differences were found between controlled and uncontrolled T2DM regarding self-reported
 or objectively assessed PA levels.

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## **CONTRIBUTORY STATEMENT**

Gaël Vonlanthen: investigation; formal analysis, visualisation; writing - original draft.
Pedro Marques-Vidal: conceptualization; data curation; formal analysis; writing - review &
editing; supervision. Pedro Marques-Vidal had full access to the data and is the guarantor of
the study.

### **COMPETING INTERESTS**

- The authors report no conflict of interest.
- 346 FUNDING

The CoLaus | PsyCoLaus study was supported by research grants from GlaxoSmithKline (N/A), the Faculty of Biology and Medicine of Lausanne (N/A), the Swiss National Science Foundation (grants 3200B0–105993, 3200B0-118308, 33CSCO-122661, 33CS30-139468, 33CS30-148401, 33CS30\_177535 and 3247730\_204523) and the Swiss Personalized Health Network (N/A) (project: Swiss Ageing Citizen Reference).

352 DATA SHARING STATEMENT

The CoLaus PsyCoLaus cohort data used in this study cannot be fully shared as they contain potentially sensitive patient information. As discussed with the competent authority, the Research Ethic Committee of the Canton of Vaud, transferring or directly sharing this data would be a violation of the Swiss legislation aiming to protect the personal rights of participants. Non-identifiable, individual-level data are available for interested researchers, who meet the criteria for access to confidential data sharing, from the CoLaus Datacenter (CHUV, Lausanne, Switzerland). Instructions for gaining access to the CoLaus data used in this study are available at https://www.colaus-psycolaus.ch/professionals/how-to-collaborate/. 

**ETHICAL STATEMENT** 

54<br/>55362The institutional Ethics Committee of the University of Lausanne, which afterwards55<br/>56<br/>57363became the Ethics Commission of Canton Vaud (www.cer-vd.ch) approved the baseline57<br/>58<br/>58364CoLaus study (reference 16/03). The approval was renewed for the first (reference 33/09), the59<br/>60365second (reference 26/14) and the third (reference PB\_2018-00040) follow-ups. The approval

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3 4	366	for the entire CoLaus PsyCoLaus study was confirmed in 2021 (reference PB_2018-00038,
5	367	239/09). The full decisions of the CER-VD can be obtained from the authors upon request. The
6 7	368	study was performed in agreement with the Helsinki declaration and its former amendments,
8 9	369	and in accordance with the applicable Swiss legislation (LRH 810.30). All participants gave their
10 11	370	signed informed consent before entering the study.
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2 3 4	481	FIGURE LEGENDS
5 6 7	482	Figure 1: selection procedure for the first, second and third follow-ups, CoLaus PsyColaus
$\begin{array}{c} 7\\ 8\\ 9\\ 10\\ 11\\ 12\\ 13\\ 14\\ 15\\ 16\\ 17\\ 18\\ 19\\ 20\\ 22\\ 32\\ 42\\ 52\\ 62\\ 72\\ 8\\ 29\\ 30\\ 132\\ 33\\ 43\\ 536\\ 37\\ 38\\ 940\\ 41\\ 43\\ 44\\ 546\\ 47\\ 48\\ 950\\ 51\\ 53\\ 54\\ 556\\ 57\\ 58\\ 960 \end{array}$	483	study, Lausanne, Switzerland.



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study, Lausanne, Switzerland.

	First sur	vey (2009-2012)		Second survey (2014-2017)			<u>ਕ</u> ਤੋਂ SThird survey (2018-2021)			
	Not controlled	Controlled	p-value	Not controlled	Controlled	p-value	Notecantrolled	Controlled	p-value	
Sample size	121	74		97	102		nt s	72		
Women (%)	37 (30.6)	22 (29.7)	1.000	28 (28.9)	32 (31.4)	0.758		35 (48.6)	0.330	
Age (years)	65.1 ± 8.8	65.9 ± 8.4	0.519	66.6 ± 8.7	69.5 ± 8.8	0.020	888 8 8.7	68.1 ± 8.7	0.652	
Swiss born (%)	85 (70.3)	43 (58.1)	0.090	59 (60.8)	67 (65.7)	0.556	<b>ૡૢ</b> \$5 <b>4</b> (69.6)	42 (58.3)	0.175	
Education (%)			0.212			0.589	(AB ta n		1.000	
High	11 (9.1)	13 (17.6)		12 (12.4)	12 (11.9)		<b>ji (2)</b> (11.4)	8 (11.1)		
Middle	29 (24.0)	18 (24.3)		24 (24.7)	19 (18.8)		<b>.</b>	17 (23.6)		
Low	81 (66.9)	43 (58.1)		61 (62.9)	70 (69.3)		<b>≥</b> 52 <b>3</b> 65.8)	47 (65.3)		
BMI (kg/m²)	30.5 ± 5.6	29.4 ± 4.1	0.161	30.5 ± 4.9	30.6 ± 5.1	0.924	<b>រ</b> 20.8 <mark>9</mark> 4.6	29.0 ± 5.6	0.378	
BMI categories (%)			0.711			1.000	nin,		0.319	
Normal	17 (14.1)	10 (13.5)		11 (11.5)	12 (11.8)		<b>نو</b> 11 <b>3</b> 13.9)	15 (20.8)		
Overweight	50 (41.3)	35 (47.3)		37 (38.5)	39 (38.2)		a 33 <mark>8</mark> 41.8)	33 (45.8)		
Obese	54 (44.6)	29 (39.2)		48 (50.0)	51 (50.0)		<b>S</b> :35 <b>4</b> 4.3)	24 (33.3)		
Smoking categories (%)			0.770			0.022	illar		0.950	
Never	37 (30.6)	25 (33.8)		26 (26.8)	39 (38.2)			28 (38.9)		
Former	65 (53.7)	40 (54.1)		57 (58.8)	40 (39.2)		38 <b>(</b> 48.1)	34 (47.2)		
Current	19 (15.7)	9 (12.2)		14 (14.4)	23 (22.6)		<b>8</b> 12 (15.2)	10 (13.9)		
Hypertension (%)	99 (81.8)	55 (74.3)	0.277	76 (78.4)	80 (78.4)	1.000	<b>67 1 1 1 1 1 1 1 1 1 1</b>	57 (79.2)	0.401	
Hypolipidemic ttt (%)	67 (55.4)	51 (68.9)	0.071				s. stat			
History of CVD (%)	18 (14.9)	12 (16.2)	0.839	18 (18.6)	20 (19.6)	0.859	16 <b>6</b> 20.3)	13 (18.1)	0.837	

BMI, body mass index; CVD, cardiovascular disease; ttt, treatment. Results expressed as mean ± standard deviation for continuous variables or as number of participants (percentage) for categorical variables. Statistical analysis by student's t-test or chi-square test.

Supplementary table 2: bivariate analysi	is, self-reported physi	BMJ Oper	n es control g	roup as defined by	njopen-2023-0789gg plasma glucose	e, stratified by survey
CoLaus PsyCoLaus study, Lausanne, Swit	zerland.			ding fo	on 21	
	First s	urvey (2009-2012)		ອ Seconີສູ	<u>ុ</u> ឆ្នាភ្ជ័vey (2014-2017)	
	Not controlled	Controlled	p-value	ە Mot controlled آ	Controlled	p-value
Sample size	121	74		52 <b>d</b>	eme 9024. 48	
Intensity of PA (min/day)				o tex	nt Su	
Sedentary	522 [394 - 660]	557 [449 - 651]	0.379	555 [405 - 665] a	<b>b b b c c c c c c c c c c</b>	0.637
Light	185 [107 - 272]	156 [109 - 243]	0.128	168 [125 - 249] a	257 [123 - 242]	0.567
Moderate	164 [95 - 249]	155 [107 - 265]	0.862	143 [105 - 246]	61 [104 - 221]	0.992
Vigorous	0.7 [0 - 4]	0.8 [0 - 4.5]	0.995	18 [0 - 46] g	· 15 [0 - 55]	0.997
At least 150 minutes MVPA per week	118 (97.5)	73 (98.7)	ş	51 (78.5) A	45 (76.3)	0.270
Intensity of PA (% of daily time)				ainin	pen.	
Sedentary	57.2 [42.4 - 68.8]	59.4 [46.8 - 68.4]	0.418	ي و(60.1 [44.6 - 68.0	58.0 [48.3 - 68.0]	0.551
Light	19.3 [11.2 - 29.7]	16.6 [12.0 - 24.5]	0.108	18.5 [13.8 - 26.7]	1.7 [12.8 - 26.6]	0.801
Moderate	17.2 [10.7 - 25.8]	16.2 [11.2 - 26.9]	0.823	<u>ם.</u> 15.0 [10.3 - 26.8]מ	<b>ලී</b> .7 [11.4 - 24.2]	0.866
Vigorous	6.0 [0 - 37.0]	6.0 [0 - 39.0]	0.980	1.9 [0 - 5.2]	<b>J</b> 1.4 [0 - 6.0]	0.963

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] br continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous variables and chi-square or Fisher's exact Agence Bibliographique de l test (§) for categorical variables.

objectively assessed	BMJ Open physical activity by d	iabetes conti	d by copyright, ince rol group as defined	y y y fasting plasma glu	icose, stratifie
, Switzerland.	survey (2014-2017)		iding for the transformed to the	girvey (2018-2021)	
Not controlled	Controlled	p-value	ស ស Not controlle	Controlled	p-value
97	102		79 dt	72	
			o tex		
624 [522 - 691]	640 [561 - 734]	0.061	625 [515 - 69 <b>3]</b> er	588 [503 - 690]	0.341
92 [69 - 124]	83 [58 - 111]	0.024	87 [65 - 115 at a	83 [68 - 102]	0.378
108 [65 - 165]	91 [54 - 134]	0.057		111 [60 - 160]	0.780
0 [0 - 1]	0 [0 - 1]	0.021	0 [0 - 2] 🤤	0 [0 - 2]	0.683
93 (95.9)	94 (92.2)	0.271	71 (89.9) Al tr	67 (93.1)	0.486
			ainin		
74.7 [67.0 - 82.6]	79.2 [72.1 - 85.1]	0.011	بع [68.1 - 84ع] 75.7	.74.5 [66.7 - 82.3]	0.587
11.1 [9.1 - 14.1]	9.8 [7.5 - 13.0]	0.008	11 [8.0 - 13.1 <mark>9</mark>	10.7 [8.4 - 12.9]	0.631
12.5 [8.3 - 20.0]	10.3 [7.3 - 16.4]	0.039	14.1 [6.9 - 18. <b>9</b> ]	<b>B</b> 14.0 [8.4 - 18.9]	0.479
0.1 [0 - 0.2]	0 [0 - 0.1]	0.021	0 [0 - 0.2]	0 [0 - 0.2]	0.582
	bjectively assessed s Switzerland. Second Not controlled 97 624 [522 - 691] 92 [69 - 124] 108 [65 - 165] 0 [0 - 1] 93 (95.9) 74.7 [67.0 - 82.6] 11.1 [9.1 - 14.1] 12.5 [8.3 - 20.0] 0.1 [0 - 0.2]	b)jectively assessed physical activity by d         switzerland.         Second survey (2014-2017)         Not controlled       Controlled         97       102         624 [522 - 691]       640 [561 - 734]         92 [69 - 124]       83 [58 - 111]         108 [65 - 165]       91 [54 - 134]         0 [0 - 1]       0 [0 - 1]         93 (95.9)       94 (92.2)         74.7 [67.0 - 82.6]       79.2 [72.1 - 85.1]         11.1 [9.1 - 14.1]       9.8 [7.5 - 13.0]         12.5 [8.3 - 20.0]       10.3 [7.3 - 16.4]         0.1 [0 - 0.2]       0 [0 - 0.1]	BMJ Open         Second survey (2014-2017)         Second survey (2014-2017)         Not controlled       Controlled       p-value         97       102         624 [522 - 691]       640 [561 - 734]       0.061         92 [69 - 124]       83 [58 - 111]       0.024         108 [65 - 165]       91 [54 - 134]       0.057         0 [0 - 1]       0 [0 - 1]       0.021         93 (95.9)       94 (92.2)       0.271         74.7 [67.0 - 82.6]       79.2 [72.1 - 85.1]       0.011         11.1 [9.1 - 14.1]       9.8 [7.5 - 13.0]       0.008         12.5 [8.3 - 20.0]       10.3 [7.3 - 16.4]       0.039         0.1 [0 - 0.2]       0 [0 - 0.1]       0.021	BMJ Open         bbjectively assessed physical activity by diabetes control group as defined         Second survey (2014-2017)         Not controlled       Controlled       p-value       Not controlled         97       102       79       624 [522 - 691]       640 [561 - 734]       0.061       625 [515 - 693         92 [69 - 124]       83 [58 - 111]       0.024       87 [65 - 115 ]       91 [54 - 134]       0.057       117 [56 - 161 ]         108 [65 - 165]       91 [54 - 134]       0.057       117 [56 - 161 ]       91 [97 ]         93 (95.9)       94 (92.2)       0.271       71 (89.9)       Arange         74.7 [67.0 - 82.6]       79.2 [72.1 - 85.1]       0.011       75.7 [68.1 - 84 @] ]       11.1 [9.1 - 14.1]       9.8 [7.5 - 13.0]       0.008       11 [8.0 - 13.1 @         12.5 [8.3 - 20.0]       10.3 [7.3 - 16.4]       0.039       14.1 [6.9 - 18.8]       11.1 [6.9 - 18.8]         0.1 [0 - 0.2]       0 [0 - 0.1]       0.021       0 [0 - 0.2]       0 [0 - 0.2]       0 [0 - 0.2]	BMJ Open         BMJ Open         Open

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] by continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous variables and chi-square or Fisher's exact test (§) for categorical variables. Physical activity data assessed using the GENEActiv macro file 'General physical activiary' version 1.9.

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Supplementary table 4: bivariate analysi	s, objectively assess	BMJ Oper ed physical activity by	n diabetes co	ontrol group as define	a open- 2023-078 ed by fasting plasma	glucose, stratified
Survey, colaus r sycolaus study, lausain	Second	l survey (2014-2017)		Third	22 O Surgey (2018-2021)	
	Not controlled	Controlled	p-value	Not controlled	Controlled	p-value
Sample size	95	100		31	<b>27</b>	
Intensity of PA (min/day)				O TEX	nt Su	
Sedentary	750 [708 - 811]	770 [722 - 822]	0.123	768 [725 - 809]	42 [706 - 821]	0.591
Light	72 [43 - 107]	60 [35 - 89]	0.076	81 [43 - 106]		0.198
Moderate	11 [6 - 22]	9 [3 - 16]	0.039	13 [6 - 22]	9 [6 - 19]	0.239
Vigorous	1 [0 - 1]	0 [0 - 1]	0.041	ي [0 - 2] 1	0 [0 - 1]	0.080
At least 150 minutes MVPA per week	19 (20.0)	13 (13.0)	0.187	8 (25.8)	6 (22.2)	0.750
Intensity of PA (% of daily time)					pen.	
Sedentary	90.2 [85 - 94.1]	92.1 [87.8 - 95.1]	0.057	ي يو(89.1 [85.5 - 94.0	9.6 [86.6 - 95.0]	0.233
Light	8.2 [5.3 - 12.2]	6.8 [4.3 - 10.5]	0.062	9.1 [5.4 - 12.3]	.3 [4.4 - 11.1]	0.252
Moderate	1.3 [0.7 - 2.4]	1.1 [0.4 - 1.8]	0.032	1.6 [0.7 - 2.4]	<b>9</b> 1.0 [0.7 - 2.2]	0.239
Vigorous	0.1 [0 - 0.2]	0 [0 - 0.1]	0.033	0.1 [0 - 0.2]	0 [0 - 0.1]	0.072

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile rame] br continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous gariables and chi-square for categorical Agence Bibliographique de l variables. Physical activity data assessed using the R-package GGIR version 1.5–9.

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		BMJ Oper	1		hjopen-zuzs-uzsi i by copyright, in		
upplementary table 5: multivariable an urvey, CoLaus   PsyCoLaus study, Lausan	alysis, objectively as ne, Switzerland.	sessed physical activit	y by control	sroup as defined b والم رو	on ∠ Cataling	ting plasma gluco	se, stratified
	Second	d survey (2014-2017)		Thirc		ey (2018-2021)	
	Not controlled	Controlled	p-value	Not controlled	seigr seigr	Controlled	p-value
Sample size	95	100		31	iteme	27	
Intensity of PA (min/day)					nt Su		
Sedentary	761 ± 7	769 ± 7	0.403	756 ± 14	iperie t and	770 ± 15	0.527
Light	78 ± 4	69 ± 4	0.184	85 ± 9	ed π ∍ur (/ I data	71 ± 9	0.317
Moderate	15 ± 1	13 ± 1	0.509	18 ± 3	ABES	15 ± 3	0.528
Vigorous	1 ± 1	1 ± 1	0.394	1±1 g	ing.	1±1	0.370
At least 150 minutes MVPA per week	1 (ref)	0.85 (0.34 - 2.14)	0.727	1 (ref)	Al tra	39 (0.07 - 2.07)	0.268
Intensity of PA (% of daily time)					ainin		
Sedentary	89.3 ± 0.6	90.4 ± 0.6	0.212	88.2 ± 1.3	g, an	90.0 ± 1.3	0.353
Light	8.9 ± 0.5	8.0 ± 0.5	0.177	9.6 ± 0.9	d sim	8.2 ± 1.0	0.316
Moderate	$1.7 \pm 0.1$	$1.5 \pm 0.1$	0.501	2.0 ± 0.3	טח J זilar 1	1.7 ± 0.4	0.581
Vigorous	$0.2 \pm 0.1$	$0.1 \pm 0.1$	0.432	0.2 ± 0.1	une echi	$0.1 \pm 0.1$	0.395

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for con a solds variables and as odds ratio and (95%) confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking statiss (never, former, current), educational ce Bibliographique de l level (low, medium, high). Physical activity data assessed using the R-package GGIR version 1.5–9.

					<u>, , , , , , , , , , , , , , , , , , , </u>		
	First survey (2009-2012)			Sec			
	Not controlled	Controlled	p-value	Not controlled	use	Controlled	p-value
Sample size	121	74		52	oer 2 seig s rel	48	
Intensity of PA (min/day)					nem ated		
Sedentary	527 ± 15	542 ± 19	0.543	525 ± 25	ent S to te	556 ± 26	0.395
Light	197 ± 10	166 ± 13	0.056	204 ± 16	vnloa Supe ext al	176 ± 16	0.237
Moderate	186 ± 11	191 ± 15	0.819	181 ± 17	nded nd da	185 ± 18	0.864
Vigorous	32 ± 8	46 ± 10	0.250	43 ± 10	from (ABE	26 ± 11	0.262
At least 150 minutes MVPA per week	1 (ref)	NC		1 (ref)	ining	85 (0.35 - 2.09)	0.731§
Intensity of PA (% of daily time)					, Al		
Sedentary	56 ± 1.5	57.3 ± 2	0.608	54.8 ± 2.4	njope train	58.8 ± 2.5	0.257
Light	20.9 ± 1	17.7 ± 1.3	0.057	21.4 ± 1.6	ing,	18.8 ± 1.7	0.275
Moderate	19.7 ± 1.2	20.2 ± 1.5	0.798	19.3 ± 1.9	nj.co and s	19.6 ± 1.9	0.291
Vigorous	$3.4 \pm 0.8$	4.8 ± 1	0.260	4.6 ± 1	m/ on simila	2.8 ± 1.1	0.257

BMJ Open **Table 1**: multivariable analysis, self-reported physical activity by control group, stratified by survey, CoLaus |PsyColausestudy, Lausanne, Switzerland.

PA, physical activity; MVPA, moderate and vigorous physical activity Results are expressed as standardized beta coeffecients. Statistical analysis by linear regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking status (never, former, current), educational level (low, medium, high). , 2025 at Agence Bibliographique de l

Vigorous

	First survey (2009-2012)	p-valu
Sample size	195	
Intensity of PA (min/day)		
Sedentary	0.040	0.599
Light	0.068	0.378
Moderate	0.003	0.968
Vigorous	-0.139	0.059
Intensity of PA (% of daily time)		
Sedentary	0.028	0.716
Light	0.066	0.388
Moderate	0.003	0.972

' physical activity and fasting place ' physical activity and fasting place ing for UC Cobb rond survey (2014-2017 rond survey (2014-2017 relate 100 relate 100

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as standardized beta ceefficients. Statistical analysis by linear regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking tatus (never, former, current), educational level (low, medium, high).

0.055

-0.141

er 2024. Downloaded from http://bmjopen.bmj.com/ o eignement Superieur (ABES) . related to text and data mining, Al training, and simi

-0.080

0.074

0.070

0.051

-0.120

0.055

0.083

0.041

0.455

0.493

0.517

0.635

0.271

0.613

0.439

0.700

Supplementary table 7: multivariable	analysis, association between obje	BMJ Open ctively asses	sed physical activity and fast	njopen-2023-07892ഇ യ 1 bv convright. inബ്	asma glucose, stratified by survey,
CoLaus   PsyCoLaus study, Lausanne, S	witzerland.		ŭ	) on 21 Idina fa	
	Second survey (2014-2017)	p-value	Third survey (2018-2021	Octob Ens	p-value
Sample size	199		151	er 20 seign srela	
Intensity of PA (min/day)				emei ted t	
Sedentary	-0.072	0.340	0.081	o tex	0.360
Light	0.203	0.005	0.126	load perie	0.152
Moderate	0.140	0.069	-0.051	ed fro eur (/ I data	0.589
Vigorous	0.012	0.871	-0.019	om h ABES	0.831
Intensity of PA (% of daily time)			ġ	ina (	
Sedentary	-0.145	0.061	0.021	bmjo Al tra	0.827
Light	0.187	0.011	0.104	inin.	0.242
Moderate	0.103	0.188	-0.072	bmj.c	0.449
Vigorous	-0.007	0.928	-0.029	d sim	0.742

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as standardized beta ceefficients. Statistical analysis by linear ž PA, physical activity, more male, female), age (continuous), BMI categories (normal, overweight, obese), smoking tages more regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking tages more regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking tages more regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking tages more regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking tages more regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking tages more regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking tages more regression adjusted for sex (male, female), age (continuous), and the GENEActiv macro file 'General physical activity at a assessed using the GENEActiv macro file 'General physical activity's are tagen adjusted for sex (male, female). Physical activity data assessed using the GENEActiv macro file 'General physical activity's are tagen adjusted for sex (male, female). Physical activity and the general physical activity adjusted for sex (male, female). Physical activity and the general physical activity adjusted for sex (male, female). Physical activity adjusted for sex (male, female). Physical activity adjusted for sex (male, female). Physical activity adjusted for sex (male, female, female). Physical activity adjusted for sex (male, female). Physical activity adjusted for sex (male, female, fe regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking status (never, former, current), educational

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23 24

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26 27

28 29

30 31

42 43

44 45 46 Light

Moderate

Vigorous

CoLaus PsyCoLaus study, Lausanne, S	Switzerland.
	Second survey (201
Sample size	195
Intensity of PA (min/day)	
Sedentary	-0.071
Light	0.154
Moderate	0.078
Vigorous	0.021
Intensity of PA (% of daily time)	
Sedentary	-0.141

bjectively assessed physical activity and fasting for 21 0 p-value Third survey (2018-2021) - C

0.352

0.052

0.339

0.782

0.080

0.053

0.372

0.880

0.154

0.074

0.012

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as standardized beta ceefficients. Statistical analysis by linear 9 regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking  $\frac{1}{2}$  (never, former, current), educational level (low, medium, high). Physical activity data assessed using the R-package GGIR version 1.5–9. 2025 at Agence Bibliographique de l

er 2024. Downloaded from http://bmjopen.bmj.com/ c eignement Superieur (ABES) . related to text and data mining, Al training, and simi

0.433

0.532

0.562

0.726

0.102

0.547

0.557

0.670

0.121

-0.105

-0.099

0.055

0.256

-0.101

-0.100

0.067

<b>pplementary table 9</b> : bivariate analysis, rvey, CoLaus PsyCoLaus study, Lausanne	objectively assessed p e. Switzerland.	BMJ Open hysical activity by di	abetes contr	by copyright, inceded on ol group as defieuding	y glycated haemoglo	slobin, stratified	
	Second	survey (2014-2017)		y for 可要 TERE	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		
	Not controlled	Controlled	p-value	Not controll	Controlled	p-value	
ample size	123	76		95 det	56		
ntensity of PA (min/day)				o tex			
Sedentary	626 [532 - 697]	638 [569 - 731]	0.151		603 [520 - 687]	0.742	
Light	89 [65 - 121]	81 [59 - 110]	0.113	90 [63 - 112 <b>6</b>	82 [70 - 100]	0.455	
Moderate	106 [62 - 162]	89 [54 - 134]	0.140	123 [63 - 16 <b>8</b> ]	102 [53 - 151]	0.552	
Vigorous	0 [0 - 1]	0 [0 - 1]	0.139	0 [0 - 2] ig	0 [0 - 2]	0.843	
t least 150 minutes MVPA per week (%)	116 (94.3)	71 (93.4)	0.798	87 (91.6) <b>A</b>	51 (91.1)	0.914	
ntensity of PA (% of daily time)				ainin			
Sedentary	75.0 [68.2 - 83.1]	79.0 [72.0 - 85.2]	0.082	بو 73.9 [66.3 - 83ع9] .	75.5 [68.4 - 82.3]	0.726	
Light	11.0 [8.9 - 13.7]	9.9 [7.1 - 13.2]	0.074	11.2 [8.0 - 13ឌ្ឌ]	10.1 [8.5 - 12.6]	0.520	
Moderate	12.5 [7.9 - 19.6]	10.3 [7.2 - 16.7]	0.106	14.6 [7.6 - 19 <sup>2</sup> ]	12.3 [7.6 - 17.7]	0.540	
Vigorous	0 [0 - 0.2]	0 [0 - 0.1]	0.144	0 [0 - 0.2] Lec	0 [0 - 0.2]	0.777	

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] for continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous ariables and chi-square for categorical gence Bibliographique de l variables. Physical activity data assessed using the GENEActiv macro file 'General physical activity' version 1.9.

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		BMJ Open		l by copyright, in		
Supplementary table 10: bivariate analysis, survey, CoLaus   PsyCoLaus study, Lausanne,	objectively assessed Switzerland.	physical activity by c	liabetes cont	rol group as defined	by glycated haemog	lobin, stratifie
	Second	survey (2014-2017)		for contractions of the second	urvey (2018-2021)	
	Not controlled	Controlled	p-value	Not controll	Controlled	p-value
Sample size	119	76		38 dt	20	
Intensity of PA (min/day)				o tex		
Sedentary	752 [719 - 812]	770 [722 - 827]	0.210	764 [727 - 80%]	742 [706 - 819]	0.612
Light	69 [40 - 105]	60 [35 - 85]	0.146	77 [41 - 106	68 [45 - 97]	0.935
Moderate	10 [5 - 19]	9 [4 - 17]	0.344	13 [6 - 22]	10 [7 - 17]	0.731
Vigorous	1 [0 - 1]	0 [0 - 1]	0.317	1 [0 - 2] u	0 [0 - 1]	0.185
At least 150 minutes MVPA per week (%)	20 (16.8)	12 (15.8)	0.852	10 (26.3) Art	4 (20.0)	0.593
Intensity of PA (% of daily time)				ainin		
Sedentary	90.4 [85.5 - 94.3]	92.1 [87.6 - 95.1]	0.172	89.6 [85.5 - 94	91.3 [87.1 - 93.5]	0.806
Light	7.9 [5.1 - 12.1]	6.9 [4.3 - 10.1]	0.116	8.6 [5.0 - 12. <b>g</b> ]	7.6 [5.4 - 11.0]	0.909
Moderate	1.2 [0.6 - 2.2]	1.1 [0.4 - 2.0]	0.324		1.1 [0.8 - 2.0]	0.659
Vigorous	0.1 [0 - 0.2]	0 [0 - 0.2]	0.113	0.1 [0 - 0.2	0.1 [0 - 0.1]	0.191

PA, physical activity; MVPA, moderate and vigorous physical activity. Results expressed as median [interquartile range] by continuous variables and as number of participants (column percentage) for categorical variables. Statistical analysis by Kruskal-Wallis test for continuous **x**ariables and chi-square for categorical Agence Bibliographique de l variables. Physical activity data assessed using the R-package GGIR version 1.5–9.

unnlementary table 11: multivariable au	nalvsis ohiectively a	BMJ Oper	1 ity by contro	al group as defined	קפיר קפיר אין		
urvey, CoLaus   PsyCoLaus study, Lausanr	ne, Switzerland.		ity by contro			iooni, stratilie	
	Second	d survey (2014-2017)		Third	son ver (2018-2021)		
	Not controlled	Controlled	p-value	Not controlled	Controlled	p-value	
Sample size	119	76		38 4	20 20		
Intensity of PA (min/day)					Down nt Su		
Sedentary	761 ± 6	770 ± 8	0.353	766 ± 12	756 ± 17	0.664	
Light	76 ± 4	68 ± 5	0.221	76±8	84 ± 11	0.570	
Moderate	13 ± 1	15 ± 1	0.494	16 ± 3		0.614	
Vigorous	1 ± 1	1 ± 1	0.974	ي پ	1±1	0.238	
At least 150 minutes MVPA per week	1 (ref)	1.31 (0.53 - 3.28)	0.560	1 (ref)	<b>6</b> 2 (0.11 - 3.42)	0.586	
Intensity of PA (% of daily time)					pen.		
Sedentary	89.5 ± 0.5	90.3 ± 0.7	0.392	ي 89.4 ± 1.1	88.3 ± 1.6	0.571	
Light	8.8 ± 0.4	7.9 ± 0.5	0.199	8.6 ± 0.8	9.5 ± 1.2	0.554	
Moderate	1.5 ± 0.1	1.7 ± 0.2	0.484	1.8 ± 0.3	2.1 ± 0.4	0.580	
Vigorous	$0.1 \pm 0.1$	$0.1 \pm 0.1$	0.982	0.2 ± 0.1	<b>une</b> 0.1 ± 0.1	0.228	

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as mean ± sem for containing with the set of the se confidence interval) for categorical variables. Statistical analysis by analysis of variance for continuous variables and by logistic regression for categorical variables, adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking stat  $\hat{B}$ s (never, former, current), educational ce Bibliographique de l level (low, medium, high). Physical activity data assessed using the R-package GGIR version 1.5–9.

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26 27

28

29

Light

Moderate

Vigorous

CoLaus PsyCoLaus study, Lausanne,	Switzerland.
	Second survey (2014
Sample size	199
Intensity of PA (min/day)	
Sedentary	-0.072
Light	0.203
Moderate	0.140
Vigorous	0.012
Intensity of PA (% of daily time)	
Sedentary	-0.145

0.340

0.005

0.069

0.871

0.061

0.011

0.188

0.928

0.187

0.103

-0.007

-9 PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as standardized beta coefficients. Statistical analysis by linear regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking raws (never, level (low, medium, high). Physical activity data assessed using the GENEActiv macro file 'General physical activity every at Agence Bibliographique de For peer review only - http://bmjopen.bmj.com/site/about/guidelines.xhtml regression adjusted for sex (male, female), age (continuous), BMI categories (normal, overweight, obese), smoking Etatus (never, former, current), educational

er 2024. Downloaded from http://bmjopen.bmj.com/ eignement Superieur (ABES) . related to text and data mining, Al training, and sim

0.081

0.126

-0.051

-0.019

0.021

0.104

-0.072

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0.360

0.152

0.589

0.831

0.827

0.242

0.449

0.742

Supplementary table 13: multivariab	le analysis, association between obje	BMJ Open ectively asse	ssed physical activity and glycate	haemoglobin, stratified by survey,
Colaus (Fsycolaus study, Lausaine, S			ig for	
	Second survey (2014-2017)	p-value	Third survey (2018-2021)	p-value
Sample size	195		58 feight	
Intensity of PA (min/day)			ted t	924 F
Sedentary	-0.071	0.352	0.121 e s	0.433
Light	0.154	0.052	-0.105 and	0.532
Moderate	0.078	0.339	-0.099 dur	0.562
Vigorous	0.021	0.782	0.055	0.726
Intensity of PA (% of daily time)			s) ing,	
Sedentary	-0.141	0.080	0.256 <b>A</b>	0.102
Light	0.154	0.053	-0.101 nin	0.547
Moderate	0.074	0.372	-0.100 g	0.557
Vigorous	0.012	0.880	0.067 d si	0.670

PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as standardized beta ceefficients. Statistical analysis by linear PA, physical activity; MVPA, moderate and vigorous physical activity. Results are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity are expressed as standardized oper control of the physical activity and the physical activity are expressed as standardized oper control oper control of the physical activity are expressed as standardized oper control oper con