

Original article

Adolescents' personal beliefs about sufficient physical activity are more closely related to sleep and psychological functioning than self-reported physical activity: A prospective study

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Abstract

Background: Preliminary evidence among adults suggests that the ways in which individuals think about their physical activity (PA) behavior is more closely associated with their well-being than self-reported PA. This study therefore aimed to examine whether and how self-reported PA and personal beliefs about sufficient PA are associated with sleep and psychological functioning in a sample of Swiss adolescents, using both cross-sectional and prospective data.

Methods: An overall sample of 864 vocational students (368 girls, 17.98 ± 1.36 years, mean $\pm$ SD) was followed prospectively over a 10-month period. At each measurement occasion, participants filled in a series of self-report questionnaires to assess their PA levels, their personal beliefs about whether or not they engage in sufficient PA, sleep (insomnia symptoms, sleep quality, sleep-onset latency, and number of awakenings), and psychological functioning (depressive symptoms, quality of life, perceived stress, and mental toughness).

Results: Adolescents who believe that they are sufficiently physically active to maintain good health reported more restoring sleep. No differences in sleep were found between adolescents who meet PA recommendations vs. those who do not. Additionally, adolescents who believe that they were sufficiently physically active also reported better psychological functioning. This close relationship between adolescents' beliefs about their PA involvement and their sleep and psychological functioning was corroborated in the prospective analyses.

Conclusion: Cognitive factors should be studied more intensively when elucidating the relationship among PA, sleep, and psychological functioning in young people, particularly when aiming to develop new exercise interventions targeting psychological outcomes.

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1. Introduction

Previous research has shown that among adolescents, higher physical activity (PA) levels are positively associated with restoring sleep.^{1,2} Positive relationships are also observed between higher PA levels and favorable psychological functioning, including decreased symptoms of depression,^{3,4} higher quality of life,^{5,6} lower stress levels,^{7,8} and more positive attitudes toward oneself and life in general.^{9,10} However, although the health-enhancing potential of PA among adolescents is well

documented, many adolescents reduce their PA levels during this period of life,^{11–13} particularly female adolescents.¹

A key issue in developing effective interventions to enhance PA levels among this age group is a deeper understanding of cognitive processes and behavior for the following reasons. First, previous investigations have shown that adolescents are generally aware that sufficient PA is important to maintain good health.^{14,15} In fact, a study among college students showed that improving health was the strongest motivator toward exercise engagement.¹⁶ Although this is a desirable outcome, it may partially explain the low interest in engaging in more PA because this population generally reports a good health perception.^{17,18} Second, Corder et al.¹⁹ have shown that

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a large proportion of adolescents (53% of girls, 34% of boys) inaccurately rate themselves as physically active, although accelerometer data showed that they are not as active as they report. Third, Gerber et al.²⁰ have suggested that the sleep-promoting effects of PA might be less based on behavioral patterns but rather depend on individuals' appraisals about being sufficiently physically active and fit. More specifically, their study of 862 university students revealed that individuals who evaluated their PA level as insufficient experienced more sleep disturbances, ruminated more about unresolved problems, and tended to worry more about difficulties initiating and maintaining sleep. This pattern of results could not be confirmed for reported time spent in PA, and whether they had met the health-related PA recommendations.²⁰ The generalizability of these findings is limited, however, because Gerber et al.²⁰ assessed a relatively homogeneous sample of young adults (all university students), focused on one specific outcome (sleep), and the study design was cross-sectional. Therefore, our study intends to expand this previous research by examining how self-reported PA and personal beliefs about sufficient PA are associated with a wider range of health outcomes (sleep and psychological functioning), in a younger and broader population (vocational students from varied professional fields), and by including prospective data. Gaining a deeper understanding of the consequences of these personal beliefs may help improve current approaches aimed at developing effective health interventions targeting adolescents PA levels, sleep, and psychological functioning.

Given this background, the general purpose of the present study was to examine whether and how self-reported PA and personal beliefs about sufficient PA are associated with sleep and psychological functioning in a sample of Swiss adolescents, using both cross-sectional and prospective data. Based on previous literature,²¹ we expected participants who met the PA recommendations outlined by the Centers for Disease Control and Prevention (CDC; <http://www.cdc.gov/physicalactivity/basics/>) to show better sleep quality and psychological functioning than peers who reported PA levels below these recommendations. Additionally, we expected that positive personal beliefs about sufficient PA would be associated with restoring sleep and favorable psychological functioning in both cross-sectional and prospective data.²⁰

2. Methods

2.1. Participants and procedures

The population is based on a (nonrepresentative) convenience sample of 2 vocational schools located in the German-speaking part of Switzerland. Students from both schools volunteered to take part in a prospective study ($n = 434$ students from school A, $n = 430$ students from school B). Students with varying professional specialties were included (e.g., polytechnicians, retail assistants, industrial clerks, structural draftsmen, hairdressers).

The questionnaires were completed in a quiet classroom in a group setting. A researcher was present to answer questions from the students. All participants were assured confidentiality

and provided written informed consent. All procedures were in line with the Declaration of Helsinki, and the local ethical committee (Ethics Committee of Northwestern and Central Switzerland; EKNZ) approved the study. At baseline and after 10 months, participants completed 2 identical batteries of psychological questionnaires in paper-and-pencil format. The first measurement took place approximately 2 weeks after the beginning of the school year (September), whereas the second measurement was performed about 1 month before the end of the school year (May). The dropout rate from baseline ($n = 1242$) to follow-up was 30% ($n = 378$), leading to an overall sample of 864 participants, including 368 girls and 496 boys (age: 17.98 ± 1.36 years, body mass index (BMI) = 22.13 ± 2.97 kg/m²). To be included, all participants had to have valid baseline data for both self-reported PA and personal beliefs about sufficient PA.

2.2. Measures

2.2.1. PA levels and personal beliefs about sufficient PA

Items from the International Physical Activity Questionnaire – Short Form (IPAQ-SF)²² were used to assess self-reported moderate-to-vigorous PA (MVPA). Previous research with adolescents showed that the predictive value of this instrument for cardiorespiratory fitness is similar to accelerometers.²³ Participants reported the number of days (from 0 to 7) for (a) vigorous PA (exercise or participation in high-intensity activities and sports such as aerobics or fast bicycling) and (b) moderate PA (e.g., bicycling at a regular pace, low-intensity sports). Participants also indicated the average duration (in minutes) for the days they engaged in these activities. Multiplication of frequency and duration scores resulted in an estimate of weekly hours invested in vigorous PA and moderate PA. The CDC guidelines were used to divide the whole sample into adolescents meeting PA recommendations and adolescents failing to meet these recommendations. Adolescents had to report either (a) at least 150 min of moderate-intensity PA per week, (b) 75 min of vigorous-intensity aerobic activity per week, or (c) an equivalent mix of moderate- and vigorous-intensity aerobic activity (of at least 150 min per week) to meet PA recommendations (see <http://www.cdc.gov/physicalactivity/everyone/guidelines/adults.html>). This classification was used to successfully discriminate between adolescents with low vs. high burnout symptoms in previous research.²⁴

Personal beliefs about sufficient PA were assessed with a single item from the Swiss Health-Enhancing Physical Activity (HEPA) Survey 1999,²⁵ which asked participants whether they thought that their current PA level was sufficient for the maintenance of good health (0 = no, 1 = yes).

2.2.2. Sleep

Sleep complaints were assessed with the Insomnia Severity Index,²⁶ which is a brief insomnia screening measure that is often used in treatment research as an outcome measure. Answers are given on 5-point rating scale from 0 (*not at all*) to 4 (*very much*). Because of time constraints, only 4 of the 7 items were considered. These items refer to the criteria for insomnia described in the *Diagnostic and Statistical Manual of*

*Mental Disorders IV*²⁷ by measuring difficulty in falling asleep, difficulties maintaining sleep, early morning awakening, and low satisfaction with sleep (e.g., “How often did you feel impaired during the last 2 weeks due to problems with falling asleep?”). Higher sum scores reflect more sleep complaints.

Additional information about sleep quality was collected with a 7-item German adaptation of the Pittsburgh Sleep Quality Index.²⁸ All items of this index referred to 2 typical weekdays and were anchored on an 8-point Likert scale referring to emotional states just after waking up in the morning (perceived quality of sleep, restoration, and mood), during daytime (sleepiness and concentration), and before going to bed (sleepiness and mood). Possible answers ranged from 1 (e.g., *very bad sleep quality*) to 8 (e.g., *very good sleep quality*). The sum score was calculated across the 7 items to obtain an overall sleep quality score, with higher scores reflecting better overall sleep quality. In addition, sleep onset latency (in minutes) and the number of awakenings during nighttime were assessed.

2.2.3. Psychological functioning

Depressive symptoms were measured with a 15-item short version of the Center for Epidemiologic Studies Depression Scale (CES-D),²⁹ which assesses cognitive, emotional, motivational, behavioral, and somatic aspects associated with depression (e.g., During the past week, “I felt sad”, “I felt lonely”, or “I felt depressed”). Evidence of the validity and adequate internal consistency of this instrument has been reported previously.³⁰ Answers were given on a 4-point Likert scale from 0 (<1 day/week) to 3 (5–7 days/week). Items were summed to obtain an overall score, with higher scores reflecting more depressive symptoms. The critical cutoff for the German version of the CES-D is 17, with 94% of the individuals above this threshold being diagnosed with depression.³⁰

The Adolescent Stress Questionnaire³¹ was used to assess adolescents’ stress. Because of time constraints, a 30-item version was used, which proved to have acceptable psychometric properties.^{32,33} Responses were given on a 5-point Likert scale ranging from 1 (*not at all stressful or irrelevant*) to 5 (*very stressful*) in reference to the past 3 months and for a broad range of stressors (e.g., arguments at home, teachers expecting too much from them, pressure to fit in with peers, concerns about their future). Items were summed to obtain an overall score, with higher scores reflecting higher perceived stress levels.

Quality of life was measured with 3 items from the Satisfaction with Life Scale.³⁴ A sample item is: “In most ways my life is close to my ideal.” Possible answers ranged from 1 (*strongly disagree*) to 7 (*strongly agree*). Previous studies with various populations demonstrated the validity and adequate reliability of the Satisfaction with Life Scale.³⁴ A sum score was built, with higher scores reflecting higher quality of life.

Mental toughness was assessed with the 18-item short form of the Mental Toughness Questionnaire (MTQ).³⁵ Mental toughness measures a person’s tendency to cope with the demands of environmental stressors (e.g., “Even when under considerable pressure I usually remain calm,” “I generally feel in control”).³⁵ Mental toughness is considered as an indicator of mental health because previous studies revealed that

individuals with high scores reported lower stress levels, less frequent depressive symptoms, and higher quality of life.^{32,36} The short and long forms of the MTQ were highly correlated in previous studies,³⁵ and the validity and reliability of the MTQ instruments has been documented.³² Responses were given on a 5-point Likert scale from 1 (*strongly disagree*) to 5 (*strongly agree*). A sum score was calculated, with higher scores reflecting higher mental toughness.

2.2.4. Confounders

School (0 = School A, 1 = School B), age (in years), sex (0 = female, 1 = male), family financial situation compared to peers (continuous variable from 1 = *much worse* to 5 = *much better*), and BMI were considered as confounders. BMI was calculated based on participants’ self-reported body weight (in kilograms) and body height (in meters), with the following formula: body weight/body height² (kg/m²).

2.3. Data analysis

Dropout analyses were performed using univariate analyses of variance (ANOVAs) based on baseline data, comparing students who dropped out and peers who took part in the baseline and follow-up data assessment (no covariates were considered in these analyses). Descriptive statistics were calculated for all study variables. In a first step, 2 separate two-way multivariate analyses of covariance (MANCOVAs) were performed (for sleep and psychological functioning) to test whether adolescents who meet PA recommendations or who believe that they are sufficiently physically active report more favorable sleep and psychological functioning. In a second step, a series of two-way univariate analyses of covariance (ANCOVAs) were carried out to examine group differences separately for each outcome. In all models that included covariates (MANCOVAs and ANCOVAs), the following variables were included as random effects: school, age, sex, family financial situation, and BMI. Finally, to examine whether positive beliefs about sufficient PA and meeting PA recommendations (assessed at baseline) predict sleep and psychological functioning 10 months later, hierarchical regression analyses were performed. Variables were introduced in the following order: baseline levels of sleep or psychological functioning (Step 1), confounders (Step 2), self-reported PA (Step 3), and personal beliefs about sufficient PA (Step 4). Across all analyses, the level of probability was set at $p < 0.05$. All statistics were calculated with SPSS Version 24.0 for Apple Mac. (IBM Corp., Armonk, NY, USA).

3. Results

3.1. Dropout analyses

At baseline, dropouts were older, $F(1, 1240) = 19.58$, $p < 0.01$, $\eta^2 = 0.02$, reported higher insomnia scores, $F(1, 1240) = 7.00$, $p < 0.01$, $\eta^2 = 0.01$, and perceived more stress, $F(1, 1240) = 5.21$, $p < 0.05$, $\eta^2 = 0.00$. By contrast, no differences were observed with regard to school, sex, family financial situation, BMI, sleep quality, sleep-onset latency, number of awakenings, depression, quality of life, and mental toughness (all $p > 0.05$).

Table 1
Descriptive statistics and psychometric properties of all outcome variables at baseline.

	Mean	SD	Items	α	Range		Skewness	Kurtosis
					Potential	Actual		
Insomnia (ISI)	4.80	3.55	4	0.71	0–16	0–16	0.75	0.13
Sleep quality (PSQI)	34.86	7.73	7	0.71	7–56	7–56	–0.34	0.35
Sleep onset latency	25.75	25.26	1	—	0+	0–180	2.30	6.74
Number of awakenings	0.80	1.26	1	—	0+	0–10	2.71	10.63
Depressive symptoms (CES-D)	9.48	7.31	15	0.87	0–45	0–42	1.18	1.49
Quality of life (SWLS)	14.66	3.43	3	0.78	3–21	3–21	–0.63	0.19
Perceived stress (ASQ)	69.52	18.02	30	0.89	30–150	30–122	0.26	–0.53
Mental toughness (MTQ)	58.43	6.59	18	0.70	18–90	39–85	0.23	0.87

Abbreviations: 0+ = potential values can be equal to or greater than 0; ASQ = Adolescent Stress Questionnaire; CES-D = Centers for Epidemiologic Studies Depression Scale; ISI = Insomnia Severity Index; MTQ = Mental Toughness Questionnaire; PSQI = Pittsburgh Sleep Quality Index; SWLS = Satisfaction with Life Scale.

3.2. Descriptive statistics

Descriptive statistics for all outcome variables at baseline are shown in Table 1. In total, 14% ($n = 121$) of the students exceeded the critical value of > 17 on the CES-D, 35% ($n = 300$) did not meet PA recommendations, and 33% ($n = 289$) felt that they were insufficiently physically active. Among adolescents above the PA recommendations ($n = 564$), 75% ($n = 425$) correctly believed that they were sufficiently physically active, whereas 25% ($n = 139$) did not. By contrast, among students who were below the PA recommendations ($n = 300$), only 50% ($n = 150$) accurately rated their PA level as being too low (Table 2).

3.3. Sleep and psychological functioning: associations with adolescents' PA levels and personal beliefs about sufficient PA

3.3.1. Cross-sectional analyses

With regard to sleep, the MANCOVA yielded a significant multivariate main effect for personal beliefs about sufficient PA,

Wilks-Lambda: $F(4, 823) = 5.08, p < 0.01, \eta^2 = 0.02$. The results of the univariate ANCOVAs (see the next paragraph for more detail) indicate that students who believe that they are sufficiently physically active reported better sleep. No significant main effect was found for self-reported PA, Wilks-Lambda: $F(4, 823) = 2.03, p = 0.09, \eta^2 = 0.01$. Similarly, the interaction term between self-reported PA and personal beliefs about sufficient PA was nonsignificant, Wilks-Lambda: $F(4, 823) = 0.81, p = 0.52, \eta^2 = 0.00$. With regard to psychological functioning, a multivariate main effect occurred for personal beliefs about sufficient PA, Wilks-Lambda: $F(4, 852) = 10.59, p < 0.01, \eta^2 = 0.05$, but not for PA, Wilks-Lambda: $F(4, 852) = 0.86, p = 0.49, \eta^2 = 0.00$. Similarly, no significant interaction effect was found, Wilks-Lambda: $F(4, 852) = 1.15, p = 0.33, \eta^2 = 0.01$. The univariate ANCOVAs (see the next paragraph for more detail) indicated that adolescents who believe that they are sufficiently physically active report better psychological functioning.

Table 2 provides the descriptive statistics separately for adolescents who were above vs. below the PA recommendations.

Table 2

Means and SD of dependent variables at baseline, and ANCOVAs comparing adolescents below vs. above PA recommendations, and adolescents who believe vs. do not believe that they are sufficiently physically active, as well as interactions between these 2 factors.

	Self-reported PA				Personal beliefs about sufficient PA				Self-reported PA		Personal beliefs about sufficient PA			
	Below recommendations ($n = 300$)		Above recommendations ($n = 564$)		Not sufficiently physically active ($n = 289$)		Sufficiently physically active ($n = 575$)		$df_M = 1$ $df_R = 855$		$df_M = 1$ $df_R = 855$		$df_M = 1$ $df_R = 855$	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	F	η^2	F	η^2	F	η^2
Insomnia (ISI)	5.11	3.62	4.37	3.27	5.66	3.60	4.11	3.19	0.02	0.000	16.60***	0.019	0.20	0.000
Sleep quality (PSQI)	33.76	7.66	35.45	7.72	32.76	7.72	35.92	7.53	0.46	0.001	15.97***	0.018	1.61	0.002
Sleep-onset latency	27.63	27.42	24.78	24.03	30.18	28.92	23.54	22.93	0.10	0.000	5.98*	0.007	0.01	0.000
Number of awakenings	0.84	1.24	0.77	1.28	1.05	1.45	0.66	1.14	5.13*	0.006	3.81*	0.004	0.20	0.000
Depressive symptoms (CES-D)	14.33	7.77	12.72	6.77	14.96	7.36	12.43	6.92	0.89	0.001	6.48*	0.008	0.01	0.000
Quality of life (SWLS)	4.79	1.14	4.94	1.14	4.49	1.20	5.08	1.06	0.01	0.000	36.10***	0.041	0.05	0.000
Perceived stress (ASQ)	7.05	1.74	6.90	1.83	7.39	1.75	6.73	1.79	0.46	0.001	12.26***	0.014	0.03	0.000
Mental toughness (MTQ)	60.32	6.08	62.00	7.08	59.48	5.70	62.39	7.08	3.68*	0.004	12.64***	0.015	0.94	0.001

Notes: All two-way ANCOVAs controlled for school, sex, age, family financial situation, and BMI. df_M = degrees of freedom for the effect of the model. df_R = degrees of freedom for the residuals of the model. Degrees of freedom for the (total) corrected model: $df_M = 8, df_R = 855$.

* $p < 0.05$; *** $p < 0.001$.

Abbreviations: ANCOVA = analysis of covariance; ASQ = Adolescent Stress Questionnaire; BMI = body mass index; CES-D = Centers for Epidemiologic Studies Depression Scale; ISI = Insomnia Severity Index; MTQ = Mental Toughness Questionnaire; PA = physical activity; PSQI = Pittsburgh Sleep Quality Index; SWLS = Satisfaction with Life Scale.

Table 3
Hierarchical multiple regression analyses predicting sleep and psychological functioning at follow-up with baseline scores of sleep and psychological functioning, social and demographic background, self-reported PA, and personal beliefs about sufficient PA as predictor variables.

Predictor	Insomnia (T2)		Sleep quality (T2)		Sleep-onset latency (T2)		Number of awakenings (T2)		Depressive symptoms (T2)		Quality of life (T2)		Perceived stress (T2)		Mental toughness (T2)	
	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	0.307***		0.182***		0.192***		0.116***		0.173***		0.255***		0.303***		0.246***	
Baseline level (T1)		0.51***		0.40***		0.43***		0.33***		0.38***		0.48***		0.53***		0.47***
Step 2	0.021***		0.011***		0.007		0.012*		0.012*		0.011*		0.010*		0.007	
School (T1)		-0.07*		0.01		-0.06		-0.10**		-0.08**		0.10**		-0.02		0.04
Gender (T1)		-0.06*		0.02		-0.03		-0.03		0.01		-0.03		-0.06		0.01
Age (T1)		0.06*		0.03		0.02		-0.10		0.02		0.04		0.00		0.03
Family financial situation (T1)		0.02		0.08*		0.02		0.00		-0.04		0.01		-0.04		0.05
BMI (T1)		0.06*		-0.04		-0.03		0.02		0.011		-0.03		0.06		-0.02
Step 3	0.001		0.000		0.001		0.003		0.004*		0.002		0.001		0.004*	
Self-reported PA (T1)		-0.02		0.01		-0.03		-0.06		-0.06*		0.03		-0.03		0.06*
Step 4	0.004*		0.004*		0.000		0.001		0.007**		0.003*		0.000		0.004*	
Personal beliefs about sufficient PA (T1)		-0.07*		0.07*		-0.01		0.03		-0.09**		0.07*		-0.02		0.07*
Total R^2	0.333***		0.197***		0.200***		0.122***		0.189***		0.262***		0.314***		0.259***	

Note: No significant interactions were found between self-reported PA and personal beliefs about sufficient PA; therefore, no interaction effects between these 2 variables are reported.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Abbreviations: BMI = body mass index; PA = physical activity; T1 = baseline; T2 = follow-up.

The inferential statistics of the univariate ANCOVAs are also presented in Table 2. After controlling for school, sex, age, family financial situation, and BMI, the univariate two-way ANCOVAs showed a main effect for personal beliefs about sufficient PA across almost all outcomes. In contrast, for self-reported PA, a significant main effect occurred only for 2 variables (number of awakenings and mental toughness). Thus, adolescents who believe that they are sufficiently physically active scored higher on all indicators of sleep and psychological functioning, even when simultaneously considering self-reported PA and after controlling for confounders. Finally, independent of their personal beliefs, adolescents who met the PA recommendations reported a lower number of awakenings and achieved higher mental toughness scores. No significant two-way interaction effects occurred for any of the outcome variables.

3.3.2. Prospective analyses

Table 3 provides the results of the hierarchical regression analyses. Levels of explained variance in the total model (R^2) ranged from 12.2% (number of awakenings) to 33.3% (insomnia). After controlling for baseline levels of sleep or psychological functioning (Step 1) and confounders (Step 2), meeting PA recommendations was associated with fewer depressive symptoms and higher mental toughness at follow-up (Step 3). When personal beliefs were introduced in the fourth step, this variable explained additional variance in insomnia, sleep quality, depressive symptoms, quality of life, and mental toughness. Positive personal beliefs about sufficient PA at baseline were associated with more restoring sleep and psychological functioning after 10 months of follow-up. None of the interaction terms between PA and personal beliefs about sufficient PA were significant (data not shown).

4. Discussion

The key findings of the present study are that adolescents who believe that they are sufficiently physically active to maintain good health report more restoring sleep and better psychological functioning. The differences in sleep and psychological functioning between adolescents who believe that they engage in sufficient PA vs. peers who do not was corroborated in the prospective analyses, highlighting that personal beliefs about sufficient PA were a stronger predictor of sleep and psychological functioning than self-reported PA. These findings support the notion that cognitive factors should be studied more intensively when elucidating the relationship among PA, sleep, and psychological functioning in young people, particularly when aiming to develop new exercise interventions targeting psychological outcomes. In other words, although the beneficial effects of MVPA for health have been well documented over the past few decades,^{37,38} simply increasing the levels of PA may not obtain the full return on investment with respect to improving sleep and psychological functioning.

Our data only partly support previous research,^{39,40} showing that physically active adolescents report more restoring sleep. Although we did not find a multivariate main effect for

self-reported PA, a univariate main effect indicated that physically active adolescents report fewer awakenings after sleep onset. Moreover, a univariate main effect occurred for mental toughness, showing that physically active adolescents are more mentally tough. This pattern of results accords well with previous research⁹ and is important because mental toughness proved to be associated with stress resilience⁹ and psychological well-being in young people.⁴¹ Nevertheless, the differences between adolescents above vs. below the PA recommendations were of relatively small magnitude, as highlighted previously by Biddle and Asare⁴² in their review on the relationship between PA and mental health in children and adolescents.

Our data strongly support the notion that positive personal beliefs about sufficient PA are associated with more restoring sleep and favorable psychological functioning. Accordingly, we corroborated adult research showing that a perceived lack of PA is more strongly related to mental health outcomes than self-reported PA.²⁰ Importantly, our study expands adult research in the sense that we were also able to provide prospective evidence showing that adolescents' positive beliefs about their PA involvement predicted fewer sleep complaints, better sleep quality, fewer depressive symptoms, greater quality of life, and more mental toughness after 10 months of follow-up. Against evidence reported in previous research,^{3,43} self-reported PA at baseline was weakly, but statistically significantly, associated with decreased depressive symptoms at follow-up. The diverging results found in our study and previous research might be due to the fact that in the present sample, we assessed older adolescents in vocational education and training, whereas prior investigations mostly examined younger students attending academic schools. That self-reported PA was not associated across time with quality of life and sleep is at odds with previous research.^{2,6,40} Nevertheless, these divergences might be attributable to the fact that in our study, personal beliefs about adolescents' PA levels were considered for the first time in combination with self-reported PA.

As mentioned previously, individual appraisals about being sufficiently physically active may be closely related to mental health outcomes, as mental health parameters are also influenced by cognitive-emotional factors.⁴⁴ For instance, cognitive models of insomnia claim that cognitive processes such as attention, perception, memory, reasoning, beliefs, attributions, and expectations play a fundamental role in the onset and maintenance of sleep complaints.⁴⁵ Moreover, researchers have emphasized that depressive episodes might result in a progressive change of dysfunctional information processing,⁴⁶ which might lead to particularly negative belief structures.⁴⁷ Furthermore, that adolescents with positive beliefs about their PA involvement reported higher degrees of mental toughness is not surprising, because mental toughness is *per se* defined as a cognitive-emotional mind-set characterized by the feeling of being influential in daily life experiences, by staying committed when problems occur, and by the belief that coping with change offers the opportunity for personal growth.³⁵ Thus, it can be assumed that

adolescents with positive beliefs about their level of PA also score more highly on psychological constructs such as self-efficacy,⁴⁸ optimism,⁴⁹ and self-control,⁵⁰ which might contribute to increased psychological functioning and sleep. In a similar vein, a recent study showed that adult exercisers who believed that regular exercising was healthy more strongly benefited from exercise on both the subjective and neurophysiological level, compared with participants who had less positive beliefs about the health-enhancing potential of regular exercise.⁵¹ Oberste et al.⁵² have also shown that exercise-induced facilitation of cognitive function is not based on physiological factors only, so that the expectation of such an effect might be necessary to elicit benefits to cognitive and mental health. This can be understood as an indication that the belief of engaging in a healthy behavior promotes psychological well-being. However, it cannot be ruled out that psychological functioning has an impact on personal beliefs about PA. In this respect, adolescents with high psychological functioning and high sleep quality have no reason to doubt that their actual behavior complies with a behavior that allows the maintenance of good health.

Finally, our findings accord well with a previous study among British adolescents, showing that many youngsters tend to over- or underestimate their PA levels. Although Corder et al.¹⁹ reported that between 34% and 53% inaccurately rated themselves as being sufficiently physically active, this percentage amounted to 50% in the present sample. However, our study also showed that, among students who in fact met recommended levels of PA, about one third inaccurately rated themselves as being insufficiently active. We assume that many adolescents are not aware of current PA recommendations.²⁵ Moreover, assessing PA via self-reports is a challenge among the adolescent population,⁵³ although the validity of the IPAQ has been established previously.²³ Therefore, it was no surprise that self-reported and subjective beliefs about sufficient PA were not "a perfect match" in the present population. To summarize, our cross-sectional findings suggest that cognitive-emotional processes and appraisals are more closely related to psychological functioning and sleep in adolescents than their self-reported levels of PA.

The strengths of this study were (a) its relatively large sample size; (b) the use of standardized and validated measures to assess PA, sleep, and psychological functioning; (c) the reference to internationally accepted standards to categorize adolescents into groups that were above vs. below PA recommendations; (d) the inclusion of an item to assess personal beliefs about sufficient PA that has proved useful in previous research with young adults; (e) the application of multivariate tests to avoid α -error inflation; and (f) the inclusion of prospective data to corroborate cross-sectional relationships.

Despite these strengths, we acknowledge that the results of the present study should be interpreted in light of certain limitations. First, the assessment of PA was based on students' self-reports. Although previous studies showed that many people find it difficult to accurately estimate their PA levels,⁵⁴ researchers have shown that the IPAQ-SF is reasonably

well correlated with physical fitness.²³ However, any self-reported PA is prone to memory bias.⁵⁵ Therefore, adolescents with better memory capacity might be able to recall PA more correctly; at the same time, better memory is associated with improved psychological functioning.⁵⁶ It cannot be ruled out that this link partially influenced the association found between psychological functioning and meeting the PA guidelines. Second, the CDC offers separate PA recommendations for children (6–17 years old) and adults (18–64 years old) (see <http://www.cdc.gov/physical/activity/basics>). Although some of the adolescents were younger than 18 years in the present sample, we decided to use the adult standards. This seemed justified because Swiss vocational students typically have working hours similar to those of adult employees. Third, a specific focus was placed on vocational students. Because a majority of Swiss adolescents ($\geq 70\%$) attend vocational schools,⁵⁷ this is a relevant target population. However, caution is needed when generalizing the findings to high school students, younger children, or older student populations. Moreover, although our sample included students with heterogeneous professional focus, we acknowledge that our population was based on convenience sampling and may therefore not be representative of the entire population of vocational students in Switzerland (e.g., students from other schools in the German- or French-speaking part of Switzerland) or in other German-speaking countries with similar VET systems. Fourth, although we found that positive baseline personal beliefs about sufficient PA predicted favorable sleep and psychological functioning at follow-up, the prospective analyses did not account for possible changes in PA over time.⁵⁸ Moreover, we did not systematically collect information about reasons for dropout. Accordingly, we can only speculate why dropouts were older, reported higher stress levels, and had higher insomnia scores, which limits the generalizability of the findings. However, similar main effects for personal beliefs about sufficient PA were found for all outcome variables if dropouts were included in the cross-sectional analyses (results provided as supplementary material online). Finally, our regression model was based on the premise that PA would predict sleep and psychological functioning. However, it is just as plausible that sleep and psychological functioning affect adolescents' PA behavior and personal beliefs about sufficient PA.⁵⁹ First, previous research with younger and older populations has shown that the relationship between depressive symptoms and PA is most likely reciprocal.^{58,60,61} Second, scholars have emphasized previously that among depressed people, dysfunctional cognitive-emotional processes such as feelings of hopelessness, pessimism, and a tendency to postpone tasks might negatively affect the motivation and self-control capacity needed to initiate and maintain regular PA.⁴⁴ Accordingly, previous studies showed that patients with major depressive disorders reported lower exercise intentions, lower exercise-related self-efficacy, more negative outcome expectations, and increased perceptions of situational barriers.⁶²

The present study explored new territory by examining the links between PA, personal beliefs about sufficient PA, sleep,

and psychological functioning. Although the study provides novel insights, from a practical perspective, the data raise just as many questions as they provide answers: for instance, is it desirable that adolescents have positive personal beliefs about sufficient PA without being sufficiently physically active? Our answer is clearly “no”, because many studies have shown that regular PA is positively associated with relevant health outcomes such as cardiovascular risk markers,⁶³ lower risks of overweight/obesity,⁶⁴ and an increased capacity to deal with stress.^{65,66} Research also shows that single PA episodes have positive effects on executive function,⁶⁷ which in turn is an important indicator of academic achievement.⁶⁸ Another question is whether sleep and psychological functioning will be impaired among adolescents who inaccurately overestimate their PA levels if they shift toward more realistic personal beliefs about sufficient PA. Although it is not currently possible to answer this question, we firmly believe that adolescents should be taught in detail how much PA is needed to maintain good health, because poorly defined goals may impede goal-oriented behavior.^{69,70} This is particularly important for adolescents who have negative beliefs about their own PA levels, although they fulfill the recommendations outlined by the CDC. We also believe that more systematic efforts are needed to teach students how they can monitor their PA levels (e.g., via pedometers and accelerometers) or visualize their physical fitness to become more aware of possible improvements.⁷¹ As outlined by Kanfer and Saslow,⁷² such an approach might be helpful in shifting self-evaluation from an unfavorable to a more favorable one. In line with this notion, interventions have shown that it is possible to increase adolescents' PA levels by using pedometers in combination with goal-setting strategies.^{73–75}

5. Conclusion

This is the first study showing that adolescents' beliefs about their own PA behavior predict variance in sleep and psychological functioning beyond self-reported PA. Therefore, cognitive factors should be explored more extensively in the study of the relationship between PA and mental health. Finally, more research is needed to examine how adolescents can learn to more realistically rate their PA behavior, and how changes in these self-evaluations may affect their well-being.

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Authors' contributions

CL made substantial contributions to conception and design of the study, was responsible for the acquisition of data, was responsible for the analysis and interpretation of data, drafted the manuscript SB made substantial contributions to conception and design of the study, was responsible for the analysis and interpretation of data, critically reviewed and revised the initial draft; FC was responsible for the analysis and

interpretation of data, critically reviewed and revised the initial draft; SL was responsible for the analysis and interpretation of data, critically reviewed and revised the initial draft; UP and MG made substantial contributions to conception and design of the study, critically reviewed and revised the initial draft. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jshs.2018.03.002.

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