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Longitudinal associations between physical activity and mental health in adolescents

Asociaciones longitudinales entre actividad física y salud mental en adolescentes

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Abstract

There is a lack of studies that examine the longitudinal relationship between physical activity (PA) and mental health with accelerometers in adolescent populations. The current study aimed to investigate whether changes in PA intensities and sedentary time (ST) are associated with mental health in a cohort of adolescents. 246 (130 boys, 116 girls) high school adolescents aged 13-15 years old (13.28 ± .57) were recruited in a city from the north of Spain. PA and ST levels were assessed by accelerometry. Psychological well-being (PWB) was measured using a self-reported validated questionnaire. Regression linear models were implemented by including PWB as the dependent variable and PA intensities and ST as predictors. Girls who increased light, moderate, and vigorous PA had significantly better PSW at follow-up, whereas no longitudinal associations were found for boys. No association between ST and PSW was identified. The results suggest changes in PA, but no in ST, have an association with PWB in adolescents. Nevertheless, the associations were stronger in girls than in boys. Because girls showed worse PWB at both time points, an optimal threshold for PA influence on mental health could explain the results. Future research is warranted.

Keywords: physical activity; mental health; adolescents; longitudinal; accelerometer.

Resumen

Actualmente faltan estudios que examinen la asociación longitudinal entre actividad física (AF) y salud mental con acelerómetros en adolescentes. El objetivo del estudio fue investigar si cambios en la AF y el tiempo sedentario (TS) se asocian con la salud mental en una cohorte de adolescentes. Participaron 246 adolescentes (130 varones, 116 mujeres) de entre 13 y 15 años (13.28 ± .57) de una ciudad del norte de España. AF y TS se midieron mediante acelerometría. El bienestar psicológico (BP) fue medido mediante un cuestionario validado. Se implementaron modelos de regresión linear incluyendo el BP como variable dependiente, y las intensidades de AF y el TS como predictores. Las mujeres que incrementaron su AF ligera, moderada y vigorosa incrementaron significativamente su BP en T2, mientras que esto no ocurrió en los varones. No hubo asociación entre el TS y el BP. Los resultados sugieren que cambios en la AF y no en el TS, se asocian a cambios en el BP en adolescentes. Sin embargo, esta asociación se dio solo en las mujeres. Debido a que estas mostraron peor BP en ambas mediciones, es posible que exista un umbral óptimo para los efectos de la AF en la salud mental. Se requieren más estudios al respecto.

Keywords: actividad física; salud mental; adolescentes; longitudinal; acelerómetro.

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Introduction

Mental health problems are illnesses that negatively impact on emotional, psychological and social well-being dimensions, so that, this will affect how a person feels, thinks and behaves (Manderscheid et al., 2010). Poor mental health can affect the person in a range of negative parameters such as self-deprecation, social disconnection, irritability and depression (Massé, 1998). PWB is commonly defined as a person´s cognitive (e.g., satisfaction with social relationships) and affective evaluation (e.g., joy) of his or her own life (Diener, 2009), and it is closely linked to mental health (Suldo et al., 2016).

Adolescence is defined by the WHO as the life period ranging from 10 to 19 years, which is characterized by psychological instability, cognitive (e.g., synaptic pruning) and behavioral changes (e.g., personal identity searching, more autonomous decision-making). Those alterations have been related to mental health problems (Blakemore & Choudhury, 2006). In fact, more than 50% of adult mental disorders have their onset before age 18 (Jones, 2013), so focus on this vital stage is crucial to prevent them in the adult population.

Evidence indicates that 14% of adolescents suffer from mental illness, with girls generally presenting worse scores (WHO, 2021). A study carried out in 12,395 adolescents from 11 European countries reported 10.5% of adolescents met the diagnostic criteria for depression and 5.8% for anxiety; and this percentage increased to 29.2% and 32% respectively when a sub-threshold diagnostic was considered (Balázs et al., 2013). Poor mental health has been associated with negative consequences in adolescents, such as physical violence, motor vehicle crashes, eating disorders, substance abuse, low academic achievement and high risk of suicide (McGorry et al., 2007; WHO 2021).

PA seems to be an important lifestyle factor to promote mental health. A systematic review carried out by Rodriguez-Ayllon et al. (2019) in preschoolers, children and adolescents concluded that PA could improve mental health. Another systematic review that involved randomized controlled trials in adolescents observed PA seems to increase quality of life, self-esteem and PWB (Hale et al., 2021). Furthermore, Biddle et al. (2019) concluded in their updated review of reviews that PA has positive mental health effects, although more research is needed and a causal relationship was not found for all the mental health constructs analyzed.

Several hypotheses have been proposed to explain how PA affects mental health. First, physiological factors may improve the brain structure and function (e.g., new capillaries growth, increased gray matter activation, greater BDNF production) through mechanisms such as the natural opiates secretion (e.g., serotonin, dopamine, endorphins, norepinephrine), the stress hormones inhibition (e.g., cortisol) and an improved blood supply (Lubans et al., 2016; Rodriguez-Ayllon et al., 2019; Schuch et al., 2016). Second, psychosocial factors may improve the person´s mood and life satisfaction through mechanisms such as social interaction (e.g., sense of identity, community participation), psychomotor skills achievement (e.g., learning new movements, achieving goals), and the distracting effect against stressors, negative and ruminative thoughts (Morgan et al., 2016; Veale, 2008). Third, the behavioral hypothesis highlights the possible PA benefits on factors such as sleep quality and duration, which that in turn would affect mental health outcomes (Lubans et al., 2016).

On the other hand, the mechanisms explaining how sedentary lifestyle could influence mental health are limited. They include feelings of loneliness linked to the nature of some of these activities (e.g., study, TV watching), the media exposure impact (e.g., aggressive behavior,

body dissatisfaction), and the displacement of other more beneficial activities (e.g., PA, sleep) (Hoare et al., 2014; Rodriguez-Ayllon et al., 2019).

Most cross-sectional studies find a positive relationship between PA and mental health (Biddle et al., 2019), although PA intensities should be considered: for instance, Costigan et al. (2019) in 1,223 Australian adolescents found that vigorous PA was positively associated with better PWB. However, longitudinal studies with accelerometers mostly do not find a relationship between PA and mental health (Opdal et al., 2019; Toseeb et al., 2014; Van Dijk et al., 2016). Nevertheless, some studies have not considered changes in PA (Toseeb et al., 2014), but the PA long-term effects in mental health. Only one study that considered PA changes found in adolescents that transition from an active to a sedentary profile was significantly associated with worse mental health (Sánchez- Oliva et al., 2020).

Previous literature tend to find an inverse relationship between ST and mental health (Biddle & Asare, 2011). Longitudinal evidence with accelerometry is very scarce. Most studies find null ST long-term effects on mental health (Slykerman et al., 2020). Nevertheless, there are exceptions: for instance, Sánchez-Oliva et al. (2020) found that an increase in ST was associated with a worse PWB two years before.

Although there are some longitudinal studies with accelerometers, to the best of our knowledge this is the first study that have taken into consideration the changes in ST and PA intensities (light, moderate, vigorous) along with gender differences. Therefore, the objective of the present study was to investigate whether there is an association between changes in PA intensities and ST with respect to mental health in adolescents. We hypothesized that participants who increased their PA levels, and decreased ST, would show significantly better mental health. Regarding gender differences on these associations, given the lack of previous studies, we tested in a more explorative fashion and we had no particular hypothesis.

Methods

Study design

A longitudinal (two years follow-up) research design was used. The repeated measures were taking in the same date (from January to March) in consecutive years (2018-2019; 2019-2020). Second measurement was taken just before COVID-19, so data was not affected for the pandemic. The study followed the principles of the Declaration of Helsinki (World Medical Association, 2013) and was approved by the Regional Ethic Committee (135/18). Potential participants were informed regarding the study and written informed consent was provided by the participants and their parents/guardians.

Participants

The sampling technique was non-probabilistic and intentional (Peat et al. 2020). The sample included students from 10 high schools in a northern Spain city. 246 adolescents (130 boys, 116 girls) aged 13 to 15 years (13.28 ± .57) agreed to participate. After applying the actigraphy inclusion criteria (described below) and considering five adolescents dropped out of the study in the second year, the final sample was 224 adolescents (119 boys, 110 girls).

Measures

Physical activity and sedentary behaviour

PA and ST were measured using GT3x accelerometers at 30 Hz and worn for 7 consecutive days (ActiGraph™, Fort Walton Beach, FL, USA). The accelerometer was attached to an elastic belt and worn around the waist and removed only in water-based activities (e.g., bathing, swimming). Adolescents were instructed on how to handle the accelerometer and how to complete a log recording when they put it on and when they removed it. Data was analyzed using Actilife v.6. (ActiGraph, Pensacola, FL, USA).

Non-wear time data was identified and removed with Choi´s algorithm (Choi et al., 2011) and log´s information. Evenson's algorithm was used to define cut-offs for all PA intensities (light, moderate, vigorous) and ST (Evenson et al., 2008), which have shown to be a valid and reliable measure in youth (Trost et al., 2011). Adolescents were included in the analysis if they wore the accelerometer for ≥10 hours per day for ≥4 days (one of them on weekends) (Colley et al., 2010).

Socioeconomic Status

The revised Family Affluence Scale II was developed for the HBSC study (Health Behaviour in School-Aged Children) to assess family socioeconomic status (SES) (Currie et al., 2014). The test classifies individuals according to three categories of socioeconomic status (low = 0–6; medium = 7–9; high = 10–13). The Family Affluence Scale II revised has been validated in different European countries (Torsheim et al., 2016).

Psychological well-being

To assess students' PWB, the short version of the General Health Questionnaire (Goldberg, 1978) was used. This scale includes 12 items regarding the subjective PWB in the last weeks. There are positive questions (e.g., "Have you felt that you are playing a useful role in life?"), whose response range was "more than usual" to "less than usual", and negative questions (e.g., "Have you had the feeling that you cannot overcome your difficulties?"), whose response range was "not at all" to "much more than usual". Different responses were added in a single factor and coded using the binary method (0,0,1,1), which has proven to be the best for demographic screening (Tait et al., 2002). Higher values in the questionnaire mean worse psychological status and vice versa. The GHQ has been validated in Spanish adolescents (López-Castedo & Fernández, 2005).

Statistical analyses

Data analysis was performed using SPSS Statistics 22 package (IBM Corp., Armonk, NY, USA). Descriptive statistics (means and standard deviation) were used to describe the main participant characteristics. Student's t-test was used to investigate the variables changes over time. Pearson correlations were conducted at both time points to analyze the relationships between PA intensities (light, moderate, and vigorous), ST and PWB. Finally, two mixed linear models were carried out for each of the PA intensities and ST. In all models, PWB at T2 was included as the dependent variable. In model 1, gender was included as a fixed factor, whereas PWB and ST at baseline, SES, and PA changes were included as covariates. In model 2, the gender*PA change interaction effect was added (reference = girls). A significance level of $p < .05$ was used.

Results

Table 1 presents the changes in the study variables over time, as well as the associations between variables at both time points. Participants significantly decreased light and moderate PA levels from T1 to T2, whereas they significantly increased vigorous PA and ST. There was a significant decrease in PWB over time. On the other hand, at T1 all PA intensities were positively associated and ST was negatively associated with all PA intensities. No significant associations were found between all PA intensities and PWB. At T2, all PA intensities were positively associated and ST was negatively associated with moderate PA.

Table 1. *Descriptive statistics and inter-correlations between variables at both time-points.*

	Year 1		Year 2			Correlations				
	M	SD	M	SD	p	1	2	3	4	5
1. ST (min)	610.93	83.91	674.96	83.02	.001	-	-.079	-.161*	-.124	.061
2. Light PA (min)	194.68	53.76	79.82	24.45	.000	-.463**	-	.636**	.507**	-.099
3. Moderate PA (min)	34.01	11.57	29.51	9.83	.000	-.364**	.535**	-	.630**	-.108
4. Vigorous PA (min)	21.25	11.40	27.85	13.33	.000	-.284**	.328**	.564**	-	-.076
5. PWB	1.89	2.15	2.28	2.48	.000	-.015	.008	-.013	-.058	-

Legend: ST= Sedentary Time, PA= Physical Activity, PBW = Psychological Well-being. Data below diagonal = 1st year correlations, Data above diagonal = 2nd year correlations. * *p*<.05; ** *p*<.01

Table 2. *The predictive role of PA and ST changes in psychological well-being.*

	ST change → PWB				Light PA change → PWB				Moderate PA change → PWB				Vigorous PA change → PWB			
	Model 1		Model 2		Model 1		Model 2		Model 1		Model 2		Model 1		Model 2	
	B	ED	B	ED	B	ED	B	ED	B	ED	B	ED	B	ED	B	ED
Gender (girls)	-.550	.292	-.551	.292	-.641*	.293	-.621*	.289	-.601*	.291	-.606	.283	-.537	.289	-.543	.286
SES	-.141	.147	-.149	.148	-.134	.146	-.146	.144	-.122	.146	-.153	.143	-.131	.147	-.147	.145
PWB at T_1	1.505**	.151	1.497**	.152	1.464**	.151	1.429**	.149	1.481**	.151	1.456**	.147	1.498**	.151	1.505**	.149
ST at T_1					-.645	.149	-.235	.162	-104	.151	-.251	.154	-.078	.151	-.091	.148
ST/PA change	-.123	.145	-.229	.194	-.319*	.145	-.675**	.201	-.312*	.144	-.820**	.213	-.223	.143	-.665**	.232
Gender * PA change			.240	.292			.689*	.316			.884**	.295			.704*	.293

Legend: ST= Sedentary Time, PA= Physical Activity, SES = Socioeconomic Status, PWB =Psychological Well-Being. * *p*<.05; **p<.01

Table 2 presents the results of the associations between changes in different PA intensities and PWB, as well as the moderator role of gender on this relationship. For each PA intensity, we estimated two models. Model 1 calculated fixed effects of PA changes in PWB after controlling the statistical effects of baseline PWB and ST, gender and SES. Model 2 additionally calculated the interaction between gender and PA changes over time, that is, differences on the association between PA changes and PWB among boys and girls.

For the whole sample, a decrease in light and moderate PA over time was associated with worse PWB; whereas no significant associations were found for ST nor vigorous PA. With respect to gender differences on these relationships, the gender * PA change interaction was significant

for light, moderate, and vigorous PA changes. Our results suggest the association between light, moderate, and vigorous PA change and PWB was significantly greater in girls than in boys. Specifically, the association between changes in light PA and PWB among girls was negative and significant (β = -.675, $p < .01$), that is, a decrease in light PA levels implied worse PWB; whereas this relationship on boys was significantly lower (β = -.675 + .689 = .014). Regarding changes in moderate PA, the association among girls was also negative and significant (β = -.820, $p < .01$), whereas this relationship on boys was significantly lower (β = -.820 + .884 = .064). In the same way, changes in vigorous PA among girls was negative and significant (β = -.665, $p < .01$); whereas this relationship on boys was significantly lower (β = -.665 + .704 = .039).

Figure 1 shows how the slope was steeper for girls than for boys. That is, changes in PA levels over time were stronger associated with PWB among girls. Finally, the associations between changes in ST and PWB did not significantly vary among girls (β = -.229, $p > .05$) and boys (β = -.229 + .240 = .011, $p > 0.05$).

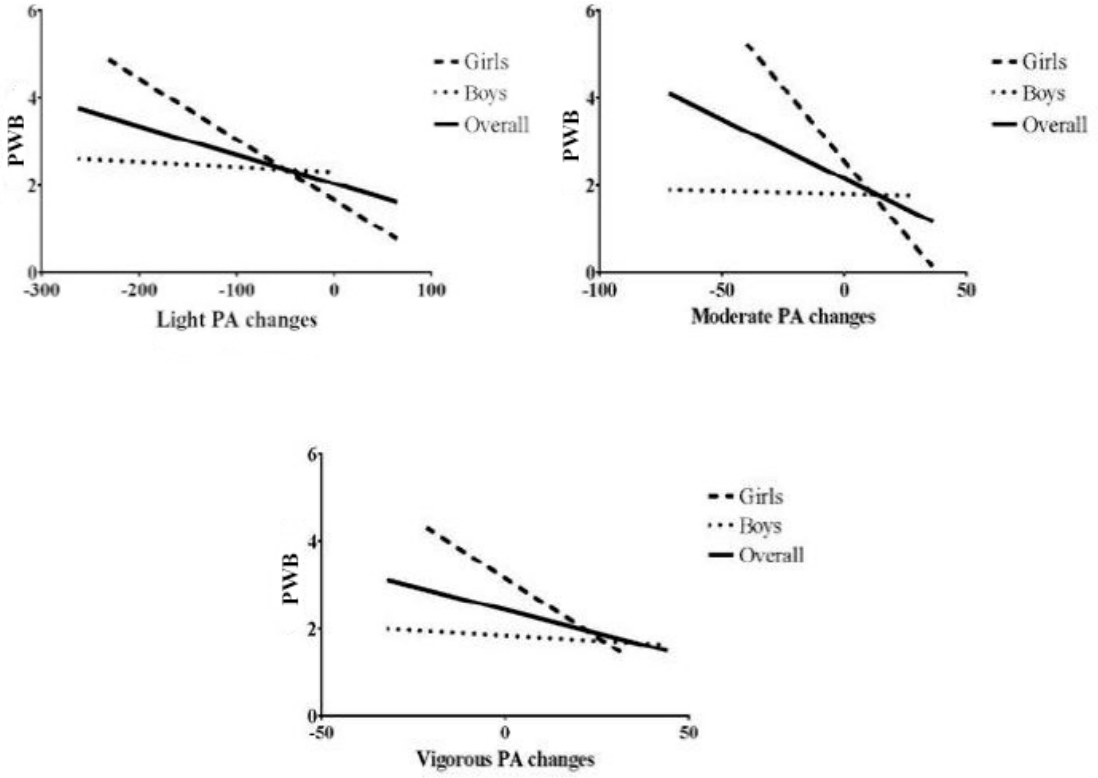

Figure 1. *PA changes associations with PWB by gender.*

Discussion

The current study aimed to investigate whether changes in PA intensities and ST are associated with mental health in a cohort of adolescents. The main result was that a decrease in all PA intensities (light, moderate, and vigorous) was associated with worse PWB in girls and vice versa, but non-significant associations were found among boys.

Baseline data reports that adolescents spent much time (>9 hours) doing sedentary activities. Similar results have been found in other studies with comparable age samples that measured

PA using accelerometers (Contardo-Ayala et al., 2019). Concerning PWB, Moehlecke et al. (2018) in 71,740 adolescents obtained a similar score with the same questionnaire. These data confirm the negative growing trend in adolescents ST, and it is also a warning regarding their mental health.

Longitudinal studies have reported in adolescents a decrease in PA levels linked to an increase in ST (Costigan et al., 2019). This trend was observed in the present study, although with certain nuances: thus, light and moderate PA levels significantly decreased over time, coinciding with other longitudinal studies (Contardo-Ayala et al., 2019)**.** However, vigorous PA increased significantly in our case (21.25 ± 11.41 to 27.85 ± 13.33, p <.01). Other researches have obtained a similar pattern, that is, an increase in vigorous PA coupled with a decrease in lower intensities (Beltran-Valls et al., 2019). These results seem to indicate that, despite reducing their total PA levels and being more sedentary, adolescents made a transition to higher intensity sports modalities. Therefore, it seems that although the existing literature indicates that total PA levels decrease in adolescence, the analysis by intensity is not conclusive in some contexts.

Perhaps, differences between studies are due to sociocultural context factors (e.g., accessibility to sport facilities) or the seasons in which the data was collected: for instance, previous studies with accelerometers has shown seasons can affect adolescents PA levels (Quante et al., 2019).

On the other hand, a reduction in PWB was observed in our study between T1 and T2 (1.89 ± 2.15 to 2.28 ± 2.48 respectively, p <.01) as in other longitudinal researches with the same questionnaire (Tochigi et al., 2016). Likewise, this situation has also been found with different psychological constructs such as depression and self-esteem, among others (Birkeland et al., 2009; Van Dijk et al., 2016). This pattern is usually attributed to the profound physical, neurological and psychological changes that affect adolescents in this vital stage (Blakemore & Choudhury, 2006).

Regarding the cross-sectional association between ST and PWB, we did not find associations between both variables. Same results have been obtained in other study using accelerometry and depression as a psychological construct (Slykerman et al., 2020). Nevertheless, systematic reviews most often observe a negative association between ST and mental health (Biddle & Asare, 2011; Rodriguez-Ayllon et al., 2019). Regarding the longitudinal association between ST and PWB, we did not find any associations. Other studies with accelerometers have obtained similar results, although they only considered the ST long-term effects and not the ST changes (Slykerman et al., 2020; Sund et al., 2010). On the contrary, a similar study to ours found that an increase in ST was associated with poorer mental health (Sánchez-Oliva et al., 2020), even though they considered together the changes in PA and ST.

The mechanisms that explain how ST affects mental health are less established compared to PA, although several hypotheses have been proposed. These include feelings of loneliness (e.g., studying), the media exposure (e.g., body dissatisfaction) and the temporal displacement of other more beneficial behaviors (e.g., sleep) (Hoare et al., 2014; Rodriguez-Ayllon et al., 2019). On this regard, it would be interesting in future studies to observe sedentary behavior modalities in more detail, since they could have a different influence on mental health (Rodriguez-Ayllon et al., 2019). For instance, the potential effects of playing a musical instrument or reading a book could be different from those of watching TV. Likewise, the content could also be another variable of greater depth to consider.

Regarding the cross-sectional association between PA and PWB, we did not find significant associations with any of the PA intensities (light, moderate, vigorous). On the contrary, the

correlational evidence is almost unanimous in finding a positive association between PA and mental health, although most previous studies measured PA with questionnaires instead of accelerometers (Rodriguez-Ayllon et al., 2019). In general, several hypotheses have been formulated to explain the PA benefits for mental health. They include physiological (e.g., secretion of natural opiates), psychological (e.g., self-efficacy) and behavioral (e.g., sleep duration) (Lubans et al., 2016; Rodriguez-Ayllon et al., 2019; Schuch et al., 2016) factors. Different systematic reviews and meta-analyses support it: for instance, Biddle et al. (2019) in their update of their review of reviews refer to a clear association between PA and mental health in children and adolescents; although at causal level for the moment, the benefits are relegated to depression and cognitive functioning. In addition, experimental studies in adolescents mostly observe benefits on mental health after applying a PA intervention (Hale et al., 2021). Moreover, according to a recent study with a day-by-day design (micro-longitudinal), it seems that the relationship could be even bidirectional, but only in the very short term (within the same day) (Van Woudenberg et al., 2020). Nevertheless, in the study authors considered only steps per day and happiness as a PA and psychological measures respectively. It would be interesting in the future to test the within-person bidirectional relationships with other psychological constructs (e.g., depression, PWB, self-esteem) and with ST and different PA intensities. For instance, a greater PA intensity could have more benefits to mental health: a HIIT intervention in 65 adolescents observed improvements in PWB, physical self-concept and cognitive capacity (executive functions) (Costigan et al., 2016).

Regarding the longitudinal association between PA and PWB, to the best of our knowledge, we have not found studies in adolescents that longitudinally evaluated the gender role on the associations between accelerometry-based PA intensities (light, moderate, vigorous) and ST with respect to PWB. In model 1, results seemed to indicate that changes in light, moderate and vigorous PA were positively related to PWB when analyzing the whole sample. However, the gender interaction in model 2 showed that the steepness of the slope was explained mostly by girls, being flatter in boys (see Figure 1). That is, changes in PA levels over time seemed to be associated with PWB mostly among girls.

Most of the previous longitudinal evidence with accelerometers has not found a relationship between PA and mental health (Opdal et al., 2019; Toseeb et al., 2014; Van Dijk et al., 2016). As pointed before, not all studies have considered the PA changes (only one measurement at T1), so this should be considered when making comparisons. Other literature with more than one measure have failed to find a connection between PA changes and mental health (Van Dijk et al., 2016). Only one recent cohort study has observed that PWB increased in those participants who augmented their PA levels between the two time points (Sánchez- Oliva et al., 2020). Perhaps, there are some factors such as the sociocultural context or the different accelerometer data processing that could explain the discrepancies between studies. On this regard, it should be interesting to explore in future studies the type of PA, since the sport modality (e.g., individual or collective, aesthetic or non-aesthetic) seems to modify the relationship between PA and mental health (Rodriguez-Ayllon et al., 2019).

Regarding the marked gender difference, there are several possible reasons for this result: first, as Van Dijk et al. (2016) pointed out, perhaps there is an optimal mental health threshold in which PA has a great potential. Precisely, an intervention study found that the exercise positive effects occurred in the group with worse mental health (Eather et al. 2016). Furthermore, there is maybe a *ceiling effect* of the mental health benefits associated with PA. In fact, Smith et al. (2018) attributed their null results due to the sample high initial PWB levels at the beginning of the intervention. On our case, because girls showed worse PWB in both time points, small

PA levels would contribute to have better PWB.Second, because women tend to show high body image concerns (Grogan, 2016), a decrease in PA may potentially translates into a less fit body, negatively affecting their mental health. Related to the above, it is possible that due to pubertal differences in the accumulation of lean/fat matter (González-Montero et al., 2010), it is easier for men to maintain a body with which they feel satisfied. Third, because men tend to show higher intrinsic motivation levels towards sport than women (Lauderdale et al., 2015), it is possible that lower PA levels are enough to obtain the mental health benefits (e.g., only with Physical Education classes). For now, all these statements are hypotheses and therefore require verification in future studies.

Conclusions

The limitations of the present study included: first, due to sample size, caution may be needed when generalizing the present results to other adolescent populations; second, having more than two data collections would allow to obtain more robust results; third, having information apart from subjective PWB such as global self-stem and happiness would allow to make stronger statements regarding mental health. Strengths of the study included PA and ST measurement with accelerometers, repeated measures at T1 and T2, and the interaction analysis by gender.

To sum up, in the present study, light, moderate and vigorous PA were positively associated with subjective PWB, but this association was stronger in girls that in boys. Due to the worse scores in PWB at both time-points in girls, an optimal threshold could explain the gender difference found, among other possibilities. On the other hand, ST was not associated with PWB in either boys or girls. These results suggest that PA changes during adolescence seem to be related with PWB. Although our design do not allow us to make causal statements, we consider pertinent to say that adolescents should be encouraged to increase their PA levels for its wide health benefits. Future studies should take measures from more time-points and add more psychological constructs in their designs; this would allow making stronger statements on this regard. Furthermore, it would be interesting to consider the PA (e.g., individual or collective, aesthetic or non-aesthetic) and ST type (e.g., reading a book, screen time) since it could increase the results accuracy. More researches are warranted in this field of knowledge.

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