Programa de Doctorado en Educación

Escuela de Doctorado de la Universitat Jaume I

Mental health and academic performance in secondary school students: DADOS study

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March, 2023

Programa de Doctorado en Educación

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Memoria presentada por **Irene Monzonís Carda** para optar al grado de doctor/a por la Universitat Jaume I

Doctoranda

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Diego Moliner Urdiales   **Mireia Adelantado Renau**

Castelló de la Plana, marzo de 2023

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Received funding

Thesis by compendium of publications

The present PhD thesis is composed by a compendium of four manuscripts that have been published or have been submitted as publications in scientific journals. The reference of each article is listed below:

Study I. Monzonís-Carda, I., Adelantado-Renau, M., Beltran-Valls, M.R., and Moliner-Urdiales, D. Mental health and academic performance in adolescent boys and girls: elucidating the role of psychological well-being and psychological distress. DADOS study. *Under review.*

Study II. Monzonís-Carda, I., Adelantado-Renau, M., Beltran-Valls, M.R., and Moliner-Urdiales, D. (2021). An examination of the association between risk of depression and academic performance according to weight status in adolescents: DADOS study. *Journal of Affective Disorders, 290,* 157-163.

https://doi.org/10.1016/j.jad.2021.04.086

Study III. Monzonís-Carda, I., Adelantado-Renau, M., Beltran-Valls, M.R., and Moliner-Urdiales, D. (2023). Risk of depression mediates the association between cardiorespiratory fitness and academic performance in adolescent boys and girls: DADOS study. *European Journal of Pediatrics, 182* (1), 67-77.

https://doi.org/10.1007/s00431-022-04645-y

Study IV. Monzonís-Carda, I., Rodríguez-Ayllon, M., Adelantado-Renau, M., and Moliner-Urdiales, D. Bidirectional longitudinal associations of mental health with academic performance in adolescents: DADOS study. *Under review.*

This thesis has been accepted by the co-authors of the publications listed above that have waved the right to present them as a part of another PhD thesis.

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List of articles:

1) Monzonís-Carda, I., Adelantado-Renau, M., Beltran-Valls, M.R., and Moliner-Urdiales, D. Mental health and academic performance in adolescent boys and girls: elucidating the role of psychological well-being and psychological distress. DADOS study. [Submitted for publication].

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Article:

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TABLE OF CONTENTS

APPENDICES

ABSTRACT

The balance between optimal mental health and adequate academic performance during secondary school period is considered an important challenge from a psychological and educational point of view, due to the derived long-term effects on future health and wealth. The overall aim of the present doctoral thesis was to investigate the relationship between mental health and academic performance during secondary school period. The study sample was composed by a total of 274 adolescents, participants of DADOS (Deporte, ADOlescencia y Salud) study, aged 13.9±0.3 years old at baseline. Mental health was measured through the Spanish version of the Behavior Assessment System for Children and Adolescents. Academic performance was measured through academic grades and the Test of Educational Abilities. The main findings of the current dissertation suggest that mental health is positively associated with academic performance during secondary school period. Specifically, findings show that (i) sex does not influence this association, (ii) weight status mediates the inverse relationship between risk of depression and academic performance, and (iii) risk of depression mediates the positive relationship between cardiorespiratory fitness and academic performance. Additionally, longitudinal findings suggest that academic performance is associated with mental health 2 years later, but not *vice versa*, as this association is not bidirectional.

RESUMEN

Lograr un equilibrio entre una óptima salud mental y un adecuado rendimiento académico durante la etapa de educación secundaria obligatoria se considera un importante desafío desde el punto de vista psicológico y educativo, debido a los efectos duraderos sobre la salud y el bienestar. El objetivo principal de la presente tesis doctoral fue investigar la relación entre la salud mental y el rendimiento académico durante la etapa de educación secundaria. La muestra estuvo formada por un total de 274 adolescentes participantes del proyecto DADOS (Deporte, ADOlescencia y Salud), con una edad de 13.9±0.3 años al inicio del estudio. La salud mental se evaluó mediante la adaptación española del sistema de evaluación de la conducta en niños y adolescentes. El rendimiento académico se midió mediante las calificaciones académicas y el test de habilidades académicas. Los principales hallazgos de la presente tesis doctoral sugieren que la salud mental se asocia positivamente con el rendimiento académico durante la etapa de educación secundaria. Específicamente, los resultados muestran que (i) el sexo no influye en esta asociación, (ii) la composición corporal media la relación inversa entre el riesgo de depresión y el rendimiento académico y (iii) el riesgo de depresión media la relación positiva entre la resistencia cardiorrespiratoria y el rendimiento académico. Además, los hallazgos longitudinales sugieren que el rendimiento académico se asocia con la salud mental 2 años después, pero no *vice versa*, por lo que la asociación no es bidireccional.

1. General introduction

Adolescence, the transitional period between childhood and adulthood, is considered a critical stage of life due to the substantial biological, psychological and social changes that occur during this timeframe (Patton & Viner, 2007). Psychological research considers adolescence as a vulnerable period for the onset of mental health disorders (Solmi et al., 2022). Indeed, according to the World Health Organization (WHO) reports, one in five adolescents experiences a mental health disorder that may persist later in life (WHO, 2020a). This fact is a major public health concern, due to the growing body of research showing higher prevalence of depression, anxiety, and stress across the globe (Polanczyk et al., 2015; Salari et al., 2020; Xiong et al., 2020) and the negative consequences derived from suffering them during adolescence. For instance, depression and anxiety have been associated with functional and cognitive impairments in the adolescent population (Weavers et al., 2021; F. F. Zhang et al., 2018), which may lead to affect them on their daily life-activities.

Adolescents spend most of their time in the school setting where they perform their daily life-activities. In this context, there is a vast amount of research highlighting the importance of academic performance, due to the well-known relationship with future health, employability, and social triumph (French et al., 2015; Lê-Scherban et al., 2014). Nonetheless, adolescents' academic performance is an educational concern, since it tends to decline during secondary school period (Wijsman et al., 2016). Thus, an emerging body of research is examining the potential factors that influence academic performance during this critical period of life. So far, it is already known that the experience of bullying victimization (Samara et al., 2021) and burnout (Madigan & Curran, 2021) leads to worse academic performance during adolescence. Recent research has also started to examine how mental health status could be positively associated with academic performance (Agnafors et al., 2021). Yet, the little work that has explored to what extent mental health and academic performance are associated during adolescence is still in its infancy and further research is needed to confirm or contrast prior findings.

In accordance with the current public health and educational concerns mentioned above, this PhD thesis provides new insights on the association between mental health and academic performance among a sample of Spanish secondary school students within the framework of DADOS (Deporte ADOlescencia y Salud) study.

1.1. Mental health

<u>Concept</u>

Mental health is understood as a dual-factor state that relies on the balance of experiencing psychological well-being and psychological distress (Antaramian et al., 2010; WHO, 2022). This is a complex construct characterized by multiple state possibilities, since psychological well-being and psychological distress are not necessarily opposite ends of a single continuum (Winefield et al., 2012). Indeed, these are different but related concepts that should be considered simultaneously in order to analyze the complete conceptualization of mental health (Keyes, 2014). According to the current state of knowledge, a good mental health status is achieved when there is a presence of psychological well-being along with an absence of psychological distress (WHO, 2022).

The presence of psychological well-being involves the experience of positive affective states and optimal functioning (Huppert, 2009; Winefield et al., 2012). Specifically, a positive affective state relies on experiencing feelings of happiness, contentment, confidence, and affection. In addition, an optimal functioning occurs when the self-control of your own life is achieved and positive social relationships are established. In this context, several psychological well-being indicators have been used in the scientific literature, such as happiness, self-esteem, life-satisfaction, health-related quality of life, positive affect, and interpersonal relationships (Cohen, 2004; Du et al., 2017; Ryff, 2013).

The presence of psychological distress relies on the experience of negative affective states and emotional disturbances (M. Phillips, 2009; Winefield et al., 2012). Those who suffer from psychological distress tend to feel worthless, sad, and insecure. Moreover, when these emotional disturbances are severe and remain for a long time, they may lead into the diagnosis of a mental health disorder (American Psychiatric Association, 2013). For this reason, the scientific literature has considered negative affect and mental health disorders as the most important indicators for assessing psychological distress (M. Phillips, 2009). In this line, anxiety and depression have been extensively considered potential indicators of

psychological distress, as they are the most common mental health disorders that occur during adolescence (WHO, 2020a).

<u>Assessment</u>

Mental health is a complex state to measure, due to the fact that it is a dual-factor state formed by several psychological well-being and distress indicators. Therefore, several measures have been used to assess mental health indicators in the adolescent population. Overall, self-reported measurements are the most widely used instruments for measuring mental health in adolescents, due to the fact that they offer the opportunity to collect data from large number of participants with relatively low cost.

Several self-reported questionnaires are widely available to measure indicators of psychological well-being or psychological distress. For instance, the Mental Health Continuum Short-Form (MHC-SF) (Lamers et al., 2011), the WHO 5 well-being index (WHO-5) (Topp et al., 2015), the KIDSCREEN scales (Ravens-Sieberer et al., 2006), or the Satisfaction with Life Scale (Diener et al., 1985) could be used for assessing psychological well-being indicators among the adolescent population. Similarly, with regard to psychological distress, several instruments such as the Becks Anxiety Inventory (BAI) (Beck et al., 1988), the Strengths and Difficulties Questionnaire (SDQ) (R. Goodman, 1997), the Hospital Anxiety and Depression Scale (HADS) (Zigmond & Snaith, 1983), and the Kessler Psychological Distress Scale (K10) (Andrews & Slade, 2001) have been used for assessing psychological distress indicators.

Apart from the specific instruments for assessing psychological well-being or psychological distress in isolation, instruments assessing both subdomains of mental health have also been implemented in some studies. In this sense, for instance, the Positive and Negative Affect Scale (PANAS) (Watson et al., 1988) provides information about positive and negative affect, which are psychological well-being and psychological distress indicators, respectively. Similarly, the Behavior Assessment System for Children and Adolescents (BASC) (Reynolds & Kamphaus, 2004) offers a global value of the dual-factor model of

mental health as well as specific information about psychological well-being and psychological distress indicators.

1.2. Academic performance

<u>Concept</u>

Academic performance is considered a multifactorial construct that refers to the extent to which students achieve educational goals (Donnelly et al., 2016). Specifically, according to the current evidence on the fields of psychology and education, the achievement of these educational goals depends on the multiple factors that encompass students' personal characteristics and their socio-cultural environment (J. Lee & Shute, 2010). In addition, regarding the extensive evidence provided by the Program for International Student Assessment (PISA) reports, developed by the Organization for Economic Co-operation and Development (OECD, 2019), and the scientific literature (Deary et al., 2007; Shi & Qu, 2021), cognitive abilities have been considered paramount factors closely linked to academic performance (Rohde & Thompson, 2007).

Academic performance relies on the fulfillment of educational goals. In this line, students who obtain higher academic performance tend to reach higher academic attainment and better academic grades. Specifically, academic attainment can be understood as the highest academic level achieved by the students. In addition, academic grades refer to the extent to which students acquire specific learning competencies in accordance with the scholar system (Schneider & Preckel, 2017). Therefore, academic attainment and academic grades have been considered paramount indicators in the educational research for studying students' academic performance.

Cognitive abilities can be understood as the abilities that the human brain has for processing, storing, and using the information in order to successfully overcome real-life challenges (Sternberg & Sternberg, 2009). In the educational context, there is evidence showing a strong relationship between cognitive abilities and academic performance among secondary school students (Rohde & Thompson, 2007). In tandem with this fact, intelligence, attention, memory, and academic abilities have received the consideration of the cognitive abilities that most directly influence the learning process and, in turn, academic performance (Shi & Qu, 2021).

<u>Assessment</u>

Academic performance can be assessed through several indicators that provide information about the students' achievement in the school setting. In accordance with the conceptualization of academic performance given above, educational research includes two main sets of indicators; the levels of fulfillment of educational goals and the factors that influence academic performance.

In regard with academic performance measured through the levels of fulfillment of educational goals there are two main indicators that have been widely used: academic attainment and academic grades. Particularly, these measures can be collected through self-reported questionnaires or obtained from official certificates. For instance, researchers can use academic attainment for measuring the highest academic level achieved by the students. Similarly, students' academic grades can be used for assessing the student progression in each academic subject during an academic year. Interestingly, the academic grades of math and language have been broadly considered important indicators of academic performance, due to the paramount role that executive function plays on these areas of knowledge (Bull & Scerif, 2001).

Regarding the assessment of the factors that influence academic performance it is worth stressing some standardized tests that are widely used for assessing cognitive abilities. For instance, the Wechsler Abbreviated Scale of Intelligence (WASI) (Dumont et al., 2014), the Stroop color-word test (Scarpina & Tagini, 2017), and the N-back working memory test (Kirchner, 1958) could be used for assessing intelligence, attention, and memory, respectively. Interestingly, we could also examine academic abilities through standardized questionnaires such as the Test of Educational Abilities (TEA) (Thurstone & Thurstone, 2004), that provides information about the students' verbal, numeric, and reasoning abilities.

1.3. Mental health and academic performance during adolescence

Mental health and academic performance during secondary school are health and educational challenges that have an important short-term and long-term influence on health (French et al., 2015; Lê-Scherban et al., 2014; Weavers et al., 2021; F. F. Zhang et al., 2018). Despite the paramount interest of these constructs during adolescence, the existing scientific evidence reveals some knowledge gaps that need further exploration.

Prior systematic reviews and meta-analysis have shown that most of the evidence analyzing the association between mental health and academic performance in adolescents has mainly analyzed the mental health components separately (Amholt et al., 2020; Riglin et al., 2014). On the one hand, psychological well-being components related to a positive affective state (Seligman & Csikszentmihalyi, 2000), such as high levels of self-esteem and good social relationships, seem to be positively associated with academic performance (Wu et al., 2020). On the other hand, the psychological distress components, related to a negative affective state and the symptomatology of common mental health disorders, have been negatively associated with academic performance (Riglin et al., 2014; Rothon et al., 2009). To the best of our knowledge, few studies have examined the relationship between mental health understood as a dual-factor state and academic performance (Antaramian et al., 2010; King et al., 2021; Suldo & Shaffer, 2008). Interestingly, these studies showed that the presence of psychological well-being along with the absence of psychological distress is associated with higher academic performance in secondary school students. Thus, there is a need to further explore the association between mental health, including psychological well-being and psychological distress indicators, and academic performance in adolescents (**Study I**).

According to the current stage of knowledge, there is not clear evidence about how the cycle between mental health and academic performance may be operating during the adolescence period. So far, most of the longitudinal studies investigating the association between mental health and academic performance have been performed in one direction or the other (Almroth et al., 2018; Riglin et al., 2014; Wickersham et al., 2021; W. Zhang et al.,

2019). Some authors focused on how the common mental health disorders of depression and anxiety affect academic performance later in life (Riglin et al., 2014; Wickersham et al., 2021). By contrast, other studies have investigated the opposite direction (Almroth et al., 2018; W. Zhang et al., 2019). Yet, the body of evidence analyzing the bidirectional longitudinal association between mental health and academic performance in the adolescent population is still in its infancy and shows some limitations. For instance, bidirectional longitudinal studies have examined the association between psychological well-being (Bortes et al., 2021; Z. J. Ng et al., 2015; Steinmayr et al., 2016; Wu et al., 2020) or psychological distress indicators (Van Der Ende et al., 2016; W. Zhang et al., 2019) with academic performance in isolation, which does not capture how the overall picture of mental health associates with academic performance over time. In addition, no consensus has been reached on the direction of this association. Some authors suggest a bidirectional association (Z. J. Ng et al., 2015; W. Zhang et al., 2019), while the others suggest an unidirectional association from mental health to academic performance (Van Der Ende et al., 2016; Wu et al., 2020) or from academic performance to mental health (Adelantado-Renau et al., 2022; Bortes et al., 2021). Hence, this scarce and diverse knowledge needs further exploration in order to elucidate the complete picture of the relationship between mental health and academic performance during adolescence (**Study IV**).

1.3.1. The role of sex

Prior evidence has shown that the prevalence of mental health and academic performance differs among adolescent boys and girls. During this transitional period, girls show higher risk of suffering from psychological distress (Afifi, 2007) and are more likely to obtain better academic grades (Voyer & Voyer, 2014) than boys. In this context, it is noteworthy that sex seems an important factor to consider when examining the association between mental health and academic performance in the adolescence population. Nonetheless, thus far, there is few evidence analyzing sex differences and it is mainly based on the relationship between psychological distress indicators (i.e., anxiety, depression, or stress) and academic performance (Lavoie et al., 2019; Riglin et al., 2014). Thus, the current state of knowledge is still scarce and the association between the overall picture of mental health, including psychological well-being and psychological distress indicators, and academic performance by sex needs further exploration (**Study I**).

1.3.2. The role of body composition

Overweight and obesity are considered ongoing worldwide concerns by the WHO, due to the fact that there is a prevalence of 18% of children and adolescents aged 5-19 years old all over the globe (WHO, 2020b). Unfortunately, this prevalence is even higher in Spain, with 33% of children and adolescents showing overweight, as reported by the study of Physical Activity, Sedentarism, lifestyles and Obesity in Spanish youth (PASOS) (Gasol Foundation, 2022). Due to the higher prevalence of overweight and obesity among youth, studies examining the importance of healthy body composition during adolescence has gained attention in the psychological and educational fields. On this account, it is widely understood that obese adolescents are at higher risk of developing mental health disorders (i.e., depression) (Rao et al., 2020) and obtain lower academic performance (He et al., 2019). Nonetheless, to the best of our knowledge, these associations have been examined in isolation and it would be interesting to examine how body composition might influence the association between psychological distress and academic performance in secondary school students (**Study II**).

1.3.3. The role of physical fitness

Physical fitness, understood as the capacity of the body to perform daily physical activity, is considered a powerful marker of health during adolescence (Ortega, Ruiz, Castillo, & Sjöström, 2008). So far, one of the most used indicators of physical fitness in the research field is cardiorespiratory fitness, which refers to the ability of the circulatory and respiratory systems to supply oxygen when performing prolonged strenuous exercise (Ortega, Ruiz, Castillo, & Sjöström, 2008). The current state of knowledge highlights that, on average, European children and adolescents meet the standards for healthy cardiorespiratory fitness levels (i.e., 78% of boys and 83% of girls) (Tomkinson et al., 2018). However, these percentages decline yearly, which suggests that adolescents' health is worsening (Tomkinson et al., 2019). In this context, there is clear evidence showing that cardiorespiratory fitness is negatively associated with psychological distress (i.e., depression) (Bou-Sospedra et al., 2020; Ruggero et al., 2015) and positively associated with academic performance (Álvarez-Bueno et al., 2020). At the same time, as stated previously, it is well-known that those adolescents who suffer psychological distress tend to achieve lower academic performance (Riglin et al., 2014). So, it may be plausible that the well-known cardiorespiratory fitness and academic performance association might be partially explained by psychological distress. Nonetheless, as far as we know, there is only one study developed in a sample of 144 adolescents suggesting that individuals with higher physical fitness levels show lower depressive symptoms, which may lead to better academic performance (Xiang et al., 2017). Therefore, it is of paramount interest to examine to what extent physical fitness levels may influence mental health, shaping academic performance among the adolescent population **(Study III)**.

2. Aims

Overall aim

The main aim of the present PhD thesis is to investigate the relationship between mental health and academic performance during secondary school period. This overall aim is addressed in five specific aims that correspond to cross-sectional and longitudinal data examined in four different studies.

Specific aims

Cross-sectional data was examined in three studies of the present PhD thesis, covering the following specific aims:

Specific aim 1

To analyze the association between mental health and academic performance in secondary school students (**Study I** and **Study II**).

Specific aim 2

To examine the role of sex in the association between mental health and academic performance in secondary school students (**Study I**).

Specific aim 3

To examine the role of body composition in the association between mental health and academic performance in secondary school students (**Study II**).

Specific aim 4

To examine the role of mental health as a mechanism in the association between physical fitness and academic performance in secondary school students (**Study III**).

Additionally, longitudinal data was examined in the fourth study of this PhD thesis, encompassing the following specific aim:

Specific aim 5

To analyze the bidirectional association between mental health and academic performance during secondary school period (**Study IV**).

3. Methodological overview

3.1. DADOS study design and participants

The scientific studies included in the present PhD thesis are based on secondary school students from DADOS (Deporte, ADOlescencia y Salud) study. This is a 3-year longitudinal research project aimed to investigate the role of physical activity in health and cognition in a sample of Spanish secondary school students.

For the participants' recruitment, advertising leaflets about the research project were sent to secondary schools and sports clubs from Castellon province (Spain). These leaflets included the information about the study aim and protocol, as well as the inclusion criteria: to be enrolled in second grade of secondary school (13-14 years old) and without diagnosed physical or neurological chronic diseases. Informative meetings were performed with the volunteers who met the inclusion criteria, and a written informed consent was obtained from all the students and their parents or guardians.

Data collection of DADOS study was undertaken during the months of February and May for 3 consecutive years (Timepoint 1: 2015 and 2016; Timepoint 2: 2016 and 2017; and Timepoint 3: 2017 and 2018; see **Figure 1**). Participants were invited twice to the University campus in order to conduct DADOS study assessments. During the first assessment day, participants filled in some psychological, cognitive, and healthy behaviors' questionnaires in a classroom. Later on, after a short break of 20 minutes, in which healthy snacks and drinks were given to the participants, anthropometric measurements and physical fitness assessments were performed in the sports center of the Universitat Jaume I. Additionally, during the second assessment day, blood test and pubertal stage assessments were performed during early morning hours in the laboratory of the LIFE - 'physicaL actIvity, Fitness, and hEalth' research group. A total of 274 adolescents (13.9±0.3 years old) completed the baseline assessments and 205 of them performed the assessments for the 3 consecutive years.

Timepoint 1

2nd GRADE

N = 274

2015: N = 207
2016: N = 67

Timepoint 2

3rd GRADE

N = 249

2016: N = 189
2017: N = 60

Timepoint 3

4th GRADE

N = 205

2017: N = 156
2018: N = 49
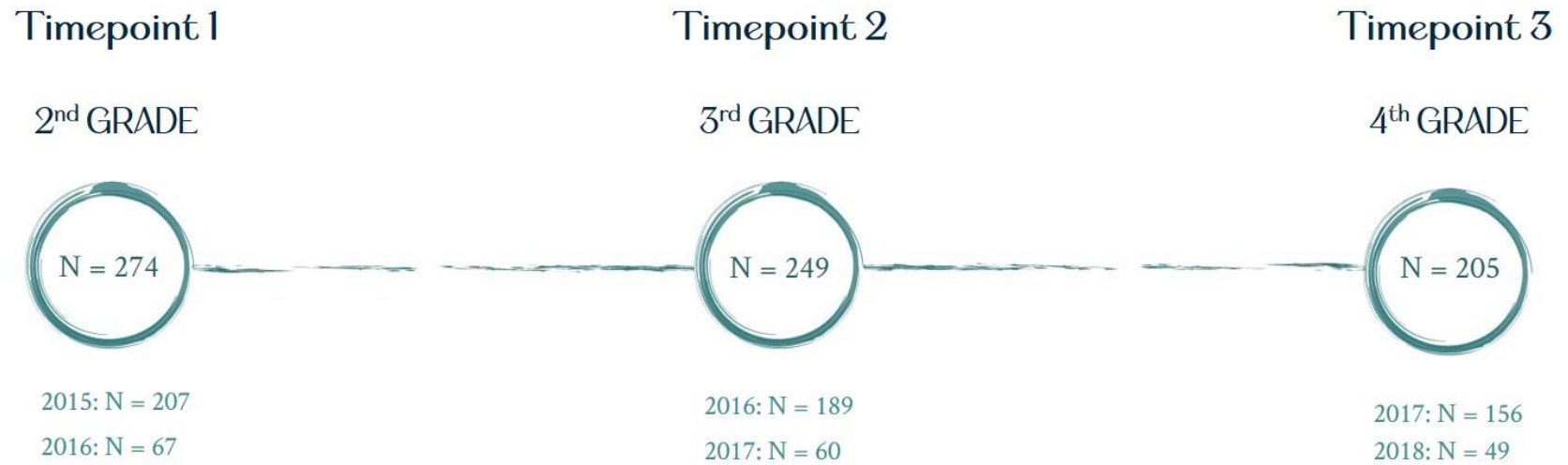
Figure 1. Participants that performed DADOS study assessments.

The sample size of the present PhD thesis ranges from 263 to 266 participants due to the fact that only those participants with complete data for the main variables of interest and the covariates of each study were included for data analyses (see **Table 1**).

Table 1

Overview of the studies included in the present PhD thesis.

	Design	Participants	Main variables of interest		Covariates
Study I	Cross-sectional study	265 adolescents (13.9±0.3 years old)	Ind.	Mental health: emotional symptoms index, psychological well-being (self-esteem and interpersonal relationships), and psychological distress (anxiety, social stress, risk of depression, and sense of inability).	Sex* Pubertal stage SES BMI
			Dep.	Academic performance: academic grades (math, language, and GPA) and academic abilities (verbal, numeric, reasoning ability, and overall score).	
Study II	Cross-sectional study	265 adolescents (13.9±0.3 years old)	Ind.	Psychological distress: risk of depression.	Sex Pubertal stage SES BMI**
			Med.	Weight status: BMI.	
			Dep.	Academic performance: academic grades (social sciences, natural sciences, math, language, physical education, and GPA) and academic abilities (verbal, numeric, reasoning ability, and overall score).	
Study III	Cross-sectional study	263 adolescents (13.9±0.3 years old)	Ind.	Cardiorespiratory fitness: VO_{2max}	Sex*** Pubertal stage SES
			Med.	Psychological distress: risk of depression.	
			Mod.	Sex.	
			Dep.	Academic performance: academic grades (math, language, and GPA) and academic abilities (verbal, numeric, and reasoning ability).	
Study IV	Longitudinal study (2-years follow-up)	266 adolescents (13.9±0.3 years old at baseline)	Ind. and Dep.	Mental health: emotional symptoms index, psychological well-being (self-esteem and interpersonal relationships), and psychological distress (anxiety, social stress, risk of depression, and sense of inability).	Sex Pubertal stage SES BMI
			Ind. and Dep.	Academic performance: academic grades (math, language, and GPA) and academic abilities (verbal, numeric, reasoning ability, and overall score).	

Note. Ind. = Independent variable; Dep. = Dependent variable; Med. = Mediator variable; Mod. = Moderator variable; GPA = Grade point average; SES = Socioeconomic status; BMI = Body mass index. *Sex was not included as a covariate in the stratified analyses by sex (Study I); **BMI was not included as a covariate in the stratified analyses by weight status neither in the mediation analyses, as this was the mediator variable (Study II); ***Sex was not included as a covariate in the moderated mediation analyses, as this was the moderator variable (Study III).

3.2. Main variables of interest

MENTAL HEALTH

Mental health status was assessed through the Spanish self-reported version of the Behavior Assessment System for Children and Adolescents (BASC-S3) aged from 12 to 18 years old (González et al., 2004). Particularly, the clinical scale of the emotional symptoms index was used as a global measure of the dual-factor model of mental health. It consists of two adaptative scales of psychological well-being (self-esteem and interpersonal relationships) and four clinical scales of psychological distress (anxiety, social stress, risk of depression, and sense of inability), composed by a total of 78 statements that participants self-rated as true of false. The emotional symptoms index, as well as the adaptative and clinical scales were calculated by converting raw scores into standard T-scores, based on the age of the participants. Specifically, in accordance with Reynolds and Kamphaus (2004), these T-scores corresponded to a mean of 50 with a standard deviation of 10. Thus, a score ≥60 in the clinical scales and a score ≤40 in the adaptative scales indicated 'at risk' of emotional disturbance that affects adolescents' feelings and thoughts. The Spanish version of the BASC-S3 has shown good internal consistency (Cronbach's α ranging from 0.73 to 0.93) (González et al., 2004).

ACADEMIC PERFORMANCE

Academic grades

Final academic grades from each academic year of secondary school were used to assess participants' academic performance. These academic grades were provided by each school's secretary office and were based on a ten-point scale in which 0 indicates the lowest achievement and 10 indicates the highest achievement. Individual grades of natural sciences, social sciences, math, language, and physical education, as well as the students' grade point average (GPA) were included in the analyses.

Academic abilities

Academic abilities were measured through the Spanish version of the TEA test (Thurstone & Thurstone, 2004) in order to assess participants' academic performance. This standardized test provides general measures of three areas of intelligence and skills of learning: verbal ability (command of language), numeric ability (speed and precision in performing operations with numbers and quantitative concepts), and reasoning ability (the skill to find logical order in sets of numbers, figures, or letters). Scores for the three academic abilities were obtained by adding positive answers. In addition, the overall score of academic abilities was calculated by adding the individual scores (i.e., overall score = verbal ability + numeric ability + reasoning ability). Based on the age range of our sample, level three of the TEA test was used, which has shown good internal consistency (Cronbach's α ranging from 0.74 to 0.89) (Thurstone & Thurstone, 2004).

3.3. Other variables of interest

SEX

Sex was self-reported by the participants during the baseline assessments.

WEIGHT STATUS

Weight status was assessed through the body mass index equation of weight/height square (kg/m^2). Firstly, body weight and height were measured in duplicate, following standardized procedures. Body weight was measured to the nearest 0.1 kg using an electronic scale (SECA 861 - Hamburg, Germany) and body height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (SECA 213 - Hamburg, Germany). Later on, average measures of body weight and height were used for calculating body mass index.

CARDIORESPIRATORY FITNESS

Cardiorespiratory fitness was assessed through the 20 meters shuttle run test proposed by Leger et al. (1988). During the test, participants ran straight between two lines 20 meters apart at a pace established by recorded audio signals. The initial speed was 8.5 km/h and it was increased 0.5 km/h each minute. The test was completed when participants could not reach the end lines at the pace of the audio signals for two consecutive times or when they stopped because of fatigue. The last stage number completed by the participants was used to estimate the maximal oxygen uptake (VO_{2max}, ml/kg/min) using the following equation reported by Léger et al. (1988): VO_{2max} = 31.025 + (3.238 × (8 + 0.5 × last stage number completed)) – (3.248 × age) + (0.1536 × (8 + 0.5 × last stage number completed) × age).

3.4. Covariates

The covariates or confounders are those variables that are included for adjusting the statistical analyses, as they may influence both the dependent and independent variables. Following the prior literature in the field of mental health and academic performance among the adolescent population, the main covariates included in the present PhD thesis were: sex, pubertal stage, socioeconomic status, and body mass index. Due to the fact that the assessments of sex and body mass index have been explained in the above section, pubertal stage and socioeconomic status are explained in this section.

PUBERTAL STAGE

Participants self-reported their pubertal stage through the standardized pictures proposed by Tanner and Whitehouse (1976). These pictures depicted external primary and secondary sex characteristics that participants could rate from stage 1 to 5. The degree of development of these stages was assessed through two components; pubic hair growth for girls and boys, in addition to breast development in girls and genital development in boys. Stage 1 corresponded to the prepubertal state and stage 5 to the most mature state. Participants' highest rating of the two components was used for data analyses.

SOCIOECONOMIC STATUS

The socioeconomic status of the study sample was self-reported by the parents or guardians during the baseline assessments through the Family Affluence Scale (FAS), developed by Currie et al. (2008). This scale was based on material conditions in the family setting, such as car ownership, bedroom occupancy, computer ownership, and home internet access. The composite FAS score was calculated for each participant based on their responses to these four items (ranging from 0 to 8). A score of 0 indicated the lowest socioeconomic status and a score of 8 the highest socioeconomic status.

3.5. Ethical standards

The DADOS study was conducted in accordance with the ethical guidelines of the Declaration of Helsinki 1964 (last version of Fortaleza, Brazil, 2013). Additionally, all the protocols performed were approved by the Research Ethics Committee from the Universitat Jaume I of Castellon (Spain).

Before participating in the study all the participants and their parents or guardians were informed of the nature and characteristics of DADOS study and all of them provided written informed consent. The collected data was alphanumerically coded for ensuring the confidentiality, following the European legislation regulating personal data and the free movement of such data (Regulation 2016/678 of the European Parliament and of the Council of 27th April 2016).

4. Scientific publications

Study I

Mental health and academic performance in adolescent boys and girls: elucidating the role of psychological well-being and psychological distress. DADOS study.

Abstract

Adolescents' mental health and academic performance are subjects of paramount interest. Previous studies have revealed a strong association between these constructs during school years. However, there is little evidence about the dual-factor model of mental health, which includes a combination of psychological well-being and distress indicators, and there is not clear consensus on the possible differences by sex. Therefore, the aims of the present study were to analyze the association between the dual-factor model of mental health and academic performance, and to analyze sex differences in a sample of secondary school students. The sample was formed by a total of 265 adolescents (126 girls) aged 13.9±0.3 years old, from DADOS study. Mental health status was self-reported through the BASC-S3 questionnaire. Academic performance was assessed through academic grades and the Spanish version of the TEA test. The emotional symptoms index was negatively associated with academic grades. Psychological well-being was positively associated with academic grades, while psychological distress was negatively associated with academic grades, except for anxiety. Stratified analyses by sex showed largely similar results. ***Conclusion:*** Our results suggest that promoting mental health during adolescence could help to enhance academic grades.

Keywords: Mental health; academic performance; school grades; psychological well-being; psychological distress; adolescents.

1. Introduction

Adolescence is a critical period for the onset of mental health disorders (Benton et al., 2021). In fact, one in five adolescents is at risk of developing a mental health disorder that may persist later in life (F. S. Lee et al., 2014), with a slightly higher prevalence among adolescent girls in comparison to boys (Afifi, 2007). This evidence is of paramount interest, since poor mental health has been related to adverse consequences in central domains of life during youth, negatively affecting school adjustment, social relationships, identity formation, and physical health (Suldo et al., 2016). Interestingly, a recent study suggests that having a poor mental health status during this time frame could be associated with lower academic performance (Agnafors et al., 2021).

Academic performance refers to the educational goals that a student has achieved in a particular period of time, and is usually measured through final grades or standardized skill tests (Donnelly et al., 2016). Successful academic performance during adolescence is an important predictor of future health, wealth, employability, and social triumph (Lê-Scherban et al., 2014). Thus, elucidating to what extent mental health is associated with adolescents' academic performance is essential in order to implement effective school-based programs to promote successful academic performance.

Good mental health status, which is a dual-factor construct that comprehends the presence of psychological well-being along with the absence of psychological distress (Antaramian et al., 2010), has been suggested to be associated with academic performance. Among its components, psychological well-being factors related to a positive affective state (Seligman & Csikszentmihalyi, 2000), such as high levels of self-concept (Trautwein et al., 2006) and good social relationships (Kiuru et al., 2020), seem to be positively associated with adolescents' academic performance (Wu et al., 2020). By contrast, the presence of psychological distress symptoms, such as social stress (Flook & Fuligni, 2008) and sense of inability (Hagger & Hamilton, 2019) have been negatively associated with academic performance in secondary school students (Rothon et al., 2009). Likewise, adolescents with

signs and symptoms of common mental health disorders, such as anxiety and depression, show lower academic performance (Riglin et al., 2014; Seligman & Csikszentmihalyi, 2000). Taking into account the concept of good mental health (Antaramian et al., 2010), the combination of psychological well-being and distress indicators is essential to fully understand its relationship with academic performance. Nevertheless, the prior scientific evidence is mainly based on analyzing psychological well-being or distress indicators in separate models. So far, only two prior studies have examined the association between a dual-factor model of mental health in the adolescent population. Both of them showed that the presence of psychological well-being and the absence of psychological distress were related to higher academic performance (Antaramian et al., 2010; Suldo & Shaffer, 2008). Interestingly, Suldo and Shaffer (2008) suggested that this association was significant in some specific indicators of academic performance, such as optimal reading skills, academic self-perceptions, school attendance, and academic goals.

Hitherto, important differences between boys' and girls' mental health (Afifi, 2007) and academic performance (Voyer & Voyer, 2014) have been shown in the adolescent population. However, as far as we know, no prior study has analyzed sex differences in the association between psychological well-being and academic performance indicators. The prior evidence analyzing sex differences has been based on the association between psychological distress indicators and academic performance (Lavoie et al., 2019; Riglin et al., 2014). For instance, these studies showed that anxiety (Riglin et al., 2014) and social stress (Lavoie et al., 2019) were more strongly associated with academic performance in girls than boys, while no significant sex difference was found between adolescents' depression and academic performance (Riglin et al., 2014). Thus, further research is needed in order to fully understand sex differences in the association between the dual-factor model of mental health and academic performance.

Recently, Howie et al. (2020) suggested that the early screening in the educational setting through self-reported questionnaires may be useful for identifying adolescents' mental health status, preventing or at least diminishing serious long-term detrimental

consequences (Patel et al., 2007). Indeed, Reynolds and Kamphaus (2004) proposed a valid screening questionnaire for assessing adolescents' mental health, which provides a dual-factor model comprising psychological well-being (i.e., interpersonal relationships and self-esteem) and psychological distress indicators (i.e., anxiety, social stress, risk of depression, and sense of inability). Therefore, this screening tool would be helpful to extend the scarce evidence regarding the dual-factor model of mental health, conformed by psychological well-being and distress indicators.

Given the scarce evidence including a dual-factor model of mental health and analyzing sex differences in the adolescent population, the main aim of this study was to analyze the association between the dual-factor model of mental health and academic performance, and to examine this association by sex in a sample of adolescents.

2. Materials and methods

2.1. Study design and participants

The present study is part of the DADOS study, which is a 3-year longitudinal research project (from 2015 to 2017) aimed to investigate the influence of physical activity in health, cognition, and psychological well-being through adolescence. The results presented in this study belong to baseline data obtained between February and May of 2015. A convenience sampling technique was used to recruit participants. For that purpose, advertising leaflets about the research project were sent to secondary schools and sports clubs located in Castellon province (Spain), which included basic information and the general DADOS study inclusion criteria (i.e., to be enrolled in second grade of secondary school and without diagnosed physical or neurological chronic diseases). Volunteers who met the inclusion criteria (as reported by participants' parents or guardians) were included in the study. A total of 265 adolescents (126 girls) completed the baseline assessment with valid data for all the analyzed variables of this study.

Adolescents and their parents or guardians were informed of the nature and characteristics of the study, and all provided written informed consent. The DADOS study protocol was designed in accordance with the ethical guidelines of the Declaration of Helsinki 1964 (last revision of Fortaleza, Brazil, 2013) and approved by the Research Ethics Committee of the Universitat Jaume I of Castellon (Spain).

2.2. Mental health

The S3 self-reported Spanish version of the BASC Questionnaire, for adolescents aged 12-18 years, was used to assess participants mental health status (González et al., 2004). The clinical scale of the emotional symptoms index was used to analyze the dual-factor model of mental health. It is composed by two adaptative scales of psychological well-being (self-esteem and interpersonal relationships) and four clinical scales of psychological distress (anxiety, social stress, risk of depression, and sense of inability). All of them were calculated by transforming raw scores into standard T-scores with an average of 50 and standard deviations of 10 points. Higher values of the emotional symptoms index indicate higher emotional

disturbance. According to Reynolds and Kamphaus (2004) a score ≥60 in the clinical scales and a score ≤40 in the adaptative scales indicated 'at risk' of emotional disturbance that affects adolescents' feelings and thoughts.

2.3. Academic performance

Academic performance was assessed through the final academic grades from first year of secondary school, provided by each school's secretary office. They were based on a ten-point scale, in which 0 indicates the lowest achievement and 10 indicates the highest achievement. Individual grades for math and language, as well as the GPA were included in the analyses. GPA was defined as the average of the scores achieved by students in all subjects of the academic year: math, language, foreign language, social sciences, natural sciences, and physical education.

Level 3 of the Spanish version of the TEA test was used to measure academic abilities of the study sample (Thurstone & Thurstone, 2004). This test provides general measures of three areas of intelligence and skills of learning: verbal (command of language), numeric (speed and precision in performing operations with numbers and quantitative concepts), and reasoning (the skill to find logical order in sets of numbers, figures, or letters). Scores for the three areas were obtained by adding positive answers, and overall score was calculated by adding the three areas scores (verbal + numeric + reasoning) (reliability: verbal $\alpha = 0.74$, numeric $\alpha = 0.87$, reasoning $\alpha = 0.77$, and overall score $\alpha = 0.89$).

2.4. Covariates

Since adolescence is a period characterized by developmental changes at a different pace, sex and pubertal stage were included as confounders (Ortega, Ruiz, Castillo, Moreno, et al., 2008). In addition, socioeconomic status and weight status were also included as relevant confounders given their association with mental health (Currie et al., 2008; Reiss, 2013) and academic performance (Donnelly et al., 2016; Santana et al., 2017).

Pubertal stage was self-reported using standardized pictures according to the five stages described by Tanner and Whitehouse (1976), based on external primary and secondary sex characteristics. The degree of development was assessed through two components: pubic

hair growth for boys and girls, plus genital development in boys, and breast development in girls. A 5-point maturity rating (from 1 to 5) was used for each component, in which stage 1 corresponded to the prepubertal state and stage 5 to the mature state. The highest rating of the two components was used for data analyses.

Socioeconomic status was reported by parents or guardians through the FAS scale, developed by Currie et al. (2008). It was used as a proxy of socioeconomic status (ranging from 0 to 8) and its components were based on material conditions in the family such as car ownership, bedroom occupancy, computer ownership, and home internet access.

Weight status was measured through body mass index, calculated as weight/height squared (kg/m^2). Body weight was measured to the nearest 0.1 kg using an electronic scale (SECA 861 - Hamburg, Germany). Body height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (SECA 213 - Hamburg, Germany). Weight and height were measured in duplicate, following the standardized procedures, and average measures were used for the data analyses.

2.5. Statistical analysis

Descriptive characteristics of the study sample comprised continuous and categorical variables that were presented as mean ± standard deviation or percentages, respectively. All variables were checked for normality using both graphical (normal probability plots) and statistical (Kolmogorov-Smirnov test) procedures. For descriptive purposes of the sample, sex differences were assessed using t-test for continuous variables.

Multiple linear regression was used to analyze the association between mental health and academic performance indicators adjusting for sex, pubertal stage, socioeconomic status, and body mass index. The emotional symptoms index and each of its components (i.e., psychological well-being and distress indicators) were entered as the independent variables and each academic performance indicator (i.e., academic grades and academic abilities) was entered as the dependent variable in separate models. Later on, data was stratified by sex in order to examine the association between mental health and academic performance indicators among girls and boys in separate models. Sex-stratified linear regression analyses

were adjusted for pubertal stage, socioeconomic status, and body mass index. All the analyses were performed using the IBM SPSS Statistics for Windows version 22.0 (Armonk, NY: IBM Corp), and the level of significance was set as $p < 0.05$.

3. Results

Characteristics of the study sample by sex are shown in **Table 2**. Adolescent boys showed lower emotional disturbance than girls, obtaining lower scores in the clinical scales of the emotional symptoms index (43.8 vs. 48.7; $p < 0.001$), anxiety (41.9 vs. 50.4; $p < 0.001$), social stress (44.6 vs. 47.9; $p = 0.002$), risk of depression (44.9 vs. 47.6; $p = 0.011$), and sense of inability (47.0 vs. 49.4; $p = 0.027$). Meanwhile, boys showed significantly higher self-esteem (55.1 vs. 51.2; $p < 0.001$) and numeric ability than girls (14.8 vs. 12.0; $p < 0.001$).

Table 2

Descriptive characteristics of the study sample.

	All	Boys	Girls	p
	N = 265	N = 139	N = 126	
Physical characteristics				
Age (years)	13.9 ± 0.3	13.9 ± 0.3	13.9 ± 0.3	0.990
Pubertal stage (II - V) (%)	8/34/48/10	10/32/43/15	5/36/54/5	-
Weight (kg)	54.2 ± 9.2	54.6 ± 9.6	53.8 ± 8.8	0.479
Height (cm)	163.1 ± 7.9	164.7 ± 8.5	161.3 ± 6.7	**<0.001**
Body mass index (kg/m^2)	20.3 ± 2.7	20.0 ± 2.5	20.6 ± 2.9	0.076
Socioeconomic status (0 - 8)	4.2 ± 1.4	4.0 ± 1.3	4.4 ± 1.4	**0.031**
Mental health				
Emotional symptoms index (ESI)	46.1 ± 8.9	43.8 ± 6.5	48.7 ± 10.3	**<0.001**
Psychological well-being				
Interpersonal relationships	51.8 ± 7.3	52.4 ± 6.1	51.2 ± 8.4	0.185
Self-esteem	53.3 ± 7.6	55.1 ± 4.7	51.2 ± 9.5	**<0.001**
Psychological distress				
Anxiety	46.0 ± 10.4	41.9 ± 8.9	50.4 ± 10.2	**<0.001**
Social stress	46.2 ± 8.7	44.6 ± 6.6	47.9 ± 10.3	**0.002**
Risk of depression	46.2 ± 8.3	44.9 ± 6.0	47.6 ± 10.1	**0.011**
Sense of inability	48.1 ± 9.1	47.0 ± 8.3	49.4 ± 9.8	**0.027**
Academic performance				
Academic grades (0 - 10)				
Math	6.9 ± 1.6	7.0 ± 1.6	6.7 ± 1.6	0.312
Language	6.8 ± 1.5	6.6 ± 1.5	6.9 ± 1.5	0.126
Grade point average	7.1 ± 1.3	7.0 ± 1.3	7.2 ± 1.3	0.309
Academic abilities				
Verbal ability (0 - 50)	18.7 ± 5.3	19.2 ± 5.9	18.2 ± 4.6	0.139
Numeric ability (0 - 30)	13.5 ± 4.7	14.8 ± 4.6	12.0 ± 4.5	**<0.001**
Reasoning ability (0 - 30)	16.5 ± 5.8	16.1 ± 5.6	17.0 ± 6.0	0.197
Overall score (0 - 110)	48.7 ± 12.6	50.0 ± 12.8	47.2 ± 12.2	0.064

Note. Values are presented as mean ± standard deviation or percentages. Differences between sex were examined by t-test. Values in bold indicate significant results.

Table 3 shows the association between mental health and academic performance indicators, after adjusting for sex, pubertal stage, socioeconomic status, and body mass index. The emotional symptoms index was negatively associated with academic grades (β ranging from -0.245 to -0.229, all $p < 0.001$), but not with academic abilities. Regarding psychological well-being indicators, interpersonal relationships were positively associated with all academic grades (β ranging from 0.122 to 0.146, all $p < 0.05$), and self-esteem was positively associated with math ($\beta = 0.135$, $p = 0.036$) and language ($\beta = 0.128$, $p = 0.045$). Nevertheless, none of the psychological well-being indicators were significantly associated with academic abilities. Regarding psychological distress indicators, our results show that all the distress indicators, except from anxiety, were negatively associated with all academic grades indicators (β ranging from -0.379 to -0.171, all $p < 0.01$). Moreover, sense of inability was also negatively associated with all indicators of academic abilities (β ranging from -0.199 to -0.145, all $p < 0.05$).

Table 3

Linear regression analyses between mental health and academic performance indicators in adolescents (N = 265).

	Academic grades									Academic abilities											
	Math			Language			GPA			Verbal ability			Numeric ability			Reasoning ability			Overall score		
	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p
Mental health																					
ESI	.105	- .229	**.000**	.114	- .245	**.000**	.114	- .239	**.000**	.041	- .055	.391	.132	- .114	.064	.030	- .075	.250	.059	- .101	.114
Psychological well-being																					
Int. relationships	.079	.146	**.016**	.074	.122	**.045**	.083	.144	**.017**	.038	- .007	.905	.126	.076	.199	.032	.084	.174	.054	.065	.292
Self-esteem	.074	.135	**.036**	.074	.128	**.045**	.070	.096	.136	.038	.021	.749	.122	.045	.468	.025	- .016	.808	.050	.018	.776
Psychological distress																					
Anxiety	.059	- .032	.626	.062	- .047	.479	.064	- .044	.507	.039	- .023	.730	.123	- .058	.366	.025	- .019	.781	.051	- .040	.545
Social stress	.088	- .180	**.004**	.087	- .171	**.006**	.096	- .188	**.002**	.038	- .010	.880	.124	- .060	.315	.029	- .069	.276	.053	- .059	.347
Risk of depression	.094	- .194	**.001**	.115	- .239	**.000**	.104	- .207	**.001**	.040	- .046	.459	.125	- .072	.223	.025	- .021	.732	.053	- .057	.358
Sense of inability	.167	- .334	**.000**	.199	- .379	**.000**	.201	- .377	**.000**	.056	- .135	**.029**	.158	- .197	**.001**	.045	- .145	**.019**	.088	- .199	**.001**

Note. β = standardized regression coefficient. Analyses were adjusted by sex, pubertal stage, socioeconomic status, and body mass index. Values in bold indicate significant results. ESI = Emotional Symptom Index; Int. = Interpersonal; GPA = Grade point average.

Table 4 shows the multiple linear regression analyses between mental health and academic performance among boys, after adjusting for pubertal stage, socioeconomic status, and body mass index. These analyses showed a negative association of the emotional symptoms index with language (β = -0.283, p < 0.001) and GPA (β = -0.189, p = 0.021). No significant association was found between psychological well-being indicators and academic performance in our sample. Regarding psychological distress indicators, social stress was negatively associated with language (β = -0.215, p = 0.009), and risk of depression was negatively associated with language (β = -0.285, p < 0.001) and GPA (β = -0.194, p = 0.018). Sense of inability was negatively associated with all academic grades' indicators along with numeric ability and the overall score of academic abilities (β ranging from -0.299 to -0.194, all p < 0.05).

Table 4

Linear regression analyses between mental health and academic performance indicators in adolescent boys (N = 139).

	Academic grades									Academic abilities											
	Math			Language			GPA			Verbal ability			Numeric ability			Reasoning ability			Overall score		
	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p
Mental health																					
ESI	.101	- .133	.109	.170	- .283	**.000**	.135	- .189	**.021**	.048	- .034	.687	.098	- .116	.165	.084	- .159	.059	.104	- .127	.126
Psychological well-being																					
Int. relationships	.096	.115	.176	.101	.100	.240	.113	.117	.166	.050	- .058	.503	.090	.071	.404	.069	.103	.234	.090	.044	.607
Self-esteem	.085	.039	.646	.104	.115	.172	.101	.025	.762	.047	- .002	.977	.090	.067	.433	.077	.136	.112	.095	.083	.328
Psychological distress																					
Anxiety	.084	- .019	.822	.108	- .132	.110	.103	- .055	.506	.047	.008	.926	.089	- .063	.447	.063	- .066	.436	.091	- .048	.565
Social stress	.090	- .082	.331	.136	- .215	**.009**	.116	- .126	.127	.048	- .021	.806	.086	- .021	.798	.076	- .133	.117	.094	- .076	.364
Risk of depression	.105	- .147	.075	.172	- .285	**.000**	.137	- .194	**.018**	.047	- .011	.898	.096	- .102	.221	.083	- .155	.064	.100	- .109	.186
Sense of inability	.121	- .194	**.019**	.232	- .379	**.000**	.188	- .299	**.000**	.070	- .152	.073	.122	- .194	**.019**	.078	- .138	.102	.127	- .200	**.016**

Note. β = standardized regression coefficient. Analyses were adjusted by pubertal stage, socioeconomic status, and body mass index. Values in bold indicate significant results. ESI = Emotional Symptom Index; Int. = Interpersonal; GPA = Grade point average.

The multiple linear regression analyses between mental health and academic performance in adolescent girls, after adjusting for pubertal stage, socioeconomic status, and body mass index are presented in **Table 5**. These analyses showed a negative association of the emotional symptoms index with all academic grades' indicators (β ranging from -0.296 to -0.208, all $p < 0.05$). In addition, when we examined psychological well-being indicators, only self-esteem was positively associated with math ($\beta = 0.205$, $p = 0.026$). Regarding psychological distress indicators, social stress was negatively associated with math ($\beta = -0.258$, $p = 0.004$) and GPA ($\beta = -0.239$, $p = 0.007$). Risk of depression was negatively associated with all academic grades' indicators (β ranging from -0.235 to -0.206, all $p < 0.05$). Sense of inability was negatively associated with all academic grades' indicators along with numeric ability and the overall score of academic abilities (β ranging from -0.487 to -0.197, all $p < 0.05$).

Table 5

Linear regression analyses between mental health and academic performance indicators in adolescent girls (N = 126).

	Academic grades									Academic abilities											
	Math			Language			GPA			Verbal ability			Numeric ability			Reasoning ability			Overall score		
	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p
Mental health																					
ESI	.129	- .296	**.001**	.083	- .208	**.021**	.122	- .268	**.003**	.018	- .069	.453	.028	- .115	.210	.007	- .016	.867	.016	- .077	.408
Psychological well-being																					
Int. relationships	.071	.163	.065	.061	.136	.125	.079	.160	.070	.015	.044	.627	.022	.081	.368	.011	.063	.490	.017	.078	.391
Self-esteem	.083	.205	**.026**	.060	.140	.131	.073	.146	.111	.014	.034	.719	.017	.042	.656	.015	- .091	.337	.011	- .016	.862
Psychological distress																					
Anxiety	.047	- .045	.615	.043	.030	.736	.054	- .031	.729	.017	- .057	.530	.017	- .049	.588	.008	.020	.823	.011	- .030	.744
Social stress	.110	- .258	**.004**	.063	- .145	.105	.109	- .239	**.007**	.013	.000	.996	.024	- .098	.285	.008	- .032	.728	.013	- .052	.573
Risk of depression	.098	- .235	**.009**	.083	- .206	**.022**	.098	- .217	**.015**	.017	- .066	.477	.017	- .047	.612	.012	.069	.456	.011	- .008	.930
Sense of inability	.270	- .487	**.000**	.175	- .375	**.000**	.256	- .462	**.000**	.025	- .109	.240	.061	- .219	**.017**	.029	- .151	.104	.047	- .197	**.033**

Note. β = standardized regression coefficient. Analyses were adjusted by pubertal stage, socioeconomic status, and body mass index. Values in bold indicate significant results. ESI = Emotional Symptoms Index; Int. = Interpersonal; GPA = Grade point average.

4. Discussion

The main finding of the present study indicates that adolescents' mental health status was significantly associated with academic grades, and shows largely similar results among boys and girls. This study expands the scarce literature about the association between mental health and academic performance in the adolescent population on the basis of the dual-factor model of mental health, including a wide range of psychological well-being and distress indicators.

The results of our study show that the emotional symptoms index was negatively associated with academic grades in our sample of adolescents. These results are partially in line with the only two prior studies analyzing the dual-factor model of mental health and its association with academic performance in adolescents aged 10 to 16 years old (Antaramian et al., 2010; Suldo & Shaffer, 2008). Thus, our finding also supports the idea that the combination of the presence of psychological well-being and the absence of psychological distress is associated with better academic performance in secondary school students. Regarding psychological well-being, our results indicate that self-esteem and interpersonal relationships were positively associated with academic performance in secondary school students, concurring with the findings of Trautwein et al. (2006) and Kiuru et al. (2020). Likewise, regarding psychological distress indicators, our findings agree with previous studies showing that social stress (Ye et al., 2019), symptoms of depression (Riglin et al., 2014), and sense of inability (Hagger & Hamilton, 2019) were negatively associated with academic performance in adolescents.

A possible explanation of these results could be that having a healthy global perception of the self along with having good interpersonal relationships may generate a psychological well-being state during puberty (Triana et al., 2019). It is plausible that this fact fulfills them with higher motivation and sense of belonging to school and society, providing higher security for facing personal and scholar challenges (Heimpel et al., 2002; Virtanen et al., 2020). These facts in combination with the lack of social stress, depressive symptoms, and sense of inability may lead to an adequate environment for concentration and a higher

interest on social and school activities, which may help adolescents to succeed in secondary school (Breslau et al., 2011).

The present study has shown similar results in the association between the emotional symptoms index and academic performance among our sample of adolescent boys and girls. Nevertheless, regarding psychological well-being, only self-esteem was positively associated with math in girls, and no significant association was found in boys. A possible explanation for these sex disparities in self-esteem may be explained by the fact that girls tend to be more aware of their personal appearance and are more frequently dissatisfied by their body image than boys (Jimenez-Flores et al., 2017), which makes them more vulnerable to experience emotional and self-perceived disturbances, influencing their academic performance. Regarding psychological distress, social stress and risk of depression were negatively associated with academic grades in boys and girls, showing largely similar results. Thus, despite the fact that girls are more likely to be exposed to stressful social events (Lavoie et al., 2019) and are at higher risk of depression than boys (Thapar et al., 2012), our results suggest that their association with academic performance may be independent of sex. In fact, adolescent boys and girls who experience stress or depressive symptoms are characterized by showing a maladaptive behavior and a school refusal (Gonzálvez et al., 2018), which may explain their relationship with academic performance in the adolescent population. However, despite the plausible explanations given above, the slight differences found in some associations must be interpreted with caution, since they may also be explained by the lower statistical power derived from analyzing this association by groups.

In this study, mental health indicators showed significant associations with academic grades, while only sense of inability was significantly associated with academic abilities. These results could be explained by the nature of our academic performance indicators and the meaning of sense of inability. In fact, academic grades take implicit the student progression during an academic year in each subject, while academic abilities are assessed by a standardized test in a single-time point trial (Baker, 2006). Thus, the lack of passion and perseverance, as well as not feeling capable or determinant to obtain goals (Duckworth &

Seligman, 2005), which are the main characteristics of the sense of inability described by González et al. (2004), may be clearly related to the ability to perform well on school grades, as well as to succeed in standardized skill tests in a specific time point (Donnelly et al., 2016). To the best of our knowledge, this is the first study that examines the association between mental health and academic performance on the basis of the dual-factor model of mental health in the adolescent population, and analyses this association by sex. Thus, our findings may be useful for implementing school-based mental health programs, since they are scarce and mainly based on the promotion of psychological well-being (O'Connor et al., 2018; Sklad et al., 2012) or psychological distress (Blanco-Vieira et al., 2018). Therefore, our work contributes to mental health and education literature during adolescence, highlighting the importance of considering the combination of psychological well-being and distress when designing educational programs for promoting adolescents' mental health and academic performance.

5. Limitations and strengths

The present study comprises some strengths including the use of the emotional symptoms index as a dual-factor model of mental health that comprises a wide range of psychological well-being and distress indicators. In addition, our analyses have been developed with a relatively large and homogeneous sample in terms of age, and all statistical analyses were controlled for potential confounders. However, the cross-sectional design of this study prevents us to confer causal relationships between mental health and academic performance indicators.

6. Conclusion

In conclusion, our results support that mental health is associated with academic performance in adolescents, with largely similar results among boys and girls. These findings elucidate the importance of including the promotion of both psychological well-being and psychological distress, due to its relationship with academic performance during adolescence. Therefore, our results suggest that the promotion of mental health during adolescence could help to enhance academic grades.

Study II

An examination of the association between risk of depression and academic performance according to weight status in adolescents: DADOS study.

Study II

Abstract

The early identification of emotional and psychological problems during adolescence seems helpful to improve academic performance. However, the association between risk of depression and academic performance, as well as the role of health-related factors in this association remain to be elucidated. Therefore, the aims of this study were to analyze the association between risk of depression and academic performance in adolescents; to examine this association according to weight status; and to test the mediating role of weight status in this association. A sample of 265 adolescents (125 girls) aged 13.9±0.3 years old from the DADOS study was included in the analyses. Risk of depression was self-reported through the BASC-S3 questionnaire. Academic performance was assessed through academic grades and the Spanish version of the TEA test. Weight status was assessed by body mass index (kg/m^2) and dichotomized according to the international age- and sex-specific body mass index cut-offs (non-overweight vs. overweight). Linear regression analyses showed an inverse association between risk of depression and academic grades (all $p<0.05$). Further linear regressions analyzing risk of depression and academic performance (dependent variable) stratified by weight status showed stronger associations among overweight adolescents. Additionally, mediation analyses revealed that weight status acted as a mediator of this association. *Conclusion:* Educational institutions should promote the early identification of depression as well as the promotion of healthy weight status as strategies to enhance academic performance in adolescents.

Keywords: Mental health; depression; well-being; cognition; body composition; adolescents.

1. Introduction

Adolescence is a period of life in which many important biological, psychological, and social changes occur (Patton & Viner, 2007). Mental health problems tend to increase during this age span (Avenevoli et al., 2015), being depression the most prevalent mental disorder (Gotlib & Joormann, 2010). In fact, depression has been suggested to rise from 5% in early adolescence to 20% by the end of the period (Thapar et al., 2012). This mental health disorder is characterized by emotion dysregulation, lack of pleasure, suicidal behaviors, and concentration problems, which in turn may influence several aspects of adolescents' life (Gotlib & Joormann, 2010).

Depressive symptomatology has been associated with brain-related alterations and cognitive impairment (F. F. Zhang et al., 2018), affecting academic performance in high school students (Hishinuma et al., 2012). Previous studies suggested that screening for depression during adolescence through self-reported instruments may help to ensure timely identification in order to prevent potential long-term emotional, social, and economic burden (Forman-Hoffman & Viswanathan, 2018). Among its benefits, the early identification of depression may be helpful for improving academic performance in the young population (Riglin et al., 2014). Nevertheless, as far as we know, prior studies have investigated the association between depression and academic performance, but none of them analyzed the risk of developing depression before its diagnosis (Hishinuma et al., 2012; Khesht-Masjedi et al., 2019; Riglin et al., 2014).

Overweight and obesity, ongoing worldwide concerns, are major risk factors for the development of multiple diseases (M. Ng et al., 2014). In fact, an emerging body of evidence suggests that weight status during adolescence may influence both risk of depression (Rao et al., 2020) and academic performance (He et al., 2019). For instance, a previous meta-analysis concluded that overweight adolescents had higher risk of depression than their non-overweight peers (Rao et al., 2020). Likewise, the meta-analysis developed by He et al. (2019) showed an inverse association between overweight status and academic performance. Despite this fact, to the best of our knowledge, only one previous study based

on the influence of sports participation in 1036 high school students has considered weight status as a confounder in the association between depression and academic performance (Gore et al., 2001).

Collectively, a better understanding of the link between the risk of developing depression and academic performance, as well as the influence of weight status on this association, could help to shape our knowledge about possible correlates of academic performance in order to enhance it during adolescence, which is a critical period for cognition and brain development. Therefore, the aims of the present study were: (i) to analyze the association between risk of depression and academic performance in a sample of adolescents; (ii) to examine this association according to weight status categories (i.e., non-overweight vs. overweight); and (iii) to test the mediating role of weight status in the association between risk of depression and academic performance.

2. Materials and methods

2.1. Study design and participants

The present study is part of the DADOS study, which is a 3-year longitudinal research project (from 2015 to 2017) aimed to investigate the influence of physical activity on health, cognition, and psychological well-being through adolescence. The results presented in this study belong to baseline data obtained between February and May of 2015. A convenience sampling technique was used to require participants. For that purpose, advertising leaflets about the research project were sent to secondary schools and sports clubs located in Castellon province (Spain), which included basic information and the general DADOS study inclusion criteria (i.e., to be enrolled in second grade of secondary school and without diagnosed physical or neurological chronic diseases). Volunteers who met the inclusion criteria (as reported by participants' parents or guardians) contacted the research group and were included in the study. A total of 265 adolescents (125 girls) completed the baseline assessment with valid data for all the analyzed variables.

Adolescents and their parents or guardians were informed of the nature and characteristics of the study, and all provided written informed consent. The DADOS study protocol was designed in accordance with the ethical guidelines of the Declaration of Helsinki 1964 (last revision of Fortaleza, Brazil, 2013) and approved by the Research Ethics Committee of the Universitat Jaume I of Castellon (Spain).

2.2. Risk of depression

The BASC questionnaire (Reynolds & Kamphaus, 2004), in the S3 self-report Spanish version for adolescents aged 12-18 years (González et al., 2004) was used to assess risk of depression (reliability: $\alpha = 0.81$). BASC-S3 consists of statements rated as true or false. Risk of depression score was calculated by transforming raw scores into standard T-scores with an average of 50 and standard deviations of 10 points. This variable was dichotomized into 'non-risk' of developing depression (< 60) and 'at risk' of developing depression (≥ 60) according to the cut-off point established by Reynolds and Kamphaus (2004).

2.3. Academic performance

Academic performance was assessed through the final academic grades from first grade of secondary school, provided by each school's secretary office. They were based on a ten-point scale (0 indicates the lowest achievement and 10 indicates the highest achievement). GPA score and individual grades for the following subjects were included in the analyses: social sciences, natural sciences, math, language, and physical education. GPA score was defined as the average of the scores achieved by students in all subjects.

The Spanish version of the TEA test was used to measure academic abilities (Thurstone & Thurstone, 2004). This test provides general measures of three areas of intelligence and skills of learning: verbal (command of language), numeric (speed and precision in performing operations with numbers and quantitative concepts), and reasoning (the skill to find logical order in sets of numbers, figures, or letters). Scores for the three areas were obtained by adding positive answers. Overall score was calculated by adding the three areas scores (verbal + numeric + reasoning). Based on the age range of our sample, level three of the TEA test was used (reliability: verbal $\alpha = 0.74$, numeric $\alpha = 0.87$, reasoning $\alpha = 0.77$, and overall score $\alpha = 0.89$).

2.4. Weight status

Weight status was measured through body mass index, calculated as weight/height square (kg/m^2). Body weight was measured to the nearest 0.1 kg using an electronic scale (SECA 861 - Hamburg, Germany). Body height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (SECA 213 - Hamburg, Germany). Weight and height were measured in duplicate, following the standardized procedures, and average measures were used for the data analyses. Adolescents were classified as overweight (including overweight and obese) or non-overweight, according to the international age- and sex-specific body mass index cut-offs proposed by Cole and Lobstein (2012).

2.5. Covariates

Pubertal stage was self-reported using standardized pictures according to the five stages described by Tanner and Whitehouse (1976), based on external primary and secondary sex

characteristics. The degree of development was assessed through two components: pubic hair growth for boys and girls, plus breast development in girls and genital development in boys. A 5-point maturity rating (from 1 to 5) was used for each component, in which stage 1 corresponded to the prepubertal state and stage 5 to the mature state. The highest rating of the two components was used for data analyses.

Socioeconomic status was reported by the FAS scale, developed by Currie et al. (2008). It was used as a proxy of socioeconomic status (ranging from 0 to 8), which is based on material conditions in the family such as car ownership, bedroom occupancy, computer ownership, and home internet access.

2.6. Statistical analysis

Descriptive characteristics are presented as mean ± standard deviation or percentages for continuous and categorical variables, respectively. All variables were checked for normality using both graphical (normal probability plots) and statistical (Kolmogorov-Smirnov test) procedures. For descriptive purposes of the sample, sex differences were assessed using t-test for continuous variables and chi-square for categorical variables. As preliminary analyses showed no significant interactions of sex with risk of depression in relation to academic performance (all p > 0.10), all analyses were performed for the whole sample.

Multiple linear regression was used to analyze the association between risk of depression and academic performance adjusting for sex, pubertal stage, socioeconomic status, and body mass index. Risk of depression was entered as the independent variable and each academic performance indicator (i.e., academic grades and academic abilities) was entered as the dependent variable in separate models. Additionally, we conducted linear regression models to examine the association between risk of depression and academic performance by weight status categories, adjusting for sex, pubertal stage, and socioeconomic status.

Boot-strapped mediation procedures were performed to examine whether the association between risk of depression and academic performance variables was mediated by weight status, controlling for sex, pubertal stage, and socioeconomic status. The PROCESS SPSS Macro version 2.16.3, model four, with 5.000 bias-corrected bootstrap samples and 95%

confidence intervals (CIs) was used for these analyses (Hayes, 2013). Mediation was assessed by the indirect effect of the risk of depression score (independent variable) on academic performance (variables individually entered as the dependent variables) through weight status (mediator variable entering body mass index as continuous variable) (**Figure 4**). The total (c path), direct (c′ path), and indirect effects (paths a*b) are presented in **Table 8**. Indirect effects (paths a*b) with CIs not including zero were interpreted as statistically significant, which can be so regardless of the significance of the total effect (the effect of the risk of depression score on academic performance) and the direct effect (the effect on academic performance when both risk of depression score and weight status are included as predictors) (Hayes, 2013). Percentage of mediation (P_M) was calculated as: [(indirect effect/total effect) × 100] to know how much of the total effect was explained by the mediation when the following assumptions where achieved: the total effect is larger than the indirect effect and with the same direction of the effect (Hayes, 2013). All the analyses were performed using the IBM SPSS Statistics for Windows version 22.0 (Armonk, NY: IBM Corp), and the level of significance was set as $p < 0.05$.

3. Results

Descriptive characteristics of the study sample are presented in **Table 6**. Participants were 13.9 ± 0.3 years old and showed mean body mass index of 20.3 kg/m^2 (13% with overweight/obesity). Girls showed higher risk of depression score than boys (47.5 vs. 44.9; p = 0.009), and girls were more likely to be at risk of depression than boys (8% vs. 2%; p = 0.028). Overall, girls and boys showed similar values for all the academic performance indicators (all p > 0.05), except for numeric ability, in which boys obtained higher scores than girls (14.8 vs. 12.0; p < 0.001).

Table 6
Descriptive characteristics of the study sample.

	All	Boys	Girls	p
	N = 265	N = 140	N = 125	
Physical characteristics				
Age (years)	13.9 ± 0.3	13.9 ± 0.3	13.9 ± 0.3	0.971
Pubertal stage (II - V) (%)	8/33/49/10	10/32/44/14	6/35/54/5	-
Weight (kg)	54.2 ± 9.2	54.5 ± 9.6	53.9 ± 8.8	0.564
Height (cm)	163.1 ± 7.9	164.6 ± 8.6	161.4 ± 6.7	**0.001**
Body mass index (kg/m^2)	20.3 ± 2.7	20.0 ± 2.5	20.6 ± 2.9	0.060
Overweight/Obesity (%)	34 (13)	16 (11)	18 (14)	0.470
Socioeconomic status (0 - 8)	4.2 ± 1.4	4.0 ± 1.3	4.4 ± 1.4	**0.037**
Risk of depression				
Risk of depression score	46.1 ± 8.3	44.9 ± 6.0	47.5 ± 10.2	**0.009**
At risk of depression (%)	13 (4.9)	3 (2.1)	10 (8.0)	**0.028**
Academic performance				
Academic grades (0 - 10)				
Social sciences	7.0 ± 1.6	7.0 ± 1.6	7.1 ± 1.6	0.579
Natural sciences	7.0 ± 1.7	6.9 ± 1.7	7.1 ± 1.7	0.443
Math	6.9 ± 1.6	7.0 ± 1.6	6.8 ± 1.6	0.311
Language	6.8 ± 1.5	6.6 ± 1.5	6.9 ± 1.5	0.141
Physical education	8.1 ± 1.1	8.0 ± 1.1	8.1 ± 1.1	0.468
Grade point average	7.1 ± 1.3	7.1 ± 1.3	7.2 ± 1.3	0.324
Academic abilities				
Verbal ability (0 - 50)	18.7 ± 5.3	19.1 ± 5.9	18.2 ± 4.6	0.144
Numeric ability (0 - 30)	13.4 ± 4.7	14.8 ± 4.6	12.0 ± 4.5	**<0.001**
Reasoning ability (0 - 30)	16.5 ± 5.8	16.1 ± 5.6	17.0 ± 6.1	0.203
Overall score (0 - 110)	48.7 ± 12.6	50.0 ± 12.8	47.2 ± 12.3	0.066

Note. Values are mean ± standard deviation or frequency (%). Differences between sex were examined by t-test or chi-square test. Values in bold indicate significant results.

Table 7 shows the association between risk of depression and academic performance, after adjusting by sex, pubertal stage, socioeconomic status, and body mass index. According to academic grades, risk of depression score was inversely associated with social sciences, natural sciences, math, language, physical education, and GPA (all p < 0.05). No associations were found between risk of depression score and academic abilities indicators (all p > 0.05).

Table 7

Linear regression analyses between risk of depression score and academic performance indicators in adolescents (N = 265).
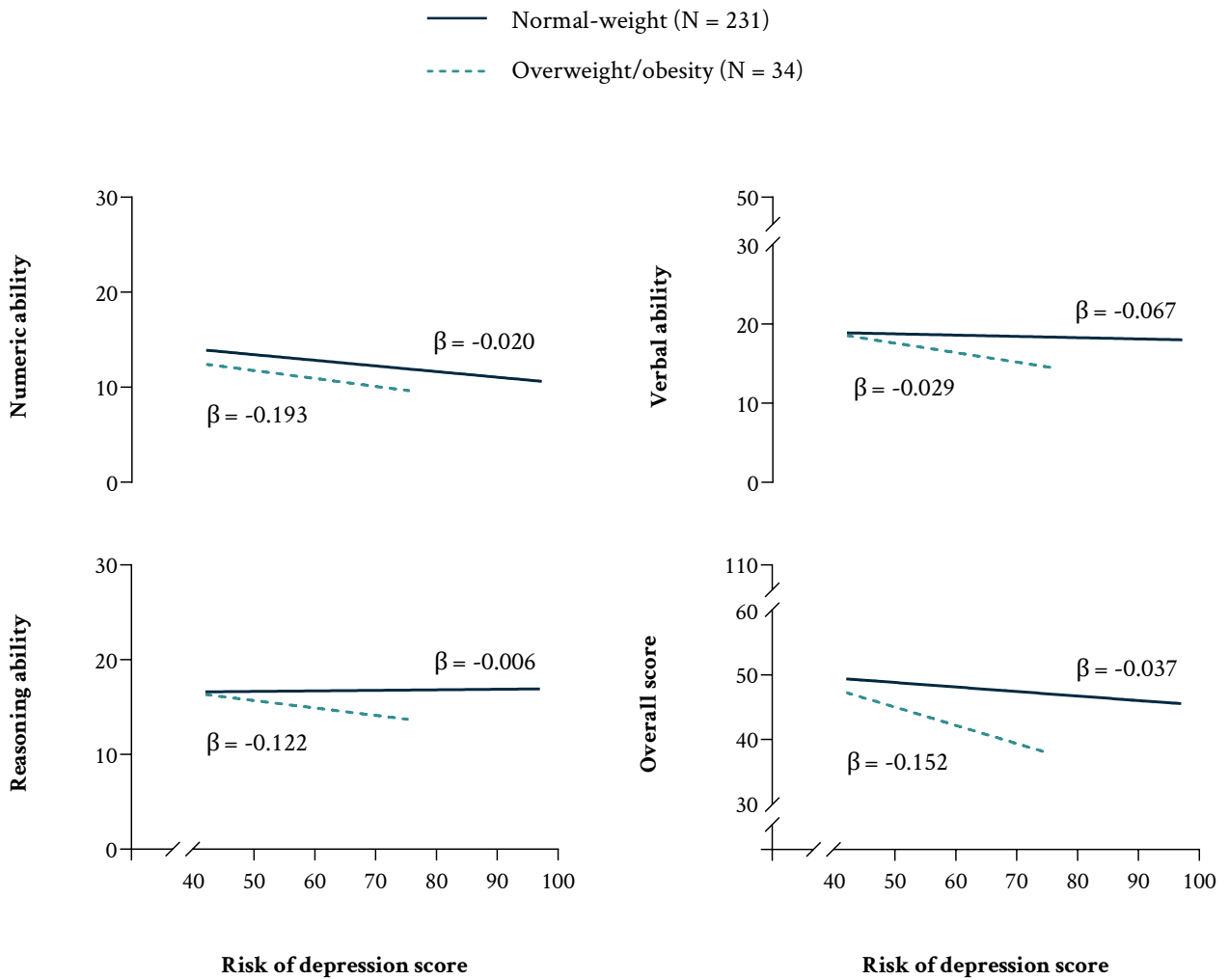
Academic performance	Risk of depression score			
	R^2	B	β	p
Academic grades				
Social sciences	0.069	- 0.028	- 0.145	**0.018**
Natural sciences	0.055	- 0.029	- 0.143	**0.020**
Math	0.080	- 0.037	- 0.193	**0.002**
Language	0.098	- 0.044	- 0.239	**0.000**
Physical education	0.012	- 0.019	- 0.142	**0.024**
Grade point average	0.089	- 0.032	- 0.206	**0.001**
Academic abilities				
Verbal ability	0.020	- 0.029	- 0.045	0.472
Numeric ability	0.106	- 0.039	- 0.068	0.253
Reasoning ability	0.004	- 0.014	- 0.020	0.755
Overall score	0.033	- 0.081	- 0.054	0.386

Note. B = non-standardized regression coefficient. β = standardized regression coefficient. Analyses were adjusted by sex, pubertal stage, socioeconomic status, and body mass index. Values in bold indicate significant results.

Figure 2 and **Figure 3** show the stratified multiple linear regression analysis between risk of depression score and academic performance indicators by weight status categories (i.e., non-overweight vs. overweight), adjusting by sex, pubertal stage, and socioeconomic status. **Figure 2** shows that risk of depression score was inversely associated with academic grades in math, language, and GPA (β ranged from -0.453 to -0.159, all p < 0.05), with a stronger association among overweight adolescents. Regarding academic abilities, **Figure 3** shows that risk of depression score and academic abilities were not significantly associated (all p > 0.05).
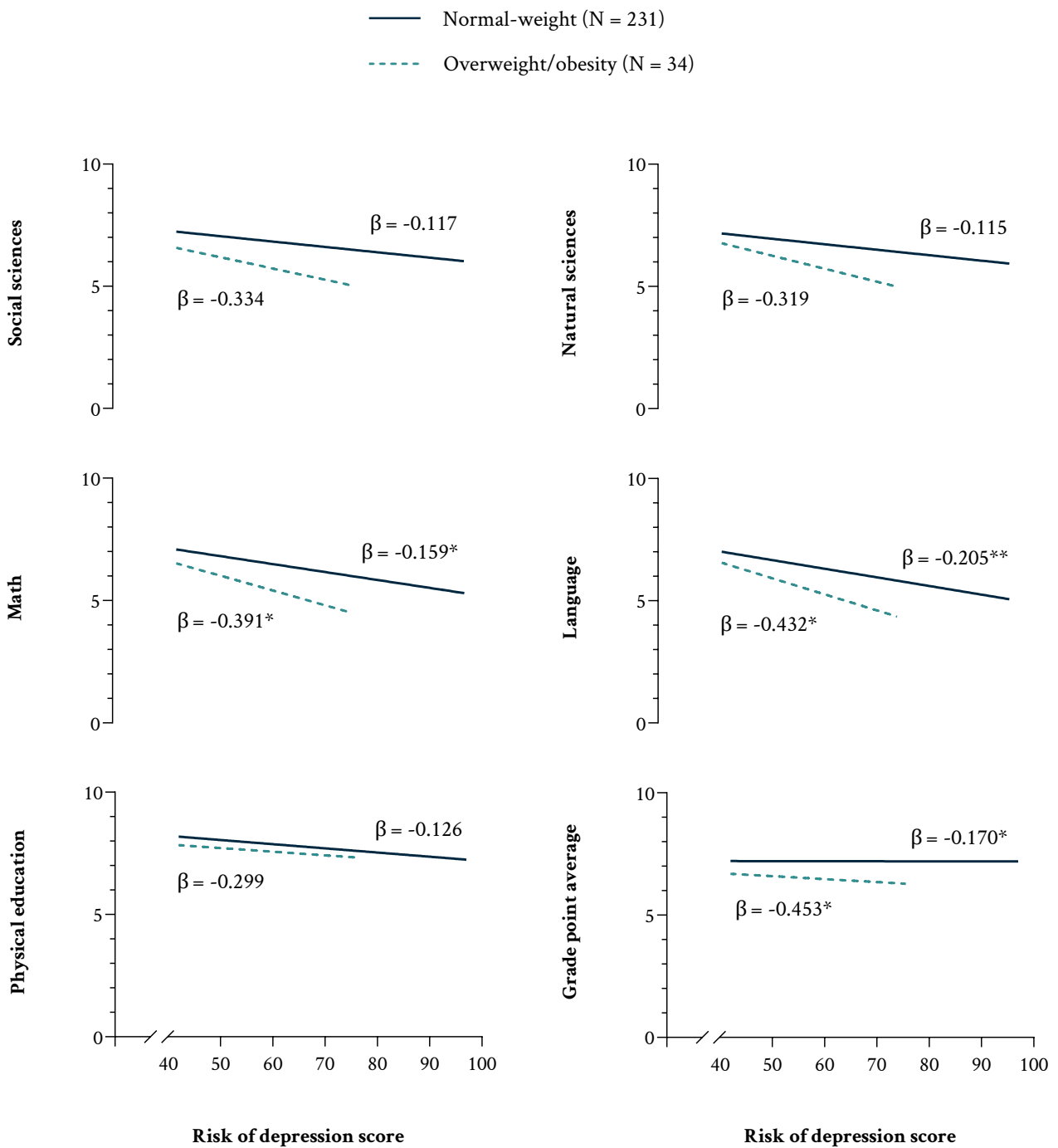
Figure 2. Multiple linear regression analysis between risk of depression score and academic grades in non-overweight and overweight adolescents. Analyses were adjusted by sex, pubertal stage, and socioeconomic status. β = standardized regression coefficient. *p<0.05; **p<0.01.

Figure 3. Multiple linear regression analysis between risk of depression score and academic abilities in non-overweight and overweight adolescents. Analyses were adjusted by sex, pubertal stage, and socioeconomic status. β = standardized regression coefficient.

Simple mediation analyses' results are presented in **Figure 4** and **Table 8**, which show that risk of depression score indirectly influenced some academic performance variables through weight status, controlling for sex, pubertal stage, and socioeconomic status. Risk of depression score was almost significantly associated with weight status (path *a*) and weight status was inversely and significantly associated with some academic performance indicators (path *b*) (i.e., social sciences, natural sciences, math, language, GPA, numeric ability, and overall score in academic abilities). A significant total effect (path *c*) was observed for risk of depression with all academic grades. The direct effect (path *c'*) of risk of depression score on academic performance when weight status was included in the model was significant for all academic grades. Regarding academic abilities, the total effect (path *c*) and the direct effect (path *c'*) were not significant. There was a significant indirect relationship (path a*b) of risk of depression score with social sciences, natural sciences, math, language, and GPA when weight status was included as mediator. No significant indirect relationship (path a*b) was found between risk of depression score and academic abilities when weight status was included as mediator. This indicates that weight status mediated the relationship between risk of depression and academic grades. The total effect of risk of depression score on academic performance explained by weight status ranged from 9% to 14% in the academic grades of natural sciences, social sciences, math, language, and GPA.
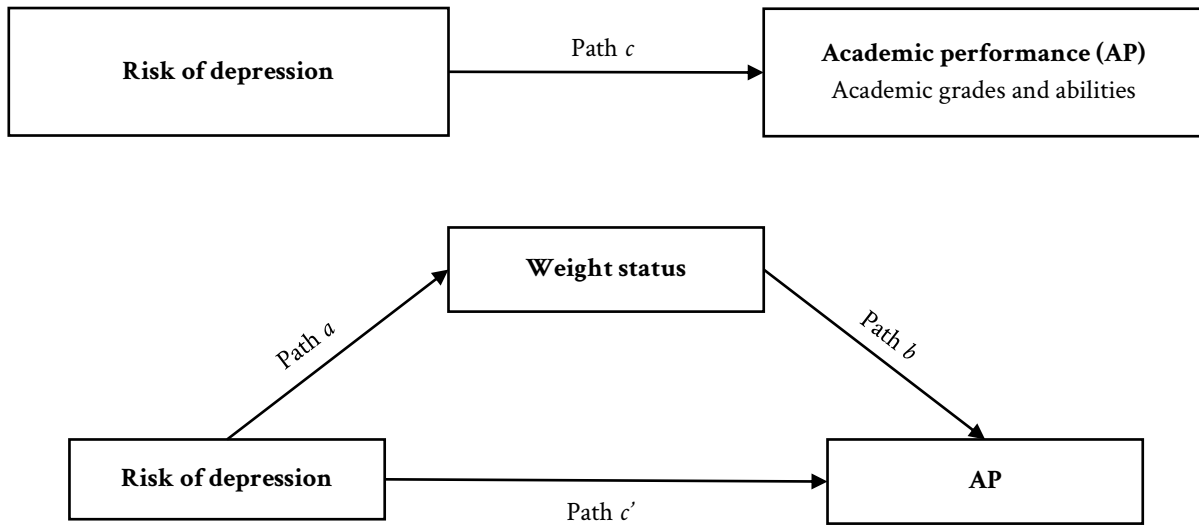
Figure 4. Simple mediation model of risk of depression (independent variable) on academic performance indicators (dependent variable) through weight status measured by body mass index as continuous variable (mediator variable). Path *a*: association between independent and mediator variables; Path *b*: association between mediator and dependent variables; Path *c*: overall association between independent and dependent variables; Path *c'*: unmediated direct effect of the independent variable on dependent variable.

Table 8

Total, direct, and indirect effects, a and b pathways, of the simple mediation analyses investigating weight status as a mediator between risk of depression and academic performance indicators in adolescents (N = 265).

	Total effect (c)	Direct effect (c')	Path a	Path b	Indirect effect (ab)	BC 95% CI lower; upper	$P_{M\,(\%)}$
Academic grades							
Social sciences	-0.033 (0.012)**	-0.028 (0.012)*	0.038 (0.020)	-0.122 (0.037)**	**-0.005 (0.003)**	-0.011; -0.001	14
Natural sciences	-0.033 (0.012)**	-0.028 (0.012)*	0.038 (0.020)	-0.122 (0.039)**	**-0.005 (0.003)**	-0.012; -0.001	14
Math	-0.041 (0.012)***	-0.037 (0.012)**	0.038 (0.020)	-0.104 (0.036)**	**-0.004 (0.003)**	-0.010; -0.001	10
Language	-0.048 (0.011)***	-0.044 (0.011)***	0.038 (0.020)	-0.112 (0.035)**	**-0.004 (0.003)**	-0.011; -0.001	9
Physical education	-0.020 (0.008)*	-0.019 (0.008)*	0.038 (0.020)	-0.031 (0.026)	-0.001 (0.002)	-0.005; 0.001	−
Grade point average	-0.035 (0.009)***	-0.032 (0.009)***	0.038 (0.020)	-0.093 (0.029)**	**-0.004 (0.002)**	-0.009; -0.001	10
Academic abilities							
Verbal	-0.036 (0.040)	-0.030 (0.040)	0.038 (0.020)	-0.152 (0.126)	-0.006 (0.006)	-0.021; 0.003	−
Numeric	-0.049 (0.034)	-0.041 (0.034)	0.038 (0.020)	-0.233 (0.107)*	-0.009 (0.006)	-0.026; 0.001	−
Reasoning	-0.025 (0.044)	-0.015 (0.044)	0.038 (0.020)	-0.249 (0.139)	-0.010 (0.007)	-0.026; 0.001	−
Overall	-0.110 (0.094)	-0.086 (0.094)	0.038 (0.020)	-0.634 (0.295)*	-0.024 (0.018)	-0.068; 0.001	−

Note. Results showed as unstandardized coefficients (standard error, SE) and BC 95% CI based on 5000 bootstraps. All analyses were adjusted for sex, pubertal stage, and socioeconomic status. Statistically significant indirect effects indicating that 0 is not in the 95% CI of the indirect effect are presented in bold. BC = bias corrected; CI = confidence interval; P_M = percentage of mediation. *p < 0.05; **p < 0.01; ***p < 0.001.

4. Discussion

The main findings of the present study indicate that risk of depression in adolescents is inversely associated with academic performance, revealing a stronger association among overweight adolescents compared to the non-overweight peers. Moreover, our results show that the inverse association between risk of depression and academic performance is mediated by weight status. These results highlight the value of the early identification of risk of depression due to its association with academic performance in adolescents, adding new knowledge about the negative influence of the excess of body weight on this association.

The results of our study seem to be partially in line with the previous studies analyzing the association between depressive symptoms and academic performance, in which diagnosed depression was inversely associated with school attainment in the young population (Hishinuma et al., 2012; Khesht-Masjedi et al., 2019; Riglin et al., 2014). Therefore, our findings suggest that being at risk of developing depression has already a negative impact on academic performance during adolescence. A possible justification of these results could be explained by the symptomatology of depression, which may start before the diagnosis. Indeed, adolescents at risk of depression may have a diminished ability to think or concentrate, a gradually loss of interest in social and school activities, or increased feelings of worthless (American Psychiatric Association, 2013), which in turn may impair adolescents' cognitive abilities and self-perception, adversely affecting their academic performance.

The stratified analysis by weight status examining the association between risk of depression and academic performance revealed a stronger association among overweight adolescents compared to non-overweight. In addition, our mediation analyses suggested that risk of depression contributes to adolescents' academic performance through weight status. These findings partially concur with prior research showing the key role of weight status on risk of depression and academic performance in adolescents. In fact, in a recent meta-analysis Rao et al. (2020) indicated that obese adolescents have higher risk of developing depression. Likewise, in a large meta-analysis including 60 studies from children and adolescents across

the world, He et al. (2019) reported an inverse association between weight status and academic performance.

To our knowledge, this is the first study investigating the association between risk of depression and academic performance considering weight status, which hampers direct comparisons. Consequently, we speculate that there are two possible explanations for the specific association between risk of depression and academic performance based on weight status, which are related to behavioral factors (Milaneschi et al., 2019) and neurocognitive mechanisms (Liang et al., 2014; Reinert et al., 2013). For instance, some behavioral factors commonly adopted by overweight and obese adolescents, such as sedentary patterns, lower sleep duration, and higher consumption of caloric food may increase depressive symptoms and negatively affect academic performance (Milaneschi et al., 2019). Additionally, neuroscientific studies suggest that obesity affects the neural structures and functions of the brain related to learning processes, which may be reflected in depression symptomatology and lower academic performance (Liang et al., 2014; Reinert et al., 2013).

In the analyses of the present study, risk of depression was associated with academic grades, but not with academic abilities. These divergent results for academic performance indicators may be partially explained by several issues. Academic grades are the result of the student progression for each subject scored by different teachers through exams and tasks during an academic year, while academic abilities are assessed by a standardized test in a single time-point trial (Baker, 2006). Additionally, unlike academic abilities' test, which mainly requires good cognitive skills, the multidimensional nature of academic grades also involves emotional and social factors (i.e., effort, teacher influence, attitude) (Petrides et al., 2005). Similarly, it is likely that teachers assign better grades to healthier adolescents because of their higher school attendance and commitment to long-term educational goals (Lê-Scherban et al., 2014; Pan et al., 2013).

The early identification of depressive symptoms is of vital importance during adolescence in order to provide personalized assistance aimed to improve mental health and academic performance. Given the influence of weight status on this association, healthy lifestyle

promotion programs designed to improve weight status may help to reduce the risk of developing depression and to enhance academic performance in adolescents, with its subsequent benefits. In fact, a successful academic performance during adolescence is considered a strong predictor of physical and mental health in adult life (Gottfredson & Deary, 2004).

5. Limitations and strengths

The current study has some limitations that should be mentioned. First, the cross-sectional design of our analyses prevents us from inferring causal relationships. Second, the psychological state of the participants was not examined through the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (American Psychiatric Association, 2013); thus, participants with clinical depression may have been included in the study. Third, biological factors closely linked to overweight/obesity, such as genetic characteristics (Goodarzi, 2018), were not considered. In addition, although this study has been carried out in a relatively large age-matched sample of adolescents from Spain, this fact could also limit the generalizability of our findings. Alongside these limitations, the main strength of this study was its novelty, being the first one investigating the relationship between the risk of developing depression and academic performance in adolescents, testing if weight status categories have an impact in this association, and also examining if weight status mediates this association. Additional strengths comprise the use of validated and standardized tests to assess the main variables of this study, and the inclusion of pubertal stage and socioeconomic status as covariates, which are relevant given its relation with depression (E. Goodman et al., 2003; McGuire et al., 2019) and academic performance (Donnelly et al., 2016; Navarro et al., 2015).

6. Conclusion

Our findings revealed that the risk of developing depression was inversely associated with academic performance in adolescents. Moreover, excessive weight status may have a negative influence in this association, appearing to be a mediator in the inverse association between risk of depression and academic performance in adolescents. We consider that the understanding of the association between the early identification of mental health problems and academic performance is of great interest for families, educators, and policy makers, in order to support the promotion of psychological well-being and the prevention of academic failure among adolescents. Moreover, the identification of modifiable key factors involved in the association between mental health issues and academic performance, such as healthy lifestyles, may open new prevention and intervention strategies from a public health and educational perspective.

Study III

Risk of depression mediates the association between cardiorespiratory fitness and academic performance in adolescent boys and girls: DADOS study.

Abstract

This study aims to analyze the mediating role of risk of depression in the association between cardiorespiratory fitness and academic performance in a sample of adolescents, and to test the moderation effect of sex. A total of 263 adolescents (125 girls, 13.9±0.3 years) from the DADOS study were included in the analysis. Cardiorespiratory fitness was assessed by the 20-m shuttle run test. Academic performance was assessed through the final academic grades and the TEA test. Risk of depression was evaluated through the BASC-S3 questionnaire. Mediation analyses were performed to determine the direct and indirect associations between cardiorespiratory fitness, risk of depression, and academic performance. Indirect effects with CIs not including zero were interpreted as statistically significant, and percentages of mediation were calculated in order to know how much of the association was explained by the mediation. Our findings indicated a significant mediating effect of risk of depression in the association between cardiorespiratory fitness with final grades in math, language, and GPA (percentages of mediation: 26%, 53%, and 29%, respectively). These analyses were not moderated by sex (all CIs included 0). *Conclusion:* Risk of depression acts as a possible underlying mechanism in the association between cardiorespiratory fitness and academic grades in adolescents. Educational and health institutions could benefit from our findings, since the promotion of higher cardiorespiratory fitness levels might reduce risk of depression with potential benefits on adolescents' academic performance.

1. Introduction

Mental health disorders are defined as the combination of the presence of psychological distress and the absence of psychological well-being (Antaramian et al., 2010). The most common mental health disorder worldwide is depression (Gotlib & Joormann, 2010) and its prevalence increases substantially during adolescence, particularly in girls (Thapar et al., 2012). Previous evidence suggests that the presence of common signs and symptoms of depression during this age span is expected to produce poor long-term outcomes, such as functional impairments and mental health difficulties (Weavers et al., 2021). Hence, strategies to reduce the onset of depressive symptoms in adolescents are needed.

Previous research in adolescent population has shown that high levels of cardiorespiratory fitness, which is the ability of the circulatory and respiratory systems to supply oxygen when performing prolonged strenuous exercise (Ortega, Ruiz, Castillo, & Sjöström, 2008), may protect against the development of depressive symptoms (Alves Donato et al., 2021). It is plausible that this effect is related to improvements in serotonin levels (Wipfli et al., 2011) and mood (Peluso & Guerra de Andrade, 2005) derived from participation in regular physical activity, which is required to achieve high levels of cardiorespiratory fitness (Ortega, Ruiz, Castillo, & Sjöström, 2008). On the other hand, a growing body of evidence suggests that cardiorespiratory fitness is positively associated with brain structure and function in preadolescent population, leading to better cognitive function and academic performance (Chaddock et al., 2010; Hillman et al., 2015).

Academic performance refers to the educational goals achieved by students in a particular period of time, and is usually assessed through academic grades or standardized tests (Donnelly et al., 2016). Higher academic performance during adolescence has been associated with better health (Lê-Scherban et al., 2014), especially in adolescent girls, which showed a 13% better future self-rated health status and a 1.4% lower body mass index for each standard deviation of academic performance. Moreover, higher academic performance has been also associated with better earnings in adulthood (French et al., 2015). Thus,

understanding the factors that influence academic performance in adolescents is essential for promoting future health and wealth.

The positive association between cardiorespiratory fitness and academic performance has been well-documented in our (Adelantado-Renau et al., 2018; Beltran-Valls et al., 2018) and other samples of adolescents (Álvarez-Bueno et al., 2020). Nevertheless, little is known about the mechanisms behind this association. Some of the explanations provided for this positive association are based on physical indicators, such as body mass index (Beltran-Valls et al., 2018), and metabolic biomarkers, such as leptin or brain-derived neurotrophic factor (BDNF) (Adelantado-Renau et al., 2018; C. Phillips, 2017). In fact, higher fitness levels could be related to adolescents' healthy weight-status and optimal biomarkers concentration levels, which may be plausible explanations by which fitness may shape adolescents' academic performance. On the other hand, neurobiological, psychosocial, and behavioral mechanisms have also been suggested to explain the positive association between cardiorespiratory fitness and academic performance (Lubans et al., 2016). Indeed, Lubans et al. (2016) suggested that higher engagement in physical activity, as a proxy of fitness levels, may alter structural and functional compositions of the brain, provide improved self-perception, and also confer better coping skills, which altogether may shape adolescents' academic performance. Although multiple mechanisms might explain the association between cardiorespiratory fitness and academic performance, there is little evidence regarding common mental health disorders that usually emerge during adolescence period (Thapar et al., 2012).

To our knowledge, only one previous study has examined the mediating role of depressive symptoms in the association between physical fitness and academic performance in adolescents (Xiang et al., 2017), suggesting that the combination of healthy fitness levels and lower depressive symptoms may lead to better academic performance. However, further research is needed in order to elucidate the interrelationship between cardiorespiratory fitness, depression, and academic performance during a phase of multiple physical, psychological, and emotional changes (Sawyer et al., 2012). Therefore, the main aim of the

current study was to analyze the mediating role of risk of depression in the association between cardiorespiratory fitness and academic performance in a sample of adolescents. In addition, given the higher prevalence of risk of depression (Thapar et al., 2012) and lower levels of cardiorespiratory fitness (Tomkinson et al., 2018) among adolescent girls, we speculate that the mediation model presented above might be moderated by sex. Thus, a secondary aim was to investigate whether the mediating role of risk of depression in the association between cardiorespiratory fitness and academic performance was moderated by sex.

2. Materials and methods

2.1. Study design and participants

The present study is part of the DADOS study, which is a 3-year longitudinal research project (from 2015 to 2017) aimed to investigate the influence of physical activity on health, cognition, and psychological well-being through adolescence. Advertising leaflets about the research project were sent to secondary schools and sports clubs located in Castellon province (Spain), which included main information about the aim, the study protocol, and the inclusion criteria: to be enrolled in second grade of secondary school (13-14 years old) and without diagnosed physical or neurological chronic diseases. Volunteers who met the inclusion criteria were included in the study. The results presented in this study belong to baseline data obtained between February and May of 2015. A total of 274 adolescents completed the baseline assessments of DADOS study. From them, 4 participants were excluded due the lack of data on cardiorespiratory fitness, 1 participant was excluded because did not provide the official academic grades, 2 were excluded because did not report their pubertal stage, and 4 were excluded for not providing the information about their socioeconomic status. Thus, a total of 263 adolescents (125 girls, 47.5%) were included in the analyses.

Adolescents and their parents or guardians were informed of the nature and characteristics of the study, and all provided written informed consent. The DADOS study protocol was designed in accordance with the ethical guidelines of the Declaration of Helsinki 1964 (last revision of Fortaleza, Brazil, 2013) and approved by the Research Ethics Committee of Universitat Jaume I of Castellon (Spain).

2.2. Risk of depression

The S3 self-reported Spanish version of the BASC questionnaire (González et al., 2004) was used to assess risk of depression. BASC-S3 has been designed for adolescents aged 12-18 years old and consists of several statements that must be rated as true or false. Specifically, the scale of risk of depression is composed by 14 statements that assess adolescents' feelings of loneliness, sadness, and their incapacity to enjoy life. Risk of depression score was

calculated by transforming raw scores into standard T-scores with an average of 50 and standard deviations of 10 points. For descriptive proposes of this study, risk of depression score was dichotomized into 'non-risk' (< 60) and 'at risk' (≥ 60) according to the cut-off point established by Reynolds and Kamphaus (Reynolds & Kamphaus, 2004). The Spanish version of this questionnaire shows good internal consistency (Cronbach's α = 0.81) (González et al., 2004). In addition, optimal reliability results have also been obtained for the sample of the current study, showing high internal consistency (Cronbach's α = 0.78).

2.3. Academic performance

Academic performance was assessed through two components: academic grades and academic abilities. First, we took the final academic grades from first grade of secondary school, provided by each school's secretary office. They were based on a ten-point scale (0 indicates the lowest achievement and 10 indicates the highest achievement). Individual grades for math, language, and GPA were included in the analyses. GPA score was defined as the average of the scores achieved by students in social sciences, natural sciences, math, language, and physical education. Second, we used the Spanish version of the TEA test in order to measure academic abilities (Thurstone & Thurstone, 2004). This test provides general measures of three areas of intelligence and skills of learning, which are obtained by adding the correct answers in each academic ability. Verbal ability evaluates the command of language (range: 0 - 50), numeric ability evaluates the speed and precision in performing operations with numbers and quantitative concepts (range: 0 - 30), and reasoning ability evaluates the skill to find logical order in sets of numbers, figures, or letters (range: 0 - 30). Based on the age range of our sample, level three of TEA test was used (internal consistency: verbal α = 0.74, numeric α = 0.87, and reasoning α = 0.77) (Thurstone & Thurstone, 2004).

2.4. Cardiorespiratory fitness

Cardiorespiratory fitness was assessed using the 20-m shuttle run test as described by Léger et al. (1988). Participants ran straight between 2 lines 20-m apart at a pace established by recorded audio signals. The initial speed was 8.5 km/h and it was increased 0.5 km/h each minute. The test was completed when participants could not reach the end lines at the pace

of the audio signals for 2 consecutive times or when they stopped because of fatigue. The last stage number completed was used to estimate the maximal oxygen uptake (VO$_{2max}$, ml/kg/min) using the following equation reported by Léger (1988): VO$_{2max}$ = 31.025 + (3.238 × (8 + 0.5 × last stage number completed)) − (3.248 × age) + (0.1536 × (8 + 0.5 × last stage number completed) × age).

2.5. Covariates

Pubertal stage was self-reported using standardized pictures according to the five stages described by Tanner and Whitehouse (Tanner & Whitehouse, 1976), based on external primary and secondary sex characteristics. The degree of development was assessed through two components: pubic hair growth for girls and boys, in addition to breast development in girls and genital development in boys. A 5-point maturity rating (from 1 to 5) was used for each component, in which stage 1 corresponded to the prepubertal state and stage 5 to the mature state. The highest rating of the two components was used for data analyses.

Socioeconomic status was reported by the FAS scale, developed by Currie et al. (2008). It was used as a proxy of socioeconomic status (ranging from 0 to 8), which is based on material conditions in the family such as car ownership, bedroom occupancy, computer ownership, and home internet access. For descriptive proposes, this variable was categorized into low (from 0 to 2), medium (from 3 to 5), and high (from 6 to 8) socioeconomic status.

2.6. Statistical analysis

Study sample characteristics are presented as mean ± standard deviation or frequencies and percentages for continuous and categorical variables, respectively. Differences between boys and girls were assessed using t-test for continuous variables and chi-square for categorical variables. Linear regression analyses were performed to confirm the relationships between cardiorespiratory fitness, risk of depression, and academic performance indicators; controlling for sex, pubertal stage, and socioeconomic status.

The mediation and moderated mediation models were analyzed using the PROCESS SPSS Macro version 2.16.3, with 5.000 bias-corrected bootstrap samples and 95% CIs (Hayes, 2013). Firstly, boot-strapped mediation procedures were performed to examine whether the

association between cardiorespiratory fitness (independent variable) and academic performance (variables individually entered as the dependent variable) was mediated by risk of depression score (mediator variable) using Model 4 (see **Figure 5**). Indirect effects (paths *a*b*) with CIs not including zero were interpreted as statistically significant, which can be so regardless of the significance of the total effect (the effect of cardiorespiratory fitness on academic performance: path *c*) and the direct effect (the effect on academic performance when both cardiorespiratory fitness and risk of depression score were included as predictors: path *c'*) (Hayes, 2013). P_M was calculated as [(indirect effect/total effect) × 100], in order to know how much of the total effect was explained by the mediation when the following assumptions where achieved: the total effect is larger than the indirect effect and with the same direction of the effect (Hayes, 2013). These analyses were adjusted by sex, pubertal stage, and socioeconomic status. Next, Model 59 was used to test the moderated mediation effect, that was whether sex moderated the direct and indirect effects of cardiorespiratory fitness on academic performance (see **Figure 6**). Likewise, if the 95% CI of the interaction did not contain 0, the moderated mediation effect could be interpreted as statistically significant. These analyses were adjusted by pubertal stage and socioeconomic status. All the analyses were performed using the IBM SPSS Statistics for Windows version 22.0 (Armonk, NY: IBM Corp), and the level of significance was set at $p < 0.05$.

3. Results

The descriptive characteristics of the study sample are shown in **Table 9**. Overall, girls showed significantly lower cardiorespiratory fitness levels (54.0 vs. 46.3, p < 0.001), higher socioeconomic status (4.0 vs. 4.4, p = 0.031), higher risk of depression score (44.9 vs. 47.5, p = 0.011), and lower numeric ability than boys (14.7 vs. 12.0, p < 0.001). In addition, the prevalence of participants at risk of depression was significantly higher in girls (2% vs. 8%, p = 0.029).

Table 9
Descriptive characteristics of the study sample by sex.

	All	Boys	Girls	p
	N = 263	N = 138	N = 125	
Physical characteristics				
Age (years)	13.9 ± 0.3	13.9 ± 0.3	13.9 ± 0.3	0.913
Pubertal stage (II - V) (%)	8/33/49/10	10/32/44/14	6/35/54/5	-
CRF (ml/kg/min)	50.3 ± 6.7	54.0 ± 5.3	46.3 ± 5.8	**< 0.001**
Socioeconomic status (0 - 8)	4.2 ± 1.4	4.0 ± 1.3	4.4 ± 1.4	-
Socioeconomic status (L/M/H) (%)	11/76/15	14/77/9	9/74/17	-
Risk of depression				
Risk of depression score (0 - 100)	46.2 ± 8.3	44.9 ± 6.0	47.5 ± 10.2	**0.011**
At risk of depression (%)	13 (4.9)	3 (2.2)	10 (8.0)	**0.029**
Academic performance				
Academic grades (0 - 10)				
Math	6.9 ± 1.6	7.0 ± 1.6	6.8 ± 1.6	0.281
Language	6.8 ± 1.5	6.6 ± 1.5	6.9 ± 1.5	0.147
Grade point average	7.1 ± 1.3	7.1 ± 1.3	7.2 ± 1.3	0.346
Academic abilities				
Verbal (0 - 50)	18.7 ± 5.3	19.1 ± 5.8	18.2 ± 4.6	0.171
Numeric (0 - 30)	13.4 ± 4.7	14.7 ± 4.5	12.0 ± 4.5	**< 0.001**
Reasoning (0 - 30)	16.5 ± 5.9	16.1 ± 5.7	17.0 ± 6.1	0.214

Note. Values are mean ± standard deviation or frequency (%). Differences between sex were examined by t-test or chi-square test. Values in bold indicate significant results. CRF = cardiorespiratory fitness; L = low socioeconomic status; M = medium socioeconomic status; H = high socioeconomic status.

Linear regressions between cardiorespiratory fitness, risk of depression score, and academic performance indicators, controlling for sex, pubertal stage, and socioeconomic status are shown in **Table 10**. Overall, cardiorespiratory fitness was positively associated with math ($\beta = 0.173$, p = 0.021), GPA ($\beta = 0.169$, p = 0.024), and numeric ability ($\beta = 0.167$, p = 0.021), whereas risk of depression score was negatively associated with cardiorespiratory fitness ($\beta = -0.230$, p = 0.002) and all academic grades indicators (β ranging from -0.262 to -0.216, all p < 0.001).
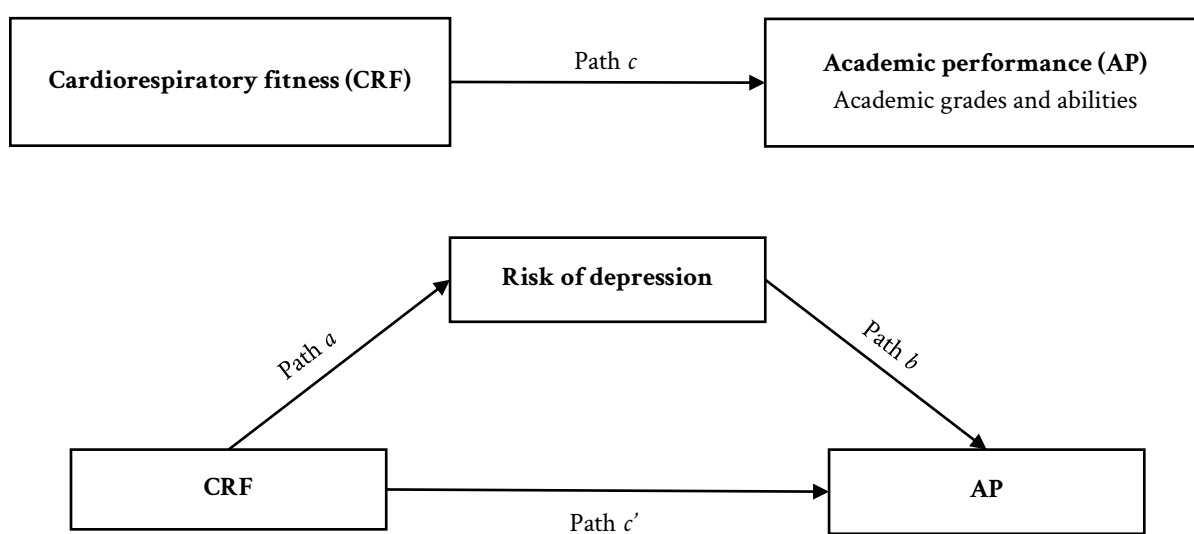
Table 10

Linear regression analyses between cardiorespiratory fitness, risk of depression score, and academic performance indicators in adolescents.

Academic performance	CRF		Risk of depression score	
	β	p	β	p
CRF	-	-	-0.230	**0.002**
Academic grades				
Math	0.173	**0.021**	-0.216	**<0.001**
Language	0.111	0.141	-0.262	**<0.001**
Grade point average	0.169	**0.024**	-0.231	**<0.001**
Academic abilities				
Verbal	0.117	0.120	-0.053	0.393
Numeric	0.167	**0.021**	-0.086	0.153
Reasoning	0.029	0.701	-0.036	0.563

Note. Analyses were adjusted by sex, pubertal stage, and socioeconomic status. Values in bold indicate statistically significant results. β = standardized regression coefficient; CRF = cardiorespiratory fitness.

Simple mediation analyses results are presented in **Table 11**, which show that cardiorespiratory fitness indirectly influenced some academic performance indicators through risk of depression score, controlling for sex, pubertal stage, and socioeconomic status. Specifically, cardiorespiratory fitness was negatively associated with risk of depression score (path *a*), and risk of depression score was negatively associated with academic grades (path *b*). Moreover, a significant total relationship was observed for cardiorespiratory with math, GPA, and numeric ability (path *c*). The direct association between cardiorespiratory fitness and academic performance, when risk of depression score was included in the model as a covariate (path *c'*), was significant for numeric ability.

Regarding the indirect association (path *a*b*), the results showed that risk of depression mediates the association of cardiorespiratory fitness with all final academic grades, but not with academic abilities. Specifically, our results suggest that high cardiorespiratory fitness levels may reduce risk of depression, which, in turn, may contribute to better academic grades in math, language, and GPA (with a P_M ranging from 26% to 53%).

Figure 5. Schematic moderation model of risk of depression as the mediator between cardiorespiratory fitness (independent variable) and academic performance indicators (dependent variable) (Model 4).
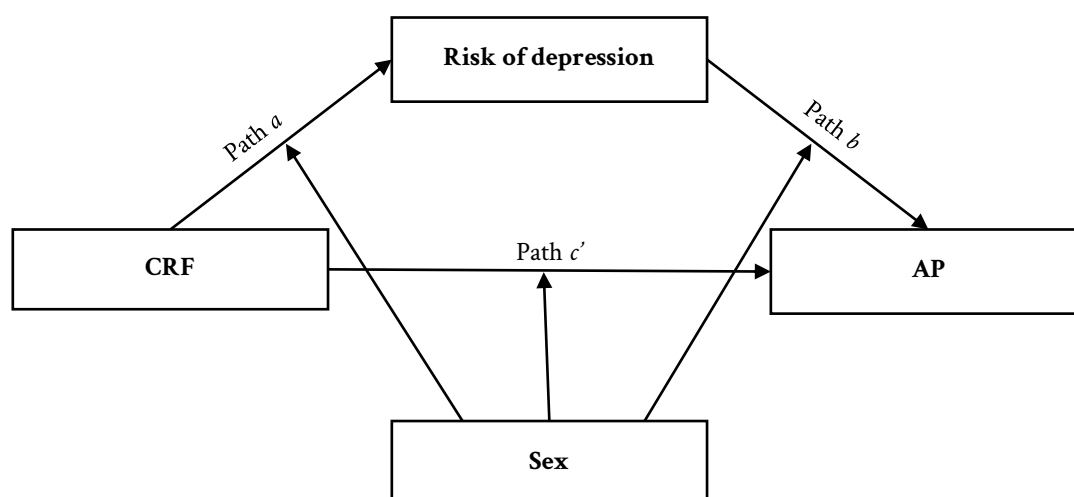
Table 11

Total, direct, and indirect effects, a and b pathways, of the mediation analyses investigating risk of depression as a mediator between cardiorespiratory fitness and academic performance indicators in adolescents (Model 4).

	Total effect (path c)			Direct effect (path c')			Path a			Path b			Indirect effect (path $a*b$)				$P_{M\,(\%)}$
	B	SE	p	B	SE	p	B	SE	p	B	SE	p	B	SE	LLCI	ULCI	
Academic grades																	
Math	0.041 (0.018)		**0.021**	0.030 (0.018)		0.088	-0.285 (0.091)		**0.002**	-0.037 (0.012)		**0.002**	**0.011 (0.004)**		0.004	0.020	26
Language	0.025 (0.017)		0.141	0.012 (0.017)		0.478	-0.285 (0.091)		**0.002**	-0.047 (0.011)		**0.000**	**0.013 (0.005)**		0.004	0.024	53
Grade point average	0.032 (0.014)		**0.024**	0.023 (0.014)		0.108	-0.285 (0.091)		**0.002**	-0.033 (0.010)		**0.001**	**0.009 (0.004)**		0.003	0.017	29
Academic abilities																	
Verbal	0.092 (0.059)		0.120	0.085 (0.060)		0.157	-0.285 (0.091)		**0.002**	-0.023 (0.040)		0.568	0.007 (0.010)		- 0.013	0.027	-
Numeric	0.117 (0.050)		**0.021**	0.107 (0.051)		**0.038**	-0.285 (0.091)		0.002	-0.035 (0.034)		0.310	0.010 (0.008)		- 0.005	0.027	-
Reasoning	0.025 (0.066)		0.701	0.019 (0.067)		0.781	-0.285 (0.091)		**0.002**	-0.023 (0.045)		0.608	0.007 (0.014)		- 0.026	0.031	-

Note. Results showed as unstandardized coefficients (standard error and bias corrected 95% confidence interval based on 5000 bootstraps). All analyses were adjusted for sex, pubertal stage, and socioeconomic status. Values in bold indicate significant results. Particularly, the indirect effect (path $a*b$) indicates significant results when 0 is not in the 95% confidence interval. B = unstandardized coefficient; SE = standard error; LLCI = lower level of confidence interval; ULCI = upper level of confidence interval; P_M = percentage of mediation.

Table 12 presents the results of the individual paths from the moderated mediation analyses. These results showed that sex only played a moderating role in the association between risk of depression and reasoning ability when adjusting for cardiorespiratory fitness (path *b*: B = -0.201, p = 0.045, 95% CI: -0.397, -0.005), showing a trend in boys but not in girls (boys: B = -0.163, p = 0.053 vs. girls: B = 0.038, p = 0.480; data not shown). However, sex did not moderate any other association (path *a*: cardiorespiratory fitness – risk of depression; path *b*: risk of depression – math, language, GPA, verbal ability, and numeric ability with cardiorespiratory fitness included as covariate) neither the direct association between cardiorespiratory fitness and academic performance when risk of depression score was included as a covariate (path *c'*) (all 95% CIs included 0).

Figure 6. Schematic model of sex as a moderator of the mediation model (Model 59).

Table 12

Moderated mediation analysis (Model 59).

Variable	B	SE	*t*	p	LLCI	ULCI
Outcome: risk of depression						
CRF	-0.448	0.127	-3.520	**0.001**	**-0.699**	**-0.197**
Sex	-17.329	9.345	-1.854	0.065	-35.732	1.074
CRF*Sex	0.338	0.184	1.831	0.068	-0.025	0.701
Outcome: math						
CRF	0.021	0.025	0.822	0.412	-0.029	0.070
Risk of depression	-0.036	0.014	-2.581	**0.010**	**-0.064**	**-0.009**
Sex	-0.760	2.303	-0.330	0.742	-5.294	3.775
CRF*Sex	0.019	0.036	0.542	0.588	-0.051	0.090
Risk of depression*Sex	-0.006	0.026	-0.222	0.824	-0.058	0.046
Outcome: language						
CRF	0.007	0.024	0.297	0.767	-0.040	0.055
Risk of depression	-0.036	0.014	-2.629	**0.009**	**-0.062**	**-0.009**
Sex	-0.799	2.212	-0.361	0.718	-3.557	5.156
CRF*Sex	0.012	0.034	0.346	0.729	-0.056	0.079
Risk of depression*Sex	-0.041	0.025	-1.618	0.107	-0.091	0.009
Outcome: GPA						
CRF	0.024	0.020	1.191	0.235	-0.016	0.064
Risk of depression	-0.028	0.011	-2.419	**0.016**	**-0.050**	**-0.005**
Sex	0.512	1.865	0.275	0.784	-3.161	4.185
CRF*Sex	-0.002	0.029	-0.054	0.957	-0.059	0.055
Risk of depression*Sex	-0.018	0.021	-0.826	0.410	-0.060	0.024
Outcome: verbal ability						
CRF	0.123	0.085	1.439	0.152	-0.045	0.291
Risk of depression	-0.026	0.048	-0.529	0.597	-0.120	0.069
Sex	3.188	7.864	0.405	0.686	-12.298	18.674
CRF*Sex	-0.078	0.122	-0.636	0.525	-0.318	0.163
Risk of depression*Sex	0.020	0.090	0.217	0.828	-0.157	0.196
Outcome: numeric ability						
CRF	0.142	0.073	1.945	0.053	-0.002	0.286
Risk of depression	-0.015	0.041	-0.352	0.726	-0.096	0.067
Sex	8.190	6.717	1.219	0.224	-5.037	21.417
CRF*Sex	-0.068	0.104	-0.648	0.517	-0.273	0.138
Risk of depression*Sex	-0.064	0.077	-0.828	0.408	-0.215	0.088
Outcome: reasoning ability						
CRF	0.078	0.095	0.825	0.410	-0.109	0.265
Risk of depression	0.038	0.054	0.707	0.480	-0.068	0.143
Sex	13.651	8.732	1.563	0.119	-3.546	30.848
CRF*Sex	-0.110	0.135	-0.814	0.416	-0.377	0.156
Risk of depression*Sex	-0.201	0.100	-2.017	**0.045**	**-0.397**	**-0.005**

Note. All analyses were adjusted for pubertal stage and socioeconomic status. Statistically significant effects indicating that 0 is not in the 95% confidence interval of the indirect effect are presented in bold. B = unstandardized coefficient; SE = standard error; LLCI = lower level of confidence interval; ULCI = upper level of confidence interval; CRF = cardiorespiratory fitness; GPA = grade point average. *p < 0.05; ***p < 0.001

The moderated mediation model was further tested by analyzing the association between cardiorespiratory fitness on academic performance through risk of depression at the different conditions of the moderator (i.e., girls and boys). As shown in **Table 13**, risk of depression significantly mediated the association between cardiorespiratory fitness and academic performance in girls when the dependent variables were math (B = 0.016, 95% CI: 0.004, 0.034), language (B = 0.016, 95% CI: 0.001, 0.035), and GPA (B = 0.012, 95% CI: 0.002, 0.027). Nevertheless, the results indicated that sex did not significantly moderate this mediation model (all 95% CIs included 0).

Table 13

Conditional indirect effects of cardiorespiratory fitness on academic performance at the conditions of the moderator (Model 59).

	B	SE	LLCI	ULCI	Index [LLCI; ULCI]
Outcome: math					
Girls	0.016	0.008	**0.004**	**0.034**	-0.012 [-0.030; 0.005]
Boys	0.005	0.005	-0.002	0.016	
Outcome: language					
Girls	0.016	0.009	**0.001**	**0.035**	-0.008 [-0.030; 0.012]
Boys	0.085	0.006	-0.004	0.022	
Outcome: GPA					
Girls	0.012	0.007	**0.002**	**0.027**	-0.012 [-0.024; 0.008]
Boys	0.005	0.005	-0.002	0.016	
Outcome: verbal ability					
Girls	0.011	0.016	-0.024	0.043	-0.011 [-0.047; 0.035]
Boys	0.001	0.012	-0.020	0.031	
Outcome: numeric ability					
Girls	0.007	0.151	-0.023	0.040	0.002 [-0.034; 0.034]
Boys	0.009	0.008	-0.007	0.026	
Outcome variable: reasoning ability					
Girls	-0.017	0.032	-0.092	0.034	0.035 [-0.023; 0.118]
Boys	0.018	0.016	-0.008	0.055	

Note. All analyses were adjusted for pubertal stage and socioeconomic status. Statistically significant effects indicating that 0 is not in the 95% confidence interval of the indirect effect are presented in bold. B = unstandardized coefficient; SE = standard error; LLCI = lower level of confidence interval; ULCI = upper level of confidence interval; GPA = grade point average.

4. Discussion

The main findings of the present study indicated that risk of depression mediated the positive association between cardiorespiratory fitness and academic performance in adolescents. Moreover, our results revealed that sex did not act as a moderator on this mediation model. These results contribute to the current scientific knowledge by suggesting the key role of risk of depression in the association between cardiorespiratory fitness and academic performance, independently of sex.

Since mediation analysis assumes that the independent variable has an effect on the mediator, influencing the dependent variable, our results suggest that high cardiorespiratory fitness levels may reduce risk of depression, which, in turn, may contribute to better academic performance. These findings are consistent with the only previous study in which depression showed to be an important factor driving the association of cardiorespiratory fitness and academic performance in a sample of 144 adolescents, including health-related and skill-related physical fitness (Xiang et al., 2017). Additionally, our results agree with previous studies showing inverse associations between cardiorespiratory fitness and depressive symptoms (Ruggero et al., 2015), as well as between the early identification of depression and academic performance among adolescents (Riglin et al., 2014).

The positive association between cardiorespiratory fitness and academic performance explained by the risk of depression may be related to both psychological and physiological mechanisms. On the one hand, prior research in the adolescent population has shown that higher cardiorespiratory fitness is positively associated with better mood, self-esteem, and social support among equals, which may provide a sense of psychological well-being (Babiss & Gangwisch, 2009; Di Liegro et al., 2019; Portugal et al., 2013), diminishing depressive symptomatology. In fact, adolescents without depressive symptoms have higher interest in school activities and an increased ability to think or concentrate than their depressed peers (American Psychiatric Association, 2013). Thus, we speculate that these changes on depressive symptoms could shape adolescents' academic performance (Riglin et al., 2014). On the other hand, cardiorespiratory fitness may optimize leptin concentration and central

levels of BDNF, which are metabolic biomarkers involved in emotional and neurocognitive processes (Farr et al., 2015; C. Phillips, 2017). Reduced leptin concentration and increased BDNF levels in physically fit adolescents are related to lower levels of depression and have also been positively associated with memory function (Di Liegro et al., 2019; Erickson et al., 2012; Farr et al., 2015), which may be related to lower depressive symptoms and cognition, positively influencing academic performance. Taken together, the previous evidence supports our data suggesting that higher levels of cardiorespiratory fitness may have beneficial effects reducing the risk of developing depression, leading to higher academic performance in adolescent population.

The moderated mediation analyses revealed that sex did not moderate the association between cardiorespiratory fitness and academic performance mediated by risk of depression. To our knowledge, this is the first study investigating this moderated mediation model, which hampers direct comparisons. Yet, our results partially concur with previous studies showing that the positive association between cardiorespiratory fitness and academic performance (Castelli et al., 2007), the negative association between cardiorespiratory fitness and depression (Alves Donato et al., 2021), as well as the negative association between depression and AP (Riglin et al., 2014) were not dependent on sex. However, despite these results support our findings, some previous evidence has suggested significant results only for adolescent boys or girls. Indeed, Castelli et al. (2007) suggested that the positive association between cardiorespiratory fitness and academic performance was significant only in adolescent girls, while Álvarez-Bueno et al. (2020) showed a stronger significant association in boys than in girls. In addition, Ruggero et al. (2015) suggested that higher cardiorespiratory fitness levels were associated with fewer depressive symptoms among adolescent girls, while Åvitsland et al. (2021) found a significant association among boys and only in girls with high socioeconomic status. Likewise, Needham et al. (2004) found a significant association between depressive symptoms and academic performance in adolescent girls, while Obradović et al. (2010) found this significant association only among adolescent boys. Despite the existing divergent results regarding the interaction of sex on

the investigated associations, our findings provide a new insight for considering the adolescence population altogether when designing programs aimed to improve physical and mental health, as well as academic performance.

Mediation and moderated mediation analyses only showed significant results when considering academic grades as the dependent variable, but not when considering academic abilities. These divergent results for academic performance variables may be explained by the fact that academic grades and abilities rely on different forms of assessment. Academic grades are the result of the student progression during an academic year, while academic abilities are assessed by a standardized test in a single time-point trial (Baker, 2006). Additionally, unlike academic abilities' test, which mainly requires good cognitive skills, the multidimensional nature of academic grades could also involve the teachers perceptions of secondary school students' prosocial behavior (Gerbino et al., 2018).

5. Limitations and strengths

The results of the current study should be interpreted with caution. First, the cross-sectional design of our analyses prevents us from interfering causal relationships. Second, biomarkers closely linked to VO_{2max} trainability and depression, such as genetics (Kwong et al., 2019; Williams et al., 2017), were not considered. Third, risk of depression, pubertal stage, and socioeconomic status were self-reported and may limit the participants to certain answer choices. Lastly, the use of a standardized test of academic abilities and the official academic grades, although socially valid measures of academic performance, can be subject to biases. Nonetheless, our mediation analysis strategy allowed us to provide novel data supporting the importance of risk of depression in the cardiorespiratory fitness and academic performance association. Moreover, the moderated mediation analysis used is a robust statistical measure for exploring the moderation effect of sex. Additional strengths comprise the use of objective and standardized measures of cardiorespiratory fitness, academic performance indicators, as well as a relatively large and age-matched sample of adolescents. Alongside these considerations, as suggested by prior research (Donnelly et al., 2016; E. Goodman et al., 2003; Wolfe et al., 2020), our statistical analyses were controlled for pubertal stage and socioeconomic status, which are relevant given their associations with cardiorespiratory fitness, depression, and academic performance.

6. Conclusion

The current study showed that risk of depression plays a mediating role in the positive association between cardiorespiratory fitness and final academic grades in math, language, and GPA in adolescents, independently of sex. Thus, our data suggest that enhancing cardiorespiratory fitness during adolescence through healthy lifestyle promotion may contribute to better academic performance, partially via reductions in the risk of developing depression. Our findings may have significant implications for public health and education professionals, suggesting that programs addressing both physical and mental health issues may benefit adolescents' academic performance. Further larger longitudinal and interventional studies are warranted to elucidate the pathways by which cardiorespiratory fitness levels may diminish the risk of depression, shaping the academic performance in the adolescent population.

Study IV

Bidirectional longitudinal associations of mental health with

academic performance in adolescents: DADOS study.

Abstract

This study analyzed the bidirectional longitudinal association between the dual-factor model of mental health and academic performance in adolescents, comprising a longitudinal assessment 2-years apart. A total of 266 secondary school students (13.9±0.3 years at baseline) from DADOS study were assessed. Mental health was assessed through the BASC-S3 questionnaire. Academic performance was assessed through the TEA test. Higher academic abilities at baseline were associated with better mental health over time. Additionally, higher academic grades were associated with better sense of inability over time. Results suggest that enhancing academic performance might positively shape adolescents' mental health at 2-years follow-up but not *vice versa*, since this association was not bidirectional. ***Conclusion:*** Our findings might guide future policies as well as health and educational professionals to effectively promote mental health in adolescent students with lower academic performance.

Keywords: Mental health; well-being; distress; academic performance; secondary school.

1. Introduction

Secondary school concurs with adolescence, a period of life in which many biological, psychological, and social changes occur (Patton & Viner, 2007). During this timeframe, students' educational goals tend to decline, leading to a worse academic performance (Barber & Olsen, 2004). Previous studies suggest that adolescents' academic performance is an important predictor of health, wealth, employability, and social triumph later in life (French et al., 2015; Lê-Scherban et al., 2014). Therefore, research on this field is gaining momentum, trying to elucidate the factors that are associated with academic performance during this critical period of life.

Scientific literature has recently identified several factors that may influence adolescents' academic performance. For instance, previous evidence has shown that childhood experience of violence (Fry et al., 2018), bullying victimization (Samara et al., 2021), school engagement (Lei et al., 2018), and burnout during adolescence (Madigan & Curran, 2021) negatively associate with academic performance. Interestingly, health-related behaviors have also been proposed as factors that shape adolescents' academic performance, such as physical activity (Poitras et al., 2016), sleep patterns (Chaput et al., 2016), and recreational screen time (Adelantado-Renau et al., 2019). Recently, research has also suggested that better mental health could be positively associated with better academic performance (Agnafors et al., 2021). However, there is scarce evidence on this field and more knowledge is needed in order to target and promote better academic performance through mental health improvements.

Mental health is argued to be one of the most serious global health challenges and affects a significant number of adolescents worldwide (Benton et al., 2021). This might be alarming, since half of the mental health disorders first appear around the age of 14 (Kessler et al., 2005), causing significant impairments in different domains of life during adulthood, such as work, social relationships, and physical health (Costello & Maughan, 2015). The school context has been proposed as an essential environment for promoting mental health (Husky et al., 2011), but there is a need to elucidate which are the most effective school-based

prevention programs (Werner-Seidler et al., 2021). For doing so, the factors that may shape mental health status in the educational context have been examined by scientists from around the world. Interestingly, some studies have considered academic performance as a possible predictor of future mental health status in the adolescent population (Almroth et al., 2018; Bortes et al., 2021; Steinmayr et al., 2016). Nonetheless, there is still not clear consensus on how this relationship works. Some authors suggest that academic performance is positively associated with better mental health status (Almroth et al., 2018; Steinmayr et al., 2016), while others identify a negative association between academic performance and psychological well-being (Bortes et al., 2021). Therefore, more research is needed in order to examine how academic performance could help to prevent mental health status throughout adolescence.

Overall, according to the prior research developed in secondary school students, the association between mental health and academic performance could be considered bidirectional during this educational period. Nevertheless, mental health and academic performance are broad concepts that need to be studied as a whole. Indeed, according to the conceptualization proposed by Antaramian et al. (2010), mental health is understood as a dual-factor concept that comprises the presence of psychological well-being along with the absence of psychological distress. Similarly, academic performance refers to the educational goals achieved by the students in a particular period of time and can be assessed though academic grades and academic ability tests (Donnelly et al., 2016). Thus, research on this field should include a wide range of indicators for elucidating the overall picture of mental health and academic performance during adolescence.

As far as we know, prior research developed among secondary school students focuses on psychological well-being or distress and their association with academic performance indicators (Amholt et al., 2020; Riglin et al., 2014). Indeed, only one recent cross-sectional study has explored the dual-factor model of mental health and its association with academic performance in the adolescent population (King et al., 2021). Specifically, King et al. (2021) suggested that mentally healthy Canadian adolescents, referring to those with presence of

psychological well-being and absence of psychological distress, obtained higher academic grades. In this context, longitudinal studies, including psychological well-being and psychological distress indicators, are needed in order to examine the reciprocal association between mental health and academic performance over time.

Prior longitudinal studies have explored the association between some isolated mental health indicators, such as depression, anxiety, or psychological well-being, and academic performance in one direction or the other. For instance, adolescents with the absence of common mental health disorders, such as depression and anxiety (Riglin et al., 2014; Rothon et al., 2009), and better psychological well-being (Amholt et al., 2020), are more likely to obtain better academic performance during adolescence period. Additionally, adolescents who had better academic aspirations were more likely to have better psychological well-being later in life (Almroth et al., 2018). Interestingly, limited studies explored the bidirectional longitudinal association between mental health and academic performance in adolescents, showing contradictory findings and exploring psychological well-being (Bortes et al., 2021; Z. J. Ng et al., 2015; Steinmayr et al., 2016; Wu et al., 2020) or distress indicators (Van Der Ende et al., 2016; W. Zhang et al., 2019) in isolation, which limited their conclusions.

All in all, an integrative longitudinal and bidirectional model, including psychological well-being and psychological distress indicators, is needed to understand the relationship between mental health and academic performance during adolescence. Indeed, this knowledge would contribute into the educational context, providing a wide range of evidence for designing prevention and intervention programs aimed to improve secondary school students' mental health and academic performance. Therefore, the aim of this study was to analyze the bidirectional longitudinal association between the dual-factor model of mental health and academic performance in a sample of secondary school students. As there is previous evidence for this association in both directions, we initially hypothesized that the bidirectional association may exist in this population.

2. Materials and methods

2.1. Study design and participants

The present study population is part of the DADOS study, which is a longitudinal research project aimed to investigate the role of physical activity in health, cognition, and psychological well-being through adolescence. Advertising leaflets about the research project were sent to secondary schools and sports clubs located in Castellon province (Spain), which included main information about the aim, the study protocol, and the inclusion criteria: to be enrolled in second grade of secondary school (13-14 years old) and without diagnosed physical or neurological chronic diseases. Volunteers who met the inclusion criteria were included in the study. Baseline data was obtained from a total sample of 266 secondary school students, between February and May of 2015, and a follow-up assessment was performed with 184 students 2-years later, between February and May of 2017. Before participating in the study, written informed consent was obtained from all the students and their parents or guardians.

The DADOS study protocol was designed in accordance with the ethical guidelines of the Declaration of Helsinki 1964 (last revision of Fortaleza, Brazil, 2013) and approved by the Research Ethics Committee of the Universitat Jaume I of Castellon (Spain).

2.2. Mental health

The self-reported Spanish version of the BASC questionnaire, for adolescents aged 12-18 years old, was used to assess participants' mental health status (González et al., 2004). The clinical scale of the emotional symptoms index was used as a global measure of the dual-factor model of mental health. It consists of two adaptative scales of psychological well-being (self-esteem and interpersonal relationships) and four clinical scales of psychological distress (anxiety, social stress, risk of depression, and sense of inability), composed by a total of 78 items. The emotional symptoms index, as well as its scales were calculated by converting raw scores into standard T-scores, based on the age of the participants. According to Reynolds and Kamphaus (2004), these T-scores corresponded to a mean of 50 with standard deviation of 10. Thus, a score ≥60 in the clinical scales and a score ≤40 in the adaptative scales

indicated 'at risk' of emotional disturbance that affects adolescents' feelings and thoughts. The Spanish version of this questionnaire shows good internal consistency (Cronbach's α = 0.81) (González et al., 2004).

2.3. Academic performance

Academic performance is commonly assessed through academic grades and standardized academic ability tests (Donnelly et al., 2016). Thus, we assessed academic performance through both, students' final academic grades and academic abilities. On the one hand, academic grades from the first and third grade of secondary school were included in this study. These grades were provided by each school's secretary office and were based on a ten-point scale in which 0 indicates the lowest achievement and 10 indicates the highest achievement. GPA score was defined as the average of the scores achieved by students in all subjects: math, language, foreign language, social sciences, natural sciences, and physical education. On the other hand, the Spanish version of the TEA test was used to measure academic abilities (Thurstone & Thurstone, 2004). This standardized test provides general measures of three areas of intelligence and skills of learning: verbal (command of language), numeric (speed and precision in performing operations with numbers and quantitative concepts), and reasoning (the skill to find logical order in sets of numbers, figures, or letters). Scores for the three areas were obtained by adding positive answers. Overall score was calculated by adding the three areas scores (verbal + numeric + reasoning). Based on the age range of our sample, level three of the TEA test was used (internal consistency: verbal α = 0.74, numeric α = 0.87, reasoning α = 0.77, and overall score α = 0.89) (Thurstone & Thurstone, 2004).

2.4. Covariates

Since adolescence period is a timeframe characterized by developmental changes at a different pace, sex and pubertal stage were included as covariates (Ortega, Ruiz, Castillo, Moreno, et al., 2008). In addition, socioeconomic status and weight status were also included as relevant covariates given their association with both, mental health (Currie et al., 2008; Reiss, 2013) and academic performance (Donnelly et al., 2016; Santana et al., 2017).

Pubertal stage was self-reported using standardized pictures according to the five stages described by Tanner and Whitehouse (1976), based on external primary and secondary sex characteristics. The degree of development was assessed through two components: pubic hair growth for boys and girls, plus genital development in boys, and breast development in girls. A 5-point maturity rating (from 1 to 5) was used for each component, in which stage 1 corresponded to the prepubertal state and stage 5 to the mature state. The highest rating of the two components was used for the data analyses.

Socioeconomic status was reported by the FAS scale, developed by Currie et al. (2008). It was used as a proxy of socioeconomic status (ranging from 0 to 8), which is based on material conditions in the family such as car ownership, bedroom occupancy, computer ownership, and home internet access.

Weight status was measured through body mass index, calculated as weight/height square (kg/m^2). Body weight was measured to the nearest 0.1 kg using an electronic scale (SECA 861 - Hamburg, Germany). Body height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (SECA 213 - Hamburg, Germany). Weight and height were measured in duplicate, following the standardized procedures, and average measures were used for the data analyses.

2.5. Statistical analysis

Descriptive characteristics of the study sample were presented as means and standard deviations or as percentages. The bidirectional association between mental health and academic performance indicators was examined using a cross-lagged modeling approach, through the Lavaan package in R (Rosseel, 2012). A depiction of the general cross-lagged panel model is presented in **Figure** 7.
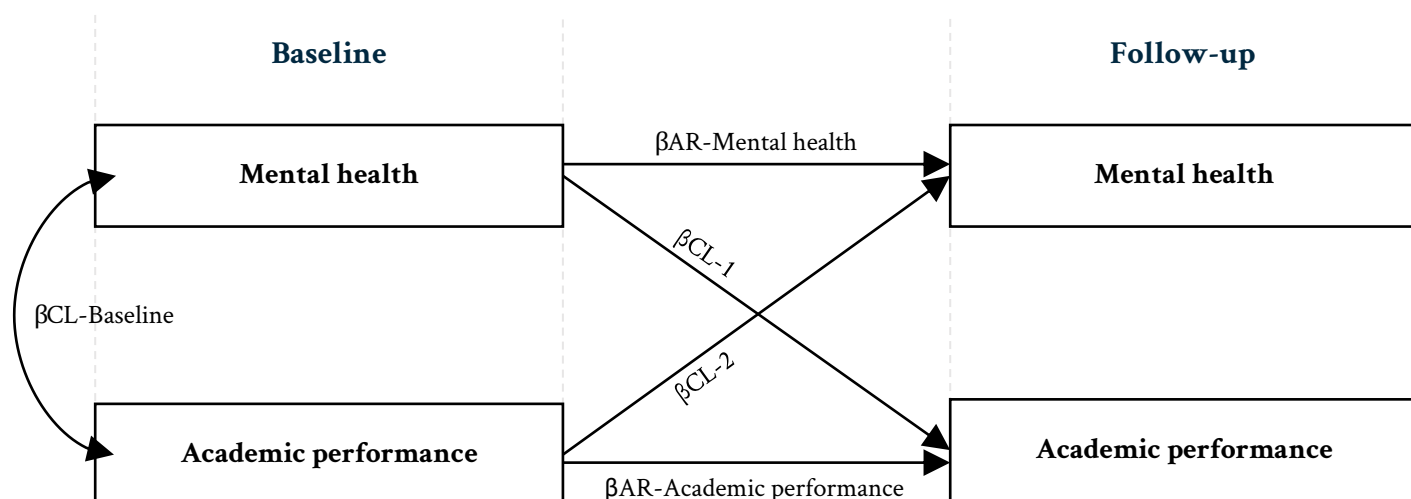
Figure 7. Visualization of the cross-lagged panel modelling approach. Time difference between baseline and follow-up was 2 years. $\beta_{CL\text{-}Baseline}$ = the cross-lagged path between mental health and academic performance at baseline, $\beta_{AR\text{-}Mental\ health}$ = the autoregressive coefficient for mental health, $\beta_{CL\text{-}1}$ = the cross-lagged path 1, $\beta_{CL\text{-}2}$ = the cross-lagged path 2, $\beta_{AR\text{-}Academic\ performance}$ = the autoregressive coefficient for academic performance.

In these path analyses, all associations were adjusted for each other: i.e., analyses were adjusted for the underlying associations of the cross-sectional paths ($\beta_{CL\text{-}Baseline}$), mental health over time (autoregressive path, $\beta_{AR\text{-}Mental\ health}$), academic performance over time (autoregressive path, $\beta_{AR\text{-}Academic\ performance}$), and the mutual prospective association that represent the bidirectional associations between mental health and academic performance variables (the cross-lagged pathways $\beta_{CL\text{-}1}$ and $\beta_{CL\text{-}2}$). These path analyses generate standardized structural regression coefficients that can be directly compared to assess the direction of the association between mental health and academic performance (Vitezova et al., 2015). In fact, these analyses have been previously used in studies with similar designs (Van Der Ende et al., 2016).

The Full Information Maximum Likelihood estimator was implemented in order to preserve all available data (Rosseel, 2012). This estimator is considered a standard approach to prevent listwise deletion of participants with missing data (Rosseel, 2012). Nevertheless, complete case analyses were also performed (with the participants with complete mental

health and academic performance data at both timepoints, N = 184) to ensure that the results were not biased due to missingness.

First, we assessed the association between the dual-factor model of mental health and academic performance adjusting for sex, pubertal stage, socioeconomic status, and weight status at baseline. Then, the associations between psychological well-being and distress indicators along with all the academic performance indicators were assessed, adjusting for sex, pubertal stage, socioeconomic status, and weight status at baseline. In these associations, the false discovery rate described by Benjamini and Hochberg (1995) was used to adjust for multiple comparisons. For the mental health indicators (i.e., psychological well-being and psychological distress indicators) we adjusted each psychological well-being pathway for a total of 14 tests (two psychological well-being domains and seven academic performance indicators) and each psychological distress pathway for a total of 28 tests (four psychological distress domains and seven academic performance indicators). According to Benjamini and Hochberg (1995), this is a practical and powerful approach for controlling the expected proportion of falsely results when multiple statistical analyses are performed.

All the statistical analyses of this study were performed using SPSS version 24.0.0.1 (IBM Corp., Armonk, NY) and R version 3.6.0 using the Lavaan package (The R foundation for Statistical Computing, Vienna, Austria).

3. Results

Descriptive characteristics of the students at baseline are presented in **Table 14**. Overall, participants self-reported good mental health status (i.e., emotional symptoms index = 46.1±8.9), showing a positive emotional adjustment in psychological well-being (all mean scores >40) and absence of psychological distress (all mean scores <60). Regarding academic performance, participants showed a mean GPA of 7.1±1.3 and an overall score of 48.7±12.6 in academic abilities. Descriptive information on mental health and academic performance at follow-up is presented in **Table S1** and shows similar results.

Table 14

Descriptive characteristics of the study sample at baseline (N=266).

	Mean or %	SD
Physical characteristics		
Age (years)	13.9	0.3
Pubertal stage (II - V) (%)	8/34/48/10	-
Weight (kg)	54.2	9.2
Height (cm)	163.0	7.9
Body mass index (kg/m^2)	20.3	2.7
Socioeconomic status (0 - 8)	4.2	1.4
Mental health		
Emotional symptoms index	46.1	8.9
Psychological well-being		
Self-esteem	53.3	7.6
Interpersonal relationships	51.8	7.3
Psychological distress		
Anxiety	46.0	10.4
Social stress	46.2	8.7
Risk of depression	46.2	8.3
Sense of inability	48.1	9.1
Academic performance		
Academic grades (0 - 10)		
Language	6.8	1.5
Math	6.8	1.6
Grade point average	7.1	1.3
Academic abilities		
Verbal ability (0 - 50)	18.7	5.3
Numeric ability (0 - 30)	13.4	4.7
Reasoning ability (0 - 30)	16.5	5.8
Overall score (0 - 110)	48.7	12.6

Note. Values are mean ± standard deviation or %. SD = standard deviation.

The bidirectional associations between the dual-factor model of mental health and academic performance, adjusting for sex, pubertal stage, socioeconomic status, and weight status are presented in **Table 15**. Cross-lagged analyses indicated that higher verbal ability (β = -0.116, p = 0.020), numeric ability (β = -0.111, p = 0.022), and the overall score of academic abilities (β = -0.109, p = 0.040) were associated with a lower emotional symptoms index over time. No associations were found between academic grades neither reasoning ability and the emotional symptoms index over time. In addition, the emotional symptoms index at baseline was not significantly associated with academic performance at follow-up. Autoregressive coefficients and additional fit measures are shown in **Table S2**. Sensitivity analyses showed that the effect sizes were largely similar when the sample was reduced to those with complete mental health and academic performance data at both timepoints (see **Table S3** and **Table S4**).

Bidirectional associations between psychological well-being and academic performance indicators are presented in **Table 16**. Based on the confounder-adjusted models, the cross-lagged analyses of this study indicated that psychological well-being indicators were not significantly associated with academic performance indicators over time in any direction (all p_{fdr} ≥0.308). Autoregressive coefficients and additional fit measures are shown in **Table S5**.

Lastly, bidirectional associations between psychological distress and academic performance indicators were presented in **Table 17**. Overall, higher scores in language (β = -0.190, p_{fdr} = 0.037), math (β = -0.169, p_{fdr} = 0.037), and GPA (β = -0.207, p_{fdr} = 0.037) at baseline were related to lower sense of inability over time. Meanwhile, no significant association was found between academic performance at baseline and anxiety, social stress, or risk of depression at follow-up (all p_{fdr} ≥0.070). In addition, no significant associations were found between mental health indicators at baseline and academic performance indicators over time. Autoregressive coefficients and additional fit measures are shown in **Table S6**.

Table 15

Bidirectional associations between mental health and academic performance based on the cross-lagged panel models.

	MH → AP		AP → MH		Cross-sectional		Fit measures	
	β_{CL-1}	p	β_{CL-2}	p	$\beta_{CL-Baseline}$	p	CFI	RMSEA
Emotional symptoms index								
Academic grades								
Language	-0.025 (-0.136, 0.086)	0.661	-0.038 (-0.158, 0.082)	0.535	-0.241 (-0.355, -0.127)	**<0.001**	0.942	0.080
Math	0.083 (-0.041, 0.208)	0.189	-0.073 (-0.178, 0.033)	0.175	-0.225 (-0.336, -0.115)	**<0.001**	0.956	0.070
GPA	0.047 (-0.042, 0.135)	0.300	-0.102 (-0.218, 0.014)	0.084	-0.236 (-0.349, -0.122)	**<0.001**	0.957	0.083
Academic abilities								
Verbal ability	-0.062 (-0.183, 0.059)	0.314	-0.116 (-0.214, -0.018)	**0.020**	-0.052 (-0.160, 0.058)	0.349	0.986	0.039
Numeric ability	-0.009 (-0.129, 0.111)	0.883	-0.111 (-0.207, -0.016)	**0.022**	-0.112 (-0.209, -0.016)	**0.023**	0.978	0.053
Reasoning ability	-0.099 (-0.212, 0.014)	0.087	-0.033 (-0.150, 0.084)	0.577	-0.071 (-0.207, 0.065)	0.306	0.959	0.063
Overall score	-0.072 (-0.173, 0.029)	0.163	-0.109 (-0.214, -0.005)	**0.040**	-0.096 (-0.207, 0.015)	0.090	0.989	0.039

Note. See Figure 7 for the visualization of the cross-lagged panel modelling approach. Cross-lagged models were adjusted by sex, pubertal stage, socioeconomic status, and body mass index. Statistically significant values are shown in bold ($p < 0.05$). MH = mental health; AP = academic performance; β_{CL-1} = the cross-lagged path 1, where mental health scores at baseline predict academic performance at follow-up; β_{CL-2} = the cross-lagged path 2, where academic performance at baseline predicts mental health at follow-up; $\beta_{CL-Baseline}$ = the cross-sectional association between mental health and academic performance within baseline; CFI = comparative fit index; RMSEA = root mean square error of approximation; GPA = grade point average.

Table 16

Bidirectional associations between psychological well-being and academic performance based on the cross-lagged panel models.

	MH → AP			AP → MH			Fit measures	
	β_{CL-1}	p	p_{fdr}	β_{CL-2}	p	p_{fdr}	CFI	RMSEA
Self-esteem								
Academic grades								
Language	-0.038 (-0.161, 0.086)	0.550	0.770	-0.045 (-0.169, 0.080)	0.483	0.680	0.954	0.061
Math	-0.150 (-0.279, -0.021)	**0.022**	0.308	0.036 (-0.089, 0.161)	0.693	0.785	0.970	0.050
GPA	-0.030 (-0.106, 0.046)	0.439	0.682	0.042 (-0.090, 0.173)	0.534	0.680	0.963	0.069
Academic abilities								
Verbal ability	0.015 (-0.116, 0.146)	0.823	0.825	0.081 (-0.014, 0.176)	0.093	0.680	0.997	0.016
Numeric ability	0.013 (-0.093, 0.119)	0.807	0.825	0.043 (-0.055, 0.140)	0.390	0.680	0.985	0.040
Reasoning ability	0.067 (-0.045, 0.178)	0.240	0.683	-0.022 (-0.145, 0.101)	0.729	0.785	0.959	0.055
Overall score	0.051 (-0.041, 0.143)	0.276	0.683	0.043 (-0.063, 0.148)	0.427	0.680	0.997	0.018
Interpersonal relationships								
Academic grades								
Language	0.044 (-0.042, 0.129)	0.318	0.683	0.036 (-0.069, 0.142)	0.500	0.680	0.966	0.054
Math	-0.075 (-0.162, 0.013)	0.094	0.439	0.046 (-0.059, 0.152)	0.388	0.680	0.969	0.053
GPA	-0.032 (-0.109, 0.045)	0.416	0.683	0.081 (-0.018, 0.180)	0.110	0.680	0.969	0.066
Academic abilities								
Verbal ability	0.025 (-0.094, 0.145)	0.677	0.825	0.033 (-0.067, 0.133)	0.520	0.680	1.000	0.000
Numeric ability	-0.011 (-0.111, 0.089)	0.825	0.825	0.047 (-0.066, 0.159)	0.415	0.680	0.984	0.042
Reasoning	0.079 (-0.005, 0.163)	0.065	0.439	0.011 (-0.117, 0.138)	0.869	0.869	0.983	0.038
Overall score	0.036 (-0.054, 0.126)	0.436	0.683	0.037 (-0.078, 0.152)	0.524	0.680	1.000	0.000

Note. See Figure 7 for the visualization of the cross-lagged panel modelling approach. Cross-lagged models were adjusted by sex, pubertal stage, socioeconomic status, and body mass index. Statistically significant values are shown in bold (p < 0.05). MH = mental health; AP = academic performance; β_{CL-1} = the cross-lagged path 1, where mental health scores at baseline predict academic performance at follow-up; β_{CL-2} = the cross-lagged path 2, where academic performance at baseline predicts mental health at follow-up; $\beta_{CL-Baseline}$ = the cross-sectional association between mental health and academic performance within baseline; CFI = comparative fit index; RMSEA = root mean square error of approximation; GPA = grade point average.

Table 17

Bidirectional associations between psychological distress and academic performance based on the cross-lagged panel models.

	MH → AP			AP → MH			Fit measures	
	β_{CL-1}	p	p_{fdr}	β_{CL-2}	p	p_{fdr}	CFI	RMSEA
Anxiety								
Academic grades								
Language	0.075 (-0.031, 0.182)	0.165	0.462	-0.052 (-0.156, 0.052)	0.324	0.454	0.942	0.084
Math	0.055 (-0.042, 0.152)	0.263	0.511	-0.074 (-0.185, 0.037)	0.190	0.332	0.947	0.080
GPA	0.061 (-0.018, 0.141)	0.130	0.404	-0.083 (-0.188, 0.022)	0.122	0.263	0.959	0.082
Academic abilities								
Verbal ability	-0.039 (-0.150, 0.072)	0.489	0.760	-0.139 (-0.245, -0.033)	**0.010**	0.070	0.977	0.053
Numeric ability	0.015 (-0.094, 0.125)	0.839	0.978	-0.137 (-0.246, -0.028)	**0.014**	0.078	0.973	0.063
Reasoning ability	0.005 (-0.106, 0.116)	0.929	0.978	-0.031 (-0.148, 0.085)	0.600	0.730	0.959	0.068
Overall score	-0.018 (-0.117, 0.081)	0.752	0.978	-0.128 (-0.240, -0.017)	**0.024**	0.112	0.984	0.050
Social stress								
Academic grades								
Language	-0.047 (-0.139, 0.045)	0.313	0.516	0.013 (-0.132, 0.159)	0.858	0.862	0.928	0.079
Math	0.059 (-0.043, 0.162)	0.255	0.511	0.012 (-0.112, 0.146)	0.862	0.862	0.942	0.071
GPA	0.049 (-0.031, 0.128)	0.232	0.511	-0.017 (-0.151, 0.118)	0.805	0.862	0.955	0.078
Academic abilities								
Verbal ability	-0.015 (-0.147, 0.117)	0.825	0.978	-0.069 (-0.197, 0.060)	0.298	0.439	0.975	0.047
Numeric ability	-0.005 (-0.114, 0.104)	0.929	0.978	-0.095 (-0.229, 0.039)	0.163	0.315	0.961	0.065
Reasoning	-0.104 (-0.219, 0.012)	0.078	0.298	-0.028 (-0.169, 0.113)	0.692	0.775	0.950	0.063
Overall score	-0.055 (-0.153, 0.043)	0.272	0.511	-0.078 (-0.209, 0.054)	0.249	0.387	0.981	0.048
Risk of depression								
Academic grades								
Language	-0.068 (-0.190, 0.055)	0.279	0.511	-0.036 (-0.206, 0.135)	0.428	0.571	0.959	0.057
Math	0.016 (-0.152, 0.183)	0.885	0.978	-0.073 (-0.188, 0.041)	0.208	0.343	0.962	0.054
GPA	-0.001 (-0.107, 0.105)	0.986	0.986	-0.116 (-0.261, 0.030)	0.118	0.263	0.964	0.067
Academic abilities								
Verbal ability	-0.098 (-0.206, 0.009)	0.072	0.298	-0.098 (-0.208, 0.012)	0.081	0.263	0.999	0.009
Numeric ability	0.011 (-0.113, 0.134)	0.865	0.978	-0.068 (-0.152, 0.016)	0.114	0.263	0.978	0.046
Reasoning ability	-0.126 (-0.254, 0.001)	0.051	0.298	-0.027 (-0.147, 0.093)	0.661	0.771	0.974	0.042
Overall score	-0.092 (-0.196, 0.013)	0.085	0.298	-0.082 (-0.178, 0.013)	0.091	0.263	0.999	0.010
Sense of inability								
Academic grades								
Language	-0.117 (-0.242, 0.009)	0.068	0.298	-0.190 (-0.325, -0.054)	**0.004**	**0.037**	0.974	0.051
Math	-0.021 (-0.150, 0.108)	0.754	0.978	-0.169 (-0.283, -0.055)	**0.004**	**0.037**	0.982	0.040
GPA	0.004 (-0.095, 0.102)	0.943	0.978	-0.207 (-0.337, -0.076)	**0.002**	**0.037**	0.976	0.059
Academic abilities								
Verbal ability	-0.095 (-0.194, 0.004)	0.060	0.298	-0.080 (-0.194, 0.034)	0.169	0.315	1.000	0.000
Numeric ability	-0.054 (-0.154, 0.046)	0.292	0.511	-0.102 (-0.204, -0.001)	**0.048**	0.192	1.000	0.000
Reasoning	-0.107 (-0.219, 0.005)	0.060	0.298	-0.051 (-0.195, 0.092)	0.484	0.616	1.000	0.000
Overall score	-0.088 (-0.172, -0.004)	**0.039**	0.298	-0.009 (-0.220, 0.021)	0.106	0.263	1.000	0.000

Note. See Figure 7 for the visualization of the cross-lagged panel modelling approach. Cross-lagged models were adjusted by sex, pubertal stage, socioeconomic status, and body mass index. Statistically significant values are shown in bold (p < 0.05). MH = mental health; AP = academic performance; β_{CL-1} = the cross-lagged path 1, where mental health scores at baseline predict academic performance at follow-up; β_{CL-2} = the cross-lagged path 2, where academic performance at baseline predicts mental health at follow-up; CFI = comparative fit index; RMSEA = root mean square error of approximation; GPA = grade point average.

4. Discussion

This study aimed to investigate the bidirectional longitudinal association between mental health and academic performance in a population of secondary school students. Overall, our main findings suggest that higher academic abilities at baseline may predict better mental health status over a 2-year period. In addition, when analyzing the specific indicators of the dual-factor model of mental health and after adjusting for multiple comparisons, our results showed that academic grades were inversely associated with sense of inability over time. However, none of the mental health indicators were associated with academic performance over time. These results expand the current literature since this is the first study analyzing longitudinal and bidirectional associations of the dual-factor model of mental health, including a wide range of psychological well-being and distress indicators, with academic performance in adolescents.

Our results indicate that higher academic performance might be associated with better mental health status at 2-years follow-up, but not *vice versa*, since the association was not bidirectional. These findings go in line with a prior bidirectional longitudinal study showing that GPA was positively associated with subjective well-being in a time span of 1-year, in a sample of German secondary school students (Steinmayr et al., 2016). Additionally, our results also concur with a longitudinal study showing that Swedish adolescents with higher academic performance have less mental health problems at 1-year follow-up (Almroth et al., 2018). A possible explanation of these results may rely on the higher levels of school belonging that is experienced by those adolescents who have higher academic abilities (Anderman, 2003). In this line, prior studies have shown that higher school belonging is associated with greater experience of more positive emotions and less negative emotions (Fong Lam et al., 2015), which, in turn, may contribute to experience an enhanced psychological well-being and a reduced psychological distress that may persist over time.

Nonetheless, our findings differ from prior bidirectional longitudinal studies showing a reciprocal association between these constructs (Z. J. Ng et al., 2015; W. Zhang et al., 2019), significant findings in the other direction (Van Der Ende et al., 2016; Wu et al., 2020), or a

negative association between academic performance and psychological well-being over time (Bortes et al., 2021). These divergent results between studies may rely on methodological issues and sample characteristics. Firstly, the inclusion criteria regarding the participants' health was not specified in the prior studies (Bortes et al., 2021; Z. J. Ng et al., 2015; Van Der Ende et al., 2016; Wu et al., 2020; W. Zhang et al., 2019), while all the participants of the present study were free of any diagnosed physical or psychological disease. Secondly, another possible explanation of these discrepancies may be related to the cultural diversity of the studies, which have been developed in the southeastern United States (Z. J. Ng et al., 2015), Northern European countries (Bortes et al., 2021; Van Der Ende et al., 2016), and China (Wu et al., 2020; F. F. Zhang et al., 2018). Indeed, this cultural diversity may lead to different educational systems in which the academic demands rely on the educational awareness of each country. Therefore, future studies are needed, examining mental health and academic performance through the indicators of this study in different adolescent populations.

Interestingly, the findings of the present study suggested that some academic performance indicators were inversely associated with anxiety and sense of inability over a 2-years follow-up; which are two specific psychological distress indicators of the dual-factor model of mental health. Nonetheless, after adjusting for multiple comparisons, only academic grades were significantly associated with sense of inability over time. Since this particular indicator captures the passion and perseverance to achieve goals in life (González et al., 2004), it might be the mental health indicator most directly influenced by academic grades. Indeed, the other indicators of mental health included in the present study may not only be influenced by academic grades, but also by other factors not taken into account, such as fitness levels (Cadenas-Sanchez et al., 2021) or lifestyle behaviors (Zhang et al., 2022). As far as we know, no prior study has analyzed the association between sense of inability and academic performance in the adolescent population, which hampers direct comparisons. Nonetheless, this significant association might be explained by the feelings of capability derived from obtaining better academic grades. In fact, due to the importance of academic performance

during secondary school (Eccles, 2013), those adolescents who obtain higher academic grades may have an enhanced self-concept and self-confidence (Dapp & Roebers, 2021), that may lead to have higher sense of ability over time. Interestingly, this particular indicator of psychological distress is of vital importance, since the sense of ability may be related to young adults' future perspectives regarding educational and employment outcomes (Veldman et al., 2015), which may shape future work, and in turn, future wealth.

Mental health at baseline was not associated with academic performance over a 2-year follow-up. Although prior bidirectional studies have suggested that psychological distress indicators, such as externalizing symptoms (Van Der Ende et al., 2016), and psychological well-being indicators (Wu et al., 2020) might be associated with academic performance over time, the longitudinal changes when including the dual-factor model of mental health associated with academic performance remain inconclusive. These contradictory findings with prior bidirectional studies might be attributed to the differences in years of follow-up between studies, as well as the characteristics of the study samples. In fact, Van Der Ende et al. (2016) found significant results in a sample of Zuid-Holland children and adolescents after 8-years of follow-up, and suggested that this association may be stronger in clinical samples. Thus, it is likely that in our sample of secondary school students, with an overall good mental health status, a longer period of emotional imbalance is required to worsen their academic performance.

The significant pathways of the present study indicate divergent results regarding the academic performance indicators that associate with the emotional symptoms index and sense of inability over time. These divergent results may be partially explained by the nature of these variables. On the one hand, academic grades are the result of the student progression for each subject scored by different teachers through exams and tasks during an academic year, while, on the other hand, academic abilities are assessed by a standardized test in a single time-point trial (Baker, 2006). Therefore, academic abilities mainly require good cognitive skills, which may be a protective factor for having a better overall health status over time (Clarke et al., 2015). Meanwhile, the multidimensional nature of academic grades

also involves emotional and social factors (i.e., effort, teacher influence, attitude) (Petrides et al., 2005). Thus, it is likely that teachers assign better grades to those students who have a better sense of ability, due to the fact that they may seem more clearly oriented to achieve goals in life because of their higher school attendance and commitment to long-term educational goals (Lê-Scherban et al., 2014; Pan et al., 2013).

All in all, these findings could have significant implications from an educational and health perspective. Given the fact that our results show a positive association of academic performance with mental health over time, teachers and health professionals should collaborate to achieve better academic results, which may help to reduce psychological distress and improve the psychological well-being of secondary school students. Thus, future interventional programs aimed to promote academic performance in the educational context could not only benefit adolescents academically, but also foster a greater mental health status during this critical period of life.

5. Limitations and strengths

One of the main strengths of this study relies on the use of a longitudinal design, which enabled to focus on changes over time. Moreover, the cross-lagged analyses simultaneously examine the direction of the association between several measures of mental health and academic performance. In addition, this study has included a wide range of mental health and academic performance sub-aspects for examining the relationship between these broad concepts in a relatively large and homogeneous sample of adolescents. However, some limitations need to be addressed. Firstly, although the study design was able to illuminate the direction of the effect, inferences about causality cannot be drown. Further, data was collected at two timepoints 2-years apart, thus, future work with additional timepoints and longer follow-up could address long-term associations. Lastly, this study was developed in a relatively small sample of Spanish adolescents, which could limit the generatability of our findings.

6. Conclusion

In conclusion, this study indicated that higher academic performance in early adolescence may be associated with better mental health status 2-years later, but not *vice versa*, since the association was not bidirectional. Additionally, our findings suggested that academic grades may be in inversely associated with sense of inability over time. These findings might guide future policies as well as health and educational professionals to effectively promote mental health in adolescent students with lower academic performance. In fact, providing emotion-focused coping strategies for diminishing the school pressure in those adolescents who obtain lower academic grades might be useful for preserving their mental health. Taken together, this bidirectional longitudinal study provides new insights about the overall picture of adolescents' mental health status, suggesting that it might be shaped by their academic performance.

Table S1

Descriptive characteristics of the study sample at follow-up.

	N	Mean or %	SD
Physical characteristics			
Age (years)	201	15.8	0.3
Pubertal stage (III - V) (%)	198	11/52/37	-
Weight (kg)	201	61.6	9.3
Height (cm)	201	168.4	8.1
Body mass index (kg/m^2)	201	21.7	2.9
Mental health			
Emotional symptoms index	201	44.8	7.0
Psychological well-being			
Self-esteem	201	53.0	7.5
Interpersonal relationships	201	52.3	6.5
Psychological distress			
Anxiety	201	44.4	10.1
Social stress	201	44.6	6.0
Risk of depression	201	45.8	6.7
Sense of inability	201	45.6	7.9
Academic performance			
Academic grades (0 - 10)			
Language	193	6.4	1.5
Math	193	6.2	1.9
Grade point average	193	6.7	1.3
Academic abilities			
Verbal ability (0 - 50)	201	22.1	5.7
Numeric ability (0 - 30)	201	16.3	5.2
Reasoning ability (0 - 30)	201	20.6	5.0
Overall score (0 - 110)	201	59.0	12.6

Note. Values are mean ± standard deviation or %. SD = standard deviation.

Table S2

Autoregressive associations and complete overview of fit indices of cross-lagged panel models estimating the bidirectional associations between mental health and academic performance.

	Autoregressive				Fit measures	
	$\beta_{\text{AR-Mental health}}$	p	$\beta_{\text{AR-Academic performance}}$	p	TLI	SRMR
Emotional symptoms index						
Academic grades						
Language	0.607 (0.440, 0.773)	<0.001	0.628 (0.440, 0.773)	<0.001	0.840	0.039
Math	0.598 (0.433, 0.762)	<0.001	0.665 (0.574, 0.757)	<0.001	0.879	0.034
GPA	0.593 (0.429, 0.757)	<0.001	0.822 (0.765, 0.879)	<0.001	0.881	0.035
Academic abilities						
Verbal ability	0.614 (0.458, 0.770)	<0.001	0.655 (0.580, 0.729)	<0.001	0.962	0.026
Numeric ability	0.595 (0.431, 0.758)	<0.001	0.703 (0.628, 0.778)	<0.001	0.940	0.053
Reasoning ability	0.615 (0.451, 0.778)	<0.001	0.621 (0.526, 0.716)	<0.001	0.888	0.033
Overall score	0.605 (0.442, 0.769)	<0.001	0.763 (0.699, 0.827)	<0.001	0.969	0.026

Note. Statistically significant values are shown in bold ($p < 0.05$). Models were adjusted for sex, pubertal stage, socioeconomic status, and body mass index. $\beta_{\text{AR-Mental health}}$ = the autoregressive coefficient for mental health score; $\beta_{\text{AR-Academic performance}}$ = the autoregressive coefficient for academic performance; TLI = Tucker-Lewis Index; SRMR = standardized root mean square residual; GPA = grade point average.

Table S3

Bidirectional associations between mental health and academic performance based on the cross-lagged panel models of the complete cases.

	MH → AP		AP → MH		Cross-sectional		Fit measures	
	$\beta_{CL\text{-}1}$	p	$\beta_{CL\text{-}2}$	p	$\beta_{CL\text{-Baseline}}$	p	CFI	RMSEA
Emotional symptoms index								
Academic grades								
Language	-0.032 (-0.132, 0.069)	0.537	-0.054 (-0.181, 0.072)	0.402	-0.175 (-0.295, -0.054)	**0.005**	0.933	0.092
Math	0.065 (-0.047, 0.178)	0.253	-0.086 (-0.198, 0.026)	0.131	-0.201 (-0.320, -0.082)	**0.001**	0.951	0.079
GPA	0.033 (-0.048, 0.115)	0.426	-0.127 (-0.249, -0.006)	**0.040**	-0.197 (-0.332, -0.063)	**0.004**	0.951	0.098
Academic abilities								
Verbal ability	-0.048 (-0.162, 0.066)	0.411	-0.137 (-0.244, -0.030)	**0.012**	0.026 (-0.100, 0.152)	0.684	0.990	0.036
Numeric ability	-0.002 (-0.114, 0.110)	0.972	-0.113 (-0.214, -0.011)	**0.030**	-0.088 (-0.212, 0.036)	0.163	0.977	0.060
Reasoning ability	-0.090 (-0.193, 0.013)	0.085	-0.057 (-0.180, 0.066)	0.362	0.029 (-0.116, 0.174)	0.696	0.962	0.067
Overall score	-0.067 (-0.162, 0.028)	0.169	-0.127 (-0.237, -0.017)	**0.024**	-0.006 (-0.126, 0.114)	0.917	0.990	0.040

Note. See Figure 7 for the visualization of the cross-lagged panel modelling approach. Cross-lagged models were adjusted by sex, pubertal stage, socioeconomic status, and body mass index. Statistically significant values are shown in bold ($p < 0.05$). MH = mental health; AP = academic performance; $\beta_{CL\text{-}1}$ = the cross-lagged path 1, where mental health scores at baseline predict academic performance at follow-up; $\beta_{CL\text{-}2}$ = the cross-lagged path 2, where academic performance at baseline predict mental health at follow-up; CFI = comparative fit index; RMSEA = root mean square error of approximation; GPA = grade point average.

Table S4

Autoregressive associations and complete overview of fit indices of cross-lagged panel models estimating the bidirectional associations between mental health and academic performance of the complete cases.

	Autoregressive				Fit measures	
	$\beta_{\text{AR-Mental health}}$	p	$\beta_{\text{AR-Academic performance}}$	p	TLI	SRMR
Emotional symptoms index						
Academic grades						
Language	0.553 (0.364, 0.741)	<0.001	0.602 (0.493, 0.711)	<0.001	0.817	0.040
Math	0.544 (0.358, 0.729)	<0.001	0.641 (0.548, 0.733)	<0.001	0.866	0.035
GPA	0.538 (0.355, 0.722)	<0.001	0.803 (0.742, 0.865)	<0.001	0.866	0.036
Academic abilities						
Verbal ability	0.562 (0.379, 0.746)	<0.001	0.656 (0.576, 0.736)	<0.001	0.972	0.026
Numeric ability	0.543 (0.357, 0.730)	<0.001	0.700 (0.621, 0.779)	<0.001	0.937	0.030
Reasoning ability	0.563 (0.376, 0.751)	<0.001	0.622 (0.526, 0.718)	<0.001	0.895	0.033
Overall score	0.556 (0.368, 0.745)	<0.001	0.759 (0.694, 0.824)	<0.001	0.974	0.026

Note. Statistically significant values are shown in bold (p < 0.05). Models were adjusted for sex, pubertal stage, socioeconomic status, and body mass index. $\beta_{\text{AR-Mental health}}$ = the autoregressive coefficient for mental health score; $\beta_{\text{AR-Academic performance}}$ = the autoregressive coefficient for academic performance; TLI = Tucker-Lewis Index; SRMR = standardized root mean square residual; GPA = grade point average.

Table S5

Autoregressive and cross-sectional associations and complete overview of fit indices of cross-lagged panel models estimating the bidirectional associations between psychological well-being indicators and academic performance.

	Autoregressive				Cross-sectional			Fit measures	
	$\beta_{AR\text{-Mental health}}$	p	$\beta_{AR\text{-Academic performance}}$	p	$\beta_{CL\text{-Baseline}}$	p	p_{fdr}	TLI	SRMR
Self-esteem									
Academic grades									
Language	0.401 (0.195, 0.606)	<0.001	0.639 (0.537, 0.741)	<0.001	0.126 (-0.005, 0.256)	0.059	0.165	0.873	0.037
Math	0.390 (0.186, 0.595)	<0.001	0.672 (0.584, 0.760)	<0.001	0.131 (0.017, 0.246)	**0.025**	0.095	0.919	0.033
GPA	0.392 (0.188, 0.595)	<0.001	0.815 (0.762, 0.869)	<0.001	0.094 (-0.032, 0.221)	0.145	0.290	0.898	0.035
Academic abilities									
Verbal ability	0.399 (0.199, 0.598)	<0.001	0.657 (0.582, 0.731)	<0.001	0.019 (-0.095, 0.133)	0.748	0.885	0.992	0.027
Numeric ability	0.391 (0.187, 0.595)	<0.001	0.703 (0.627, 0.779)	<0.001	0.043 (-0.059, 0.146)	0.405	0.567	0.958	0.030
Reasoning ability	0.395 (0.193, 0.597)	<0.001	0.627 (0.533, 0.721)	<0.001	-0.015 (-0.149, 0.118)	0.822	0.885	0.887	0.033
Overall score	0.396 (0.192, 0.599)	<0.001	0.769 (0.706, 0.831)	<0.001	0.017 (-0.101, 0.134)	0.783	0.885	0.992	0.027
Interpersonal relationships									
Academic grades									
Language	0.563 (0.312, 0.814)	<0.001	0.628 (0.523, 0.733)	<0.001	0.123 (0.027, 0.219)	**0.012**	0.091	0.905	0.034
Math	0.562 (0.312, 0.811)	<0.001	0.659 (0.571, 0.747)	<0.001	0.067 (0.017, 0.278)	**0.027**	0.095	0.914	0.031
GPA	0.557 (0.310, 0.803)	<0.001	0.817 (0.764, 0.871)	<0.001	0.146 (0.031, 0.262)	**0.013**	0.091	0.914	0.031
Academic abilities									
Verbal ability	0.568 (0.319, 0.818)	<0.001	0.657 (0.582, 0.731)	<0.001	-0.007 (-0.125, 0.111)	0.904	0.904	1.021	0.020
Numeric ability	0.563 (0.311, 0.815)	<0.001	0.706 (0.631, 0.782)	<0.001	0.080 (-0.022, 0.181)	0.123	0.287	0.956	0.025
Reasoning	0.567 (0.313, 0.822)	<0.001	0.620 (0.526, 0.715)	<0.001	0.084 (-0.059, 0.228)	0.249	0.436	0.952	0.027
Overall score	0.566 (0.313, 0.818)	<0.001	0.768 (0.706, 0.830)	<0.001	0.066 (-0.060, 0.191)	0.305	0.474	1.013	0.020

Note. Statistically significant values are shown in bold ($p < 0.05$). Models were adjusted for sex, pubertal stage, socioeconomic status, and body mass index. $\beta_{AR\text{-Mental health}}$ = the autoregressive coefficient for mental health score; $\beta_{AR\text{-Academic performance}}$ = the autoregressive coefficient for academic performance; $\beta_{CL\text{-Baseline}}$ = the cross-sectional association between psychological well-being indicators and academic performance within baseline; TLI = Tucker-Lewis Index; SRMR = standardized root mean square residual; GPA = grade point average.

Table S6

Autoregressive and cross-sectional associations and complete overview of fit indices of cross-lagged panel models estimating the bidirectional associations between psychological distress indicators and academic performance.

	Autoregressive				Cross-sectional			Fit measures	
	$\beta_{AR\text{-Mental health}}$	p	$\beta_{AR\text{-Academic performance}}$	p	$\beta_{CL\text{-Baseline}}$	p	p_{fdr}	TLI	SRMR
Anxiety									
Academic grades									
Language	0.612 (0.514, 0.709)	<0.001	0.629 (0.525, 0.733)	<0.001	-0.045 (-0.172, 0.081)	0.484	0.611	0.840	0.039
Math	0.608 (0.512, 0.705)	<0.001	0.649 (0.561, 0.737)	<0.001	-0.031 (-0.150, 0.087)	0.605	0.678	0.855	0.036
GPA	0.613 (0.516, 0.709)	<0.001	0.811 (0.758, 0.865)	<0.001	-0.042 (-0.166, 0.081)	0.502	0.611	0.888	0.036
Academic abilities									
Verbal ability	0.611 (0.516, 0.705)	<0.001	0.656 (0.582, 0.730)	<0.001	-0.021 (-0.134, 0.092)	0.720	0.774	0.938	0.030
Numeric ability	0.592 (0.494, 0.690)	<0.001	0.707 (0.633, 0.781)	<0.001	-0.055 (-0.169, 0.058)	0.342	0.479	0.925	0.031
Reasoning ability	0.613 (0.516, 0.709)	<0.001	0.624 (0.529, 0.720)	<0.001	-0.017 (-0.139, 0.105)	0.783	0.783	0.886	0.035
Overall score	0.606 (0.510, 0.702)	<0.001	0.769 (0.707, 0.832)	<0.001	-0.037 (-0.151, 0.077)	0.526	0.614	0.955	0.029
Social stress									
Academic grades									
Language	0.512 (0.377, 0.647)	<0.001	0.628 (0.523, 0.733)	<0.001	-0.174 (-0.282, -0.065)	**0.002**	**0.005**	0.802	0.041
Math	0.512 (0.374, 0.650)	<0.001	0.658 (0.567, 0.784)	<0.001	-0.182 (-0.294, -0.070)	**0.001**	**0.003**	0.842	0.037
GPA	0.509 (0.373, 0.644)	<0.001	0.821 (0.765, 0.876)	<0.001	-0.190 (-0.305, -0.075)	**0.001**	**0.003**	0.877	0.037
Academic abilities									
Verbal ability	0.512 (0.380, 0.643)	<0.001	0.657 (0.583, 0.731)	<0.001	-0.007 (-0.117, 0.102)	0.183	0.342	0.930	0.031
Numeric ability	0.500 (0.367, 0.633)	<0.001	0.704 (0.629, 0.780)	<0.001	-0.060 (-0.160, 0.041)	0.243	0.425	0.893	0.033
Reasoning ability	0.508 (0.372, 0.643)	<0.001	0.621 (0.526, 0.715)	<0.001	-0.067 (-0.199, 0.064)	0.316	0.479	0.863	0.036
Overall score	0.507 (0.374, 0.640)	<0.001	0.767 (0.704, 0.831)	<0.001	-0.056 (-0.170, 0.058)	0.332	0.479	0.947	0.031
Risk of depression									
Academic grades									
Language	0.484 (0.242, 0.726)	<0.001	0.619 (0.507, 0.730)	<0.001	-0.243 (-0.365, -0.120)	**<0.001**	**<0.001**	0.889	0.035
Math	0.476 (0.246, 0.707)	<0.001	0.651 (0.559, 0.742)	<0.001	-0.197 (-0.296, -0.099)	**<0.001**	**<0.001**	0.896	0.032
GPA	0.465 (0.227, 0.703)	<0.001	0.812 (0.752, 0.873)	<0.001	-0.211 (-0.326, -0.097)	**<0.001**	**<0.001**	0.901	0.032
Academic abilities									
Verbal ability	0.494 (0.274, 0.713)	<0.001	0.653 (0.578, 0.728)	<0.001	-0.045 (-0.141, 0.052)	0.363	0.484	0.997	0.022
Numeric ability	0.484 (0.258, 0.709)	<0.001	0.706 (0.630, 0.782)	<0.001	-0.097 (-0.161, 0.013)	0.097	0.194	0.940	0.027
Reasoning ability	0.494 (0.267, 0.721)	<0.001	0.621 (0.526, 0.717)	<0.001	-0.021 (-0.148, 0.106)	0.746	0.774	0.930	0.028
Overall score	0.489 (0.261, 0.716)	<0.001	0.763 (0.699, 0.828)	<0.001	-0.056 (-0.153, 0.042)	0.263	0.433	0.997	0.022
Sense of inability									
Academic grades									
Language	0.398 (0.228, 0.569)	<0.001	0.591 (0.478, 0.703)	<0.001	-0.387 (-0.498, -0.277)	**<0.001**	**<0.001**	0.927	0.033
Math	0.411 (0.255, 0.567)	<0.001	0.640 (0.544, 0.737)	<0.001	-0.342 (-0.443, -0.240)	**<0.001**	**<0.001**	0.952	0.028
GPA	0.391 (0.226, 0.556)	<0.001	0.813 (0.745, 0.880)	<0.001	-0.386 (-0.487, -0.286)	**<0.001**	**<0.001**	0.934	0.028
Academic abilities									
Verbal ability	0.464 (0.320, 0.608)	<0.001	0.646 (0.570, 0.722)	<0.001	-0.133 (-0.247, -0.019)	**0.022**	0.051	1.082	0.012
Numeric ability	0.449 (0.309, 0.590)	<0.001	0.693 (0.615, 0.771)	<0.001	-0.204 (-0.306, -0.102)	**<0.001**	**<0.001**	1.013	0.019
Reasoning	0.466 (0.315, 0.616)	<0.001	0.611 (0.514, 0.707)	<0.001	-0.144 (-0.271, -0.017)	**0.027**	0.058	1.006	0.022
Overall score	0.453 (0.304, 0.603)	<0.001	0.753 (0.686, 0.819)	<0.001	-0.198 (-0.311, -0.086)	**0.001**	**0.003**	1.056	0.013

Note. Statistically significant values are shown in bold (p < 0.05). Models were adjusted for sex, pubertal stage, socioeconomic status, and body mass index. $\beta_{AR\text{-Mental health}}$ = the autoregressive coefficient for mental health score; $\beta_{AR\text{-Academic performance}}$ = the autoregressive coefficient for academic performance; $\beta_{CL\text{-Baseline}}$ = the cross-sectional association between psychological distress indicators and academic performance within baseline; TLI = Tucker-Lewis Index; SRMR = standardized root mean square residual; GPA = grade point average.

5. General discussion

This section offers a brief summary of the main findings together with a general discussion of the specific findings derived from the scientific publications compiled in this PhD thesis.

Main findings

The main aim of this PhD thesis was to investigate the relationship between mental health and academic performance during secondary school period. Firstly, the cross-sectional findings from the present PhD thesis suggest that the dual-factor model of mental health, composed by the balance of psychological well-being and psychological distress indicators, is associated with academic performance. This implies that those secondary school students with high levels of psychological well-being and low levels of psychological distress are more likely to obtain better academic performance, expanding the current evidence on the field of educational psychology. In addition, our cross-sectional findings suggest that this association is independent of sex, as the results of this PhD thesis show largely similar results among boys and girls. This PhD thesis also provides new insights about the role of body composition in this association, revealing that psychological distress contributes to adolescents' academic performance through weight status. Specifically, findings show that the association between risk of depression and academic performance was stronger among overweight students compared to their non-overweight peers. Furthermore, the findings of the present PhD thesis strengthen the value of physical fitness as an important determinant of mental health and academic performance. Specifically, findings suggest that higher cardiorespiratory fitness levels diminish the risk of depression, which in turn help to improve academic performance. Lastly, although the cross-sectional studies of the present PhD thesis suggest how mental health is associated with academic performance, the longitudinal bidirectional analyses of this thesis suggest that academic performance is associated with mental health over time, and not *vice versa*, as this association is not bidirectional.

General discussion of the specific findings

The first specific aim of this PhD thesis was to analyze the cross-sectional association between mental health and academic performance in secondary school students. The results suggest that mental health is significantly associated with academic grades. Particularly, this finding partially concurs with prior evidence showing that the combination of the presence of psychological well-being along with the absence of psychological distress is associated with better academic performance in adolescents (Antaramian et al., 2010; Suldo & Shaffer, 2008). Regarding the psychological well-being indicators, results suggest that self-esteem and interpersonal relationships are positively associated with academic performance, concurring with the findings of Kiuru et al. (2020) and Trautwein et al. (2006). Similarly, regarding psychological distress indicators, results agree with prior evidence suggesting that social stress (Ye et al., 2019), risk of depression (Riglin et al., 2014), and sense of inability (Hagger & Hamilton, 2019) were inversely associated with academic performance. These findings could be explained by the emotional experiences related to mental health status. In this vein, it is plausible that those students with high levels of psychological well-being experience a healthy global perception of the self and good interpersonal relationships that may fulfill them with higher motivation and sense of belonging (Triana et al., 2019), providing higher security for facing personal and scholar challenges (Heimpel et al., 2002; Virtanen et al., 2020). Similarly, those experiencing lack of psychological distress may perceive themselves as strong and productive persons, with energy and capability to cope with their daily life demands (Arvidsdotter et al., 2016). These facts, in combination, may lead to an adequate environment for concentration and a higher interest on social and school activities, which may help students to succeed in secondary education (Breslau et al., 2011).

The second specific aim of this PhD thesis was to examine the role of sex in the association between mental health and academic performance in secondary school students. Overall, mental health was associated with academic grades among adolescent boys and girls. Nonetheless, when examining the specific indicators of mental health with academic performance by sex, only one indicator of psychological well-being remained significantly and positively associated with academic grades in adolescent girls but not in boys (i.e., self-esteem). Altogether, the stratified analyses by sex showed largely similar results among boys and girls. To our knowledge, these are the first results examining the role of sex including a broad set of indicators, which hampers direct comparisons. So of that, our results partially concur with a prior study showing no significant sex differences when examining adolescents' psychological distress (i.e., depression) with academic performance (Riglin et al., 2014). The lack of influence of sex in this association provides new insights for considering the adolescent population altogether when studying the promotion and prevention of mental health and academic performance. Nonetheless, further research is needed in this area of knowledge in order to clarify to which extent sex may influence the association of mental health and academic performance among the adolescent population.

The third specific aim of this PhD thesis was to examine the role of body composition in the association between mental health and academic performance in secondary school students. Results show that psychological distress contributes to academic performance through body composition. Specifically, the inverse association between risk of depression and academic performance was stronger among overweight secondary school students compared to their non-overweight peers. As far as we know, this is the first study investigating the association between risk of depression and academic performance considering body composition as a possible mechanism, which hampers comparisons among studies. In this context, it is plausible that these findings might be explained through the behavioral factors (Milaneschi et al., 2019) and neurocognitive mechanisms associated to body composition (Liang et al., 2014; Reinert et al., 2013). For instance, some behavioral factors commonly adopted by adolescents at risk of depression, such as sedentary patterns, lower sleep duration, and higher consumption of caloric food may increase their weight status and, in turn, negatively affect academic performance (Milaneschi et al., 2019). Additionally, neuroscientific studies suggest that obesity affects the neural structures and functions of the brain, which may be reflected in psychological distress and worse academic performance (Liang et al., 2014; Reinert et al., 2013).

The fourth specific aim of this PhD thesis was to examine the role of mental health as a mechanism in the association between physical fitness and academic performance in secondary school students. Results suggest that risk of depression mediates the positive relationship between physical fitness and academic performance in secondary school students. These findings are consistent with the study developed by Xiang et al. (2017), in which psychological distress (i.e., depression) showed to be an important factor driving the association of cardiorespiratory fitness and academic performance in a sample of secondary school students. It is plausible that some psychological and physiological factors related to physical fitness might explain this finding. Indeed, adolescents with high cardiorespiratory fitness levels tend to have higher social support among equals and to experience greater mood and self-esteem (Bou-Sospedra et al., 2020), which are psychological factors closely linked to an increased ability to think and concentrate, leading to a better academic performance (Babiss & Gangwisch, 2009; Di Liegro et al., 2019; Portugal et al., 2013). Additionally, reduced leptin concentration and increased BDNF levels in physically fit adolescents are related to lower levels of depression and have also been positively associated with memory function (Erickson et al., 2012; Farr et al., 2015), which may explain how fitness levels might diminish depressive symptoms and improve cognition, positively influencing academic performance among secondary school students (Di Liegro et al., 2019).

The fifth specific aim of this PhD thesis was to analyze the bidirectional longitudinal association between mental health and academic performance during secondary school period. Overall, results suggest that academic performance at baseline may predict mental health status 2 years later. These findings are in line with a prior bidirectional longitudinal study showing that academic performance was positively associated with psychological well-being in a time span of 1-year in a sample of German secondary school students (Steinmayr et al., 2016). Additionally, our results also concur with a longitudinal study showing that Swedish adolescents with higher academic performance have less mental health problems at 1-year follow-up (Almroth et al., 2018). A possible explanation of these results may rely on the higher levels of school belonging that is experienced by those adolescents who have higher academic performance (Anderman, 2003). In this context, prior studies have shown that higher school belonging is associated with experiencing more positive emotions and less negative emotions (Fong Lam et al., 2015), which in turn may contribute to experience an enhanced psychological well-being and a reduced psychological distress that may persist over time.

Results show that mental health at baseline was not associated with academic performance 2 years later. This finding differs from prior bidirectional studies suggesting that mental health (i.e., externalizing symptoms and subjective well-being) is associated with academic performance over time (Van Der Ende et al., 2016; Wu et al., 2020). These contradictory findings might be attributed to the differences in years of follow-up between studies, as well as the characteristics of the study samples. For instance, Van Der Ende et al. (2016) found significant results in a sample of Zuid-Holland children and adolescents after 8-years of follow-up, and suggested that this association may be stronger in clinical samples. Thus, it is likely that in our sample of secondary school students, with an overall good mental health status, a longer period of emotional imbalance is required to worsen their academic performance.

6. Strengths and limitations

This section provides a general overview of the strengths and limitations present in this PhD thesis.

Firstly, the main strength of this PhD thesis is that our findings provide new evidence on the fields of educational psychology and health, elucidating the cross-sectional and longitudinal bidirectional associations between mental health and academic performance, including a broad set of indicators and examining the role of related factors (i.e., sex, weight status, and cardiorespiratory fitness). Secondly, it is important to highlight that this PhD thesis has been developed in a relatively large and homogeneous sample in terms of age. Additional strengths comprise the use of standardized tests to assess the variables of interest (e.g., BASC-S3 and TEA). Lastly, in accordance with the prior literature in the field, all the performed statistical analyses included potential confounders related to mental health and academic performance (e.g., sex, pubertal stage, and socioeconomic status).

In spite of these aforementioned strengths, the results of this PhD thesis present certain limitations. First of all, the study sample was recruited through a convenience method, not composing a representative sample of the adolescent population, which hampers the generalizability of our findings. Second, the sampling size was limited when performing the stratified analyses (i.e., by groups of sex and weight status), which may hamper the strengths of our findings. Third, the observed associations should be interpreted with caution, since the observational design of the studies included in this PhD thesis prevents the establishment of causality. Nonetheless, the identification of these limitations offers the opportunity to stablish future perspectives of research on this area of knowledge. For instance, future research with larger and representative samples of secondary school students is needed to confirm or contrast our findings. Additionally, experimental studies on mental health and academic performance are required to draw conclusions in regard to the cause and effect of this indicators. In the same vein, the new lines of research on this

field could explore mechanisms behind the longitudinal association between academic performance and mental health. All in all, this proposed future research could help to create interventional programs aimed to improve adolescents' academic performance and mental health with rigor.

7. Conclusions

As a general conclusion, the findings of this PhD thesis suggest that there is a positive association between mental health and academic performance during secondary school period.

Cross-sectional conclusions

Mental health status is associated with academic performance in secondary school students.

Higher levels of psychological well-being are positively associated with better academic performance in secondary school students.

Higher levels of psychological distress are negatively associated with academic performance in secondary school students.

Sex did not influence the association between mental health and academic performance in secondary school students.

Weight status mediates the inverse association between risk of depression and academic performance in secondary school students.

The inverse association between risk of depression and academic performance is stronger among overweight secondary school students.

Risk of depression mediates the positive relationship between cardiorespiratory fitness and academic performance in secondary school students.

Longitudinal conclusion

Academic performance is associated with mental health at 2-years follow-up and not *vice versa*, as this association is not bidirectional during secondary school period.

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APPENDICES

Appendix I. Abbreviations

Appendix II. Acknowledgements

Appendix III. Index of tables and figures

Appendix IV. Curriculum vitae

Appendix I. Abbreviations

BAI = Becks Anxiety Inventory

BASC = Behavior Assessment System for Children and adolescents

BMI = Body Mass Index

BDNF = Brain-derived neurotrophic factor

CRF = Cardiorespiratory fitness

CIs = Confidence intervals

DADOS = Deporte, ADOlescencia y Salud

ESI = Emotional Symptoms Index

FAS = Family Affluence Scale

GPA = Grade point average

HADS = Hospital Anxiety and Depression Scale

K10 = Kessler psychological distress scale

MHC-SF = Mental Health Continuum Short Form

OECD = Organization for Economic Co-operation and Development

P_M = Percentage of mediation

PASOS = Physical Activity, Sedentarism, lifestyles and Obesity in Spanish youth

PANAS = Positive and Negative Affect Scale

PISA = Program for International Student Assessment

SES = Socioeconomic status

SPSS = Statistical Package for the Social Sciences

SDQ = Strengths and Difficulties Questionnaire

TEA = Test of Educational Ability

WASI = Wechsler Abbreviated Scale of Intelligence

WHO = World Health Organization

Appendix II. Acknowledgements

Esta tesis doctoral ha sido posible gracias a la enseñanza, la ayuda, los ánimos y el cariño de las personas que me han acompañado a lo largo de esta etapa formativa.

En primer lugar, me gustaría agradecer a Diego y a Mireia, por ser unos directores de tesis excepcionales. Diego, gracias por confiar en mi en 2016 para pedir la beca de colaboración y empezar a formar parte del grupo LIFE. Cuando inicié este camino no sabía lo que me iba a deparar y ésta ha sido una de las experiencias más enriquecedoras de mi vida. Me has enseñado la bonita profesión de enseñar e investigar, siempre con mensajes prácticos para avanzar y lograr los objetivos que hemos ido marcando. Mireia, gracias por enseñarme tanto a nivel profesional y también personal, gracias a ti he aprendido a valorar la importancia de la organización y la dedicación para lograr alcanzar todas las listas de tareas que he ido completando desde que nos conocimos.

Quería agradecer también a todos los miembros del grupo de investigación LIFE con los que he coincidido. Especialmente a Reyes, gracias por estar ahí para resolver cualquier duda en cualquier momento, por tus consejos y por todas tus revisiones. A Carlos, compi de despacho, de cafés y de muchos consejos de vida. Gracias por estar siempre ahí, pinchándome y sacándome sonrisas. Agradecer también a las becarias Lucía y Laura, gracias por vuestra ayuda y por las horas que hemos compartido revisando y pasando datos.

Me gustaría hacer una especial mención a mi supervisora de la estancia, María, por brindarme la oportunidad de formar parte del Departamento de Epidemiología del Erasmus Medical Center. Estar en Rotterdam durante tan solo 3 meses ha sido una experiencia muy bonita y enriquecedora en todos los sentidos. Eres una investigadora excelente y no tengo palabras para agradecerte cómo me enseñaste tu visión de esta profesión, rodeada de proyectos increíbles y bellísimas personas. Gracias a ti conocí a todas las compañeras de la planta 27 que hacían el trabajo más ameno. Por nuestros descansos paseando por el parque y por compartir tantos momentos juntas, ha sido un placer coincidir con vosotras, Marlou, Amy, Mojgan, Miss V y Youchan.

A los amigos que me ha brindado la universidad. A mis compañeros de carrera, Joaquin y Paula, por hacer muy agradable y divertida la etapa que me ha ayudado a llegar hasta aquí. A Irene, mi alma gemela. Por todo lo que compartimos, por los momentos de descanso en días de trabajo y por nuestras visitas a Roterdam y Viena. Gracias por estar ahí aun estando a miles de kilómetros de distancia. A Marc y Anna, por ser un grandísimo descubrimiento, por compartir conmigo vuestra bondad y vuestros conocimientos. Le doy gracias a la docencia por juntar nuestros caminos.

A mis amigos del pueblo, especialmente a todos los amigos de la peña Alboroto. Gracias por los momentos que hemos celebrado juntos y por ayudarme a desconectar. El Alboroto 2.0 ya tiene un doctor y las Mujeres Alborotadoras también tendrán una. A Sonia, por ser la persona que más puramente define la palabra amiga. Gracias por estar siempre, por ayudarme a salir de la rutina, por escucharme, por animarme y por apoyarme a cumplir mis sueños, esté donde esté. Gracias también a Jenni, Neus, María, Laia, Sonia y Noelia, por estar siempre. A Neus, por nuestra amistad y por saber que estamos una al lado de la otra, aunque no nos veamos en mil años. A mis amigos de verano y en especial a Diego, por ser el que siempre está dispuesto a salir, charlar y marcar objetivos que se acaban cumpliendo. Por todos los momentos vividos en Moncofa y en otros países de Europa. La vida con vosotros es muy fácil y divertida.

A todas las personas que he conocido en el Barbell Box. Muchas gracias a Pepe por ser el que nos ha unido a todos, a Mike por sus ejercicios mortales y a Vanesa y Kako por organizar esas comilonas que dan vida. Especialmente, me gustaría agradecer el esfuerzo que hace Pasqualeta para que salga a beber cerveza y tomar el aire. Gracias a Davisin por preguntarme siempre cómo va todo, a Manu por ver mis dramas menos drama, a Juanra por sus curiosidades sobre el cerebro que dice que estudio, a Fran por sus "sí a todo y Bizum a quién", a la *teacher* Lorena por tener tantas cosas en común, a Marce por mandarnos una programación destructora y un grandísimo etcétera de excelentísimas personas. Veros todas las semanas durante este tiempo me ha llenado de energía para poder terminar esta tesis.

A mi pareja, Alejandro, por ser la persona más bonita y especial que conozco. Gracias por todos estos años cuidándome y confiando en mí, por enseñarme tu constancia y la importancia de la perfección en aquello que nos apasiona. Estoy enormemente agradecida por tu amor, tu buena energía, tu ayuda y tu comprensión en los momentos más intensos de la tesis. Gracias también a tus padres, Pili y Ximo, por regalarme a un grandísimo compañero de vida y cuidarnos tanto con el arroz al horno de cada jueves.

A mi familia, por ser los que me han brindado la oportunidad de ser la persona que soy y por quererme incondicionalmente. Iaia, por fin puedo dar por terminada esta etapa, muchas gracias por enseñarme tu sabia visión del mundo, siempre guardo tus consejos en mi interior. A mi hermana Núria, por ser mi guía desde pequeña, por quererme y cuidarme tanto. Gracias por tu bondad y por animarme a lograr mis objetivos. Finalmente, a mis pilares fundamentales en la vida, mamá y papá, claro ejemplo de bondad, honestidad y humildad. Todo lo que soy y lo que he conseguido es gracias a vuestro esfuerzo, vuestra ayuda y vuestro cariño. Gracias por quererme tanto, por escucharme, por confiar en mí, por apoyarme en todo y por darme la libertad suficiente para volar.

Appendix III. Index of tables and figures

INDEX OF TABLES

SUPPLEMENTARY TABLES

INDEX OF FIGURES

Appendix IV. Curriculum vitae

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Professional web-site

University education

2019-2023	Doctoral Program in Education, Universitat Jaume I (Spain)
2020-2021	Master's Degree in Brain and Behavior Research, Universitat Jaume I (Spain)
2017-2018	Master's Degree in Neuropsychology and Education, Universidad Internacional de la Rioja (UNIR) (Spain)
2015-2019	Bachelor's Degree in Elementary Education with a major in Physical Activity, Universitat Jaume I (Spain)
2013-2017	Bachelor's Degree in Early Childhood Education, Universitat Jaume I (Spain) [Bachelor's excellence award]

Student fellowships

2018-2019	(5 months) North America Exchange Program at the College of Education and Human Services in Murray State University, Murray, Kentucky (United States of America).
2017-2018	(5 months) Erasmus+ Program at the Faculty of Social Sciences, University of Gdansk (Poland).
2016-2017	(7 months) Research collaboration grant (academic year 2016/2017) from the Ministry of Education, Culture, and Sport (Spain).

Researcher fellowships

2021-2022   (3 months): Complementary mobility fellowship from the Ministry of Universities of Spain (EST21/00255).

2020-2022   (1 year and 10 months): Predoctoral fellowship from the Ministry of Education and Vocational Training of Spain (FPU19/02462).

2020-2020   (4 months): Predoctoral fellowship from the Univeristat Jaume I (PREDOC/2019/60).

Research projects

2022-2023   Efectos de los descansos activos en el aula sobre la cognición, las emociones y la actividad física diaria del alumnado universitario: proyecto ACTIVCLASS2UJI (UJI-B2022-37).

2022-2023   Efectos agudos de la actividad física sobre la cognición y la actividad cerebral en adolescentes (ACT4BRAIN) (CIGE/2021/053).

2020-2022   Rendimiento académico y cognitivo: relación con los hábitos activos en alumnado de bachillerato (UJI-A2019-12).

2019-2021   Análisis de los efectos del acoso escolar sobre el rendimiento académico, el riesgo cardiovascular y el bienestar psicológico en adolescentes obesos (DADOS-BC study) (UJI-B2018-40).

2016-2018   Influencia de la actividad física sobre la salud cardiovascular y la capacidad cognitiva durante la adolescencia (DADOS-C study) (P1·1A2015-05).

2016-2017   Influencia de la práctica deportiva competitiva sobre la salud física, el bienestar psicológico y el rendimiento académico durante la adolescencia (DADOS study) (DEP2013-45515-R).

Research stays

2021-2022   (3 months): Research stay at the Department of Epidemiology, Erasmus University Medical Center, Rotterdam (The Netherlands).

Research courses attended

2022-2023   Bibliographic resources and digital profiles for research in open knowledge (30 hours).

Safety and health in research activity (25 hours).

2021-2022   Reproducible research practices (20 hours).

2020-2021   Communication and dissemination of research (25 hours).

English for research (50 hours).

Research techniques in education seminar (38 hours).

2019-2020   Methodologies and techniques of social research applied to research (60 hours).

Learning from data. Multivariate analyses (40 hours).

Research and gender perspective (20 hours).

Protection of personal data in research (10 hours).

2018-2019   How to write and publish a scientific paper (40 hours).

Courses and lectures taught

2021-2022   MP1870: Physical Activity and Health in Elementary Education (2.4 ECTS).

MP1849: Fundamentals of Motor Skills and its Educational Implications in Elementary Education (1.8 ECTS).

MI1038, MI1856, and MP1858: Practicum (1.8 ECTS).

2020-2021   MP1849: Fundamentals of Motor Skills and its Educational Implications in Elementary Education (2.5 ECTS).

MP1041: Practicum in Physical Education (3.6 ECTS).

Main contributions to scientific conferences

2022   27th Annual Congress of the European College of Sport Science. *The mediating role of emotional symptoms in the association between fitness and academic performance: DADOS study.* European College of Sport Science. Seville (Spain).

XVII Jornadas de Fomento. "*La actitud hacia el instituto y el rendimiento académico durante la etapa de Educación Secundaria Obligatoria.*" Universitat Jaume I.

VII Jornadas de Investigación para alumnado de la Facultad de Ciencias de la Salud. *"Estado de salud mental en chicos y chicas durante la adolescencia: proyecto DADOS."* Universitat Jaume I.

2021   I Congreso Internacional en Inteligencia Emocional en Entornos Educativos. *"Bienestar emocional percibido y rendimiento académico en adolescentes: Proyecto DADOS."* Universitat Jaume I.

I Congreso Internacional en Inteligencia Emocional en Entornos Educativos. *"Los síntomas emocionales y su relación con el rendimiento académico en adolescentes: Proyecto DADOS."* Universitat Jaume I.

I Congreso Internacional DOTS a l'Àgora. *Screen time during the Spanish COVID-19 confinement in a group of adolescents: DADOS study.* Universitat de Lleida.

XXVI Jornadas de Fomento. "*El tiempo de pantalla se asocia con el riesgo de depresión durante la adolescencia: proyecto DADOS.*" Universitat Jaume I.

VI Jornadas de Investigación de la Facultad de Ciencias de la Salud. *Physical activity and sensitivity to reward in active and sedentary young adults.* Universitat Jaume I.

2020   VI Congreso Internacional en Contextos Psicológicos, Educativos y de la Salud. *Prevalence and types of bullying and cyberbullying in a group of adolescent girls and boys: DADOS study.* Universidad de Almería.

VI Congreso Internacional en Contextos Psicológicos, Educativos y de la Salud. *Risk of depression and academic performance in adolescents: DADOS study.* Universidad de Almería.

VII Spanish Nutrition Society Young Researchers' Meeting. *Diet and risk of depression in secondary school students: DADOS study.* Sociedad Española de Nutrición.

XXV Jornadas de Fomento. "*Bullying y cyberbullying en un grupo de adolescentes de la provincia de Castellçon: proyecto DADOS.*" Universitat Jaume I.

2019   IV Jornadas de Investigación para alumnado de la Facultad de Ciencias de la Salud. *Estado de salud y rendimiento académico en adolescentes: proyecto DADOS.* Universitat Jaume I.

Main scientific publications

Monzonís-Carda, I., Adelantado-Renau, M., Beltran-Valls, M.R., and Moliner-Urdiales, D. Mental health and academic performance in adolescent boys and girls: elucidating the role of psychological well-being and psychological distress. DADOS study. *Under review in the European Journal of Psychology of Education.*

Monzonís-Carda, I., Rodríguez-Ayllon, M., Adelantado-Renau, M., and Moliner-Urdiales, D. Bidirectional longitudinal associations of mental health with academic performance in adolescents: DADOS study. *Under review in the journal of Learning and Individual Differences.*

Monzonís-Carda, I., Adelantado-Renau, M., Beltran-Valls, M.R., and Moliner-Urdiales, D. (2023). Risk of depression mediates the association between cardiorespiratory fitness and academic performance in adolescent boys and girls: DADOS study. *European Journal of Pediatrics, 182* (1), 67-77. https://doi.org/10.1007/s00431-022-04645-y

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