

# Unveiling the relationship of physical literacy with muscular fitness and muscle-strengthening activities in adolescents: the EHDLA study

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## ABSTRACT

**Objective** This study evaluated the relationship between physical literacy (PL) and muscular fitness (MF) as well as muscle-strengthening activities (MSA) in adolescents.

**Methods** A secondary cross-sectional study included 823 adolescents (45.1% boys) from the Eating Healthy and Daily Life Activities Study. The Spanish Perceived Physical Literacy Instrument for Adolescents (S-PPL) assessed the participants' perceived PL. The evaluation of MF in the young population was conducted using the Assessing the Levels of Physical Activity and Fitness (ALPHA-FIT) test battery. MSA were assessed by the following question: 'In the past week, how many days did you exercise to strengthen or tone the muscle, such as through push-ups, sit-ups or lifting weights?' To examine the associations between S-PPL scores and handgrip strength, standing long jump and MSA days in adolescents, we employed generalised additive models.

**Results** Participants with high perceived physical literacy (PPL) had the highest handgrip strength (mean=25.1; PPL had the highest handgrip strength (mean=25.1; bias-corrected and accelerated (BCa) bootstrapped 95% CI 24.2 to 26.0) and standing long jump (mean=149.7; confidence interval (CI) 24.2 to 26.0) and standing long jump (mean=149.7; BCa bootstrapped 95% CI 145.8 to 153.5). Conversely, those adolescents with low PPL had the lowest handgrip strength (mean=23.1; BCa bootstrapped 95% CI 22.3 to 23.8) and standing long jump (mean=137.3; BCa bootstrapped 95% CI 133.9 to 140.6). For MSA, adolescents with high PPL had the highest mean of MSA days (mean=3.0; BCa bootstrapped 95% CI 2.8 to 3.3), while the lowest mean was observed for those with low PPL (mean=2.0; BCa bootstrapped 95% CI 1.8 to 2.2).

**Conclusion** A high level of PL was associated with higher levels of MF and MSA among Spanish adolescents.

## INTRODUCTION

Insufficient physical activity levels are widely recognised as a significant public health issue in the 21st century.<sup>1 2</sup> A large proportion of children and adolescents do not engage in sufficient physical activity,<sup>3 4</sup> and the stability of physical activity behaviours is moderate to high along the life course from youth to

## WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Physical literacy is an important concept that has emerged as a potential determinant of lifelong physical activity participation.
- ⇒ No previous research has examined the relationship between PL and the different domains of physical fitness, including muscular fitness, in adolescents.

## WHAT THIS STUDY ADDS

- ⇒ A high level of physical literacy was associated with higher levels of muscular fitness and muscle-strengthening activities among Spanish adolescents.
- ⇒ All physical literacy domains were positively associated with greater muscular fitness and muscle-strengthening activities in both boys and girls.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ These findings could be used to integrate PL into interventions to increase muscular fitness and muscle-strengthening activities frequency in adolescents.

adulthood.<sup>5</sup> This lack of physical activity is closely related to low physical fitness levels among adolescents, as physical activity directly influences physical fitness.<sup>6</sup> Given the global prevalence of insufficient physical activity among youth, researchers have hypothesised that the existence of a determining factor or link contributes to this deficiency.<sup>7 8</sup> One potential factor investigated is movement competence, which refers to developing skills required for efficient performance in various movements and activities.<sup>9</sup> In support of this contention, previous studies have shown a positive association between movement competence and physical activity.<sup>10-12</sup> Consequently, it has been suggested that a more complex construct, beyond movement competence alone, may be associated with physical activity engagement.<sup>10</sup>

Physical literacy (PL) is an important concept that has emerged as a potential determinant of lifelong physical activity participation.<sup>13</sup> As a multidimensional

construct, PL has been gaining attention in the research community, and scholars are beginning to reach a consensus for some of its defining components.<sup>14</sup> PL has been defined as ‘the motivation, confidence, physical competence, knowledge and understanding needed to value and take responsibility for engagement in physical activities for life’.<sup>13</sup> Accordingly, movement skills, competence, motivational constructs and embodied experience are highlighted as the core attributes of the PL concept.<sup>9,15</sup> PL is a holistic concept that includes physical, cognitive and affective domains. Thus, PL provides an innovative perspective for encouraging movement behaviours in terms of participating in physical activity and developing fundamental movement competence. Therefore, it is imperative to regard PL as a significant factor influencing physical activity, as PL pertains to the capacity of children to comprehend, interpret and apply information concerning physical activity and movement. Consequently, PL plays a vital role in enabling children to engage in physical activities in a safe and efficient manner, as well as in cultivating healthy habits longitudinally. Children possessing an optimal level of PL are more predisposed to exhibit motivation and confidence in participating in physical activities and sports, thus fostering an active and wholesome lifestyle. This is particularly critical due to the WHO recommendations for children and adolescents to engage in a minimum of 60 min of moderate-to-vigorous intensity physical activity daily.<sup>16</sup>

In support of these findings, research has found that children with higher levels of PL are likelier to meet physical activity guidelines than those with lower levels of PL.<sup>17</sup> Brown *et al*<sup>18</sup> pointed out positive associations between PL levels and engagement in physical activity in children, as well as improvements in cardiorespiratory fitness (CRF).<sup>19</sup> Individuals with higher PL are more likely to meet the recommended levels of physical activity, according to Kanellopoulou *et al*.<sup>20</sup> Recent research by Caldwell *et al*<sup>21</sup> has further emphasised the importance of higher PL levels in determining an adolescent’s health. Individuals with higher levels of PL have been found to have a lower body fat percentage, quicker recovery from progressive aerobic tests (as indicated by a lower post-exertional heart rate), lower resting systolic blood pressure and better overall quality of life. Therefore, PL plays an important role in promoting an active lifestyle during childhood and adolescence and can also influence an individual’s health throughout the growing years.

To our knowledge, no previous research has examined the relationship between PL and the different domains of physical fitness, including muscular fitness (MF), in adolescents. Moreover, no correlational study has been carried out on the link between PL and health in adolescents. Therefore, a higher level of PL among adolescents could be associated with higher levels of MF and muscle-strengthening activities (MSA), which are determinants of long-term health.<sup>16,22</sup> Thus, this study

evaluated the relationship between PL, MF and MSA in adolescents.

## MATERIAL AND METHODS

### Study design and population

In this cross-sectional study, we conducted a secondary analysis using data from the Eating Healthy and Daily Life Activities (EHDLA) project. The EHDLA Study protocol has been previously described.<sup>23</sup> The sample for this study included adolescents (12–17 years) who were enrolled as students in three secondary schools located in Valle de Ricote, Region of Murcia, Spain. Data were collected during the 2021–2022 academic year. Regarding the exclusion criteria, adolescents were ineligible for enrolment if they: (1) were exempt from participating in physical education classes at school since the tests and questionnaires were completed during physical education lessons, (2) had any medical condition that limited physical activity or required special attention, (3) were undergoing any form of pharmacological treatment, (4) had a lack of authorisation from a parent or legal guardian to participate in the research project or (5) declined to participate in the research project.

The participants were provided with information regarding the study’s objectives and details about the assessments and questionnaires that would be administered.

Of the original 1378 adolescents involved in the EHDLA Study, 321 (23.3%) were removed from the analysis because of missing information on the following outcomes: handgrip strength ( $n=88$ ; 6.4%), standing long jump ( $n=14$ ; 1.0%) and MSA days ( $n=219$ ; 15.9%). Additionally, further exclusions were made for participants with incomplete data on perceived PL (PPL) ( $n=21$ ; 1.5%), body mass index (BMI) ( $n=43$ ; 3.1%) or energy intake ( $n=170$ ; 12.3%). Consequently, this secondary cross-sectional study included a sample of 823 adolescents (45.1% boys).

### Perceived physical literacy

The Spanish Perceived Physical Literacy Instrument for Adolescents (S-PPLI)<sup>24</sup> was used to assess the participants’ PPL. The S-PPLI has previously undergone validation for its applicability to Spanish youth. Initially designed for physical education teachers, the original Perceived Physical Literacy Instrument (PPLI) comprises 18 items.<sup>25</sup> However, the version adapted for use with adolescents in this study was condensed to nine items. Participants were instructed to rate these items on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The nine items of the S-PPLI were evenly distributed across three categories: self-perception and self-confidence, self-expression and interaction with others and knowledge and comprehension (online supplemental table S1).

### Muscular fitness

The evaluation of MF in the young population was conducted using the Assessing the Levels of Physical

Activity and Fitness (ALPHA-FIT) test battery.<sup>26</sup> To assess upper body muscular strength, the handgrip strength test was conducted using a hand dynamometer with an adjustable grip (TKK 5401 Grip D, Takei, Tokyo, Japan). Participants were provided with a brief tutorial and verbal instructions about the test. The dynamometer was adjusted according to the child's hand size, and the test was performed while the child was standing with the elbow extended and the wrist in a neutral position. Participants were verbally encouraged to 'squeeze as hard as possible' and exert their maximal handgrip strength for at least 2 s. The test was conducted twice for each hand, and the highest score for each hand was recorded. The average of the highest scores from both hands was used for further analysis. Additionally, normalised handgrip strength was calculated as the average left and right handgrip strength divided by body weight (kg).

For lower body muscular strength, the standing broad jump test was performed. Participants started behind a designated line with their feet together and jumped forward as far as possible. The distance was measured from the take-off line to the position where the back of the heel nearest to the take-off line lands on the floor. The test was performed twice, and the highest score (in cm) was selected for analysis.

### Muscle-strengthening activities

MSA were assessed by the following question: 'In the past week, how many days did you exercise to strengthen or tone the muscle, such as through push-ups, sit-ups, or lifting weights?' The possible responses were as follows: (a) none, (b) 1 day, (c) 2 days, (d) 3 days, (d) 4 days, (d) 5 days, (g) 6 days and (h) 7 days. This question has been used for health behaviour surveillance in different countries (eg, USA,<sup>27</sup> Canada<sup>28</sup> and China).<sup>29</sup> Similarly, this question was proven to have acceptable reliability for the young population ( $\alpha > 0.55$ ).<sup>14</sup> Participants who self-reported an engagement in  $MSA \geq 3$  days in the previous week were considered to meet the MSA WHO recommendations.<sup>16</sup>

### Covariates

The adolescents self-reported information regarding their sex and age. Socioeconomic status was evaluated using the Family Affluence Scale III (FAS-III),<sup>30</sup> which consists of responses to six items related to family possession and amenities, including bedrooms, vehicles, bathrooms, computers, travels or dishwashers. The FAS-III score ranged from 0 to 13 points, with higher scores indicating a higher socioeconomic status.

Physical activity and sedentary behaviour were assessed using the Youth Activity Profile Physical Questionnaire.<sup>31</sup> This self-administered questionnaire covered 7 days and included 15 items categorised into sections such as out-of-school activities, school-related activities and sedentary habits. The version validated in the Spanish population was used.<sup>32</sup>

The adolescents' body weight was measured using an electronic scale with an accuracy of 0.1 kg (Tanita BC-545, Tokyo, Japan). At the same time, height was determined by a portable height rod with an accuracy of 0.1 cm (Leicester Tanita HR 001, Tokyo, Japan). Subsequently, BMI was computed by taking the participants' body weight in kg and dividing it by the square of their height in m.

Energy consumption estimates were derived from a self-administered food frequency questionnaire, previously validated for the Spanish population,<sup>33</sup> which incorporated measuring portions consumed in the last month. Adherence to the Mediterranean diet was assessed using the Mediterranean Diet Quality Index for Children and Adolescents.<sup>34</sup>

Adolescents were queried about their usual bedtime and wake-up times on both weekdays and weekends to calculate overall sleep duration. The average sleep duration during the week and on weekends was computed using the formula  $[(\text{average sleep duration on weekdays} \times 5) + (\text{average sleep duration on weekends} \times 2)] \div 7$ .

### Statistical analysis

Visual techniques such as density and quantile–quantile plots were used to evaluate the normality of the variables, as was the Shapiro-Wilk test. In relation to categorical variables, the descriptive statistics encompass the count (n) and the percentage (%) of occurrences within each category of PPL status. For continuous variables, the descriptive statistics included the median and the IQR (given the non-normal distribution of the variables). As preliminary analyses indicated no significant interaction effects between sex and variables such as handgrip strength ( $p = 0.302$ ), standing long jump ( $p = 0.302$ ) or MSA days ( $p = 0.563$ ), the main analyses were conducted without stratification by sex. However, secondary analyses were performed stratified by sex.

To examine the associations between S-PPLI scores and handgrip strength, standing long jump and MSA days in adolescents without assuming a specific nature of the relationship, we employed generalised additive models (GAMs). GAMs are flexible models capable of capturing non-linear relationships in the data without a predefined mathematical structure. In this analysis, we used the restricted maximum likelihood method for selecting smoothness,<sup>35</sup> and a shrinkage approach was implemented using thin plate regression spline smoothers.<sup>36</sup> As a sensitivity analysis, the associations between the individual domains of the S-PPLI (ie, self-perception and self-confidence, self-expression and interaction with others and knowledge and comprehension) and handgrip strength, standing long jump and MSA days in adolescents were also tested (globally and by sex). The effective degrees of freedom of the GAM was used to quantify the degree of non-linearity in the relationship.

Regarding PPL status (low PPL, medium PPL, high PPL), covariance was analysed to assess its association with handgrip strength, standing long jump and MSA days

**Table 1** Descriptive data of the study participants according to perceived physical literacy (PPL) status (N=823)

Variables		PPL status*†		
		Low (9–31 points) n=283 (34.4%)	Medium (32–36 points) n=295 (35.8%)	High (37–45 points) n=245 (29.8%)
Age (years)	Median (IQR)	14.0 (2.0)	14.0 (2.0)	14.0 (2.0)
Sex	Boys (%)	104 (36.7)	145 (49.2)	122 (49.8)
	Girls (%)	179 (63.3)	150 (50.8)	123 (50.2)
FAS-III (score)	Median (IQR)	8.0 (3.0)	8.0 (2.5)	9.0 (3.0)
YAP-S physical activity (score)	Median (IQR)	2.4 (0.8)	2.6 (0.8)	2.9 (0.8)
YAP-S sedentary behaviour (score)	Median (IQR)	2.6 (0.8)	2.6 (0.8)	2.4 (0.8)
Overall sleep duration (min)	Median (IQR)	492.9 (79.3)	497.1 (72.9)	497.1 (64.3)
Body mass index (kg/m <sup>2</sup> )	Median (IQR)	22.5 (6.9)	21.8 (6.0)	20.9 (5.4)
Energy intake (kcal)	Median (IQR)	2631.9 (1531.8)	2589.0 (1511.2)	2575.1 (1473.8)
KIDMED (score)	Median (IQR)	6.0 (4.0)	7.0 (3.0)	8.0 (3.0)
Handgrip strength mean (kg)	Median (IQR)	21.6 (9.2)	22.0 (8.8)	23.2 (9.8)
Standing long jump (cm)	Median (IQR)	131.0 (36.9)	142.0 (39.8)	152.0 (49.0)
MSA (days)	Median (IQR)	2.0 (3.0)	2.0 (3.0)	3.0 (3.0)
MSA recommendations status‡	Non-meeting (%)	195 (68.9)	154 (52.2)	81 (33.1)
	Meeting (%)	88 (31.1)	141 (47.8)	164 (66.9)

\*According to the Spanish-Perceived Physical Literacy Scale (S-PPLI).  
†S-PPLI ranges from 9 to 45 points.  
‡According to the World Health Organization guidelines.<sup>16</sup>  
FAS-III, Family Affluence Scale III; IQR, interquartile range; KIDMED, Mediterranean Diet Quality Index for Children and Adolescents; MSA, muscular-strengthening activities; PPL, perceived physical literacy; YAP-S, Spanish Youth Active Profile.

while adjusting for several covariates. A non-parametric bias-corrected and accelerated (BCa) bootstrap method with 1000 samples was employed for this analysis. After the analysis, multiple comparisons were corrected using the false discovery rate p value method developed by Benjamini and Hochberg.<sup>37</sup> The models were adjusted for several covariates, including age, sex, socioeconomic status, physical activity, sedentary behaviour, overall sleep duration, BMI, energy intake and adherence to the Mediterranean diet.

All the statistical analyses were performed using R statistical software (V.4.3.2) from the R Core Team in Vienna, Austria, and RStudio (V.2023.09.1+494) from Posit in Boston, Massachusetts, USA. The threshold for statistical significance was set at a p value of less than 0.05.

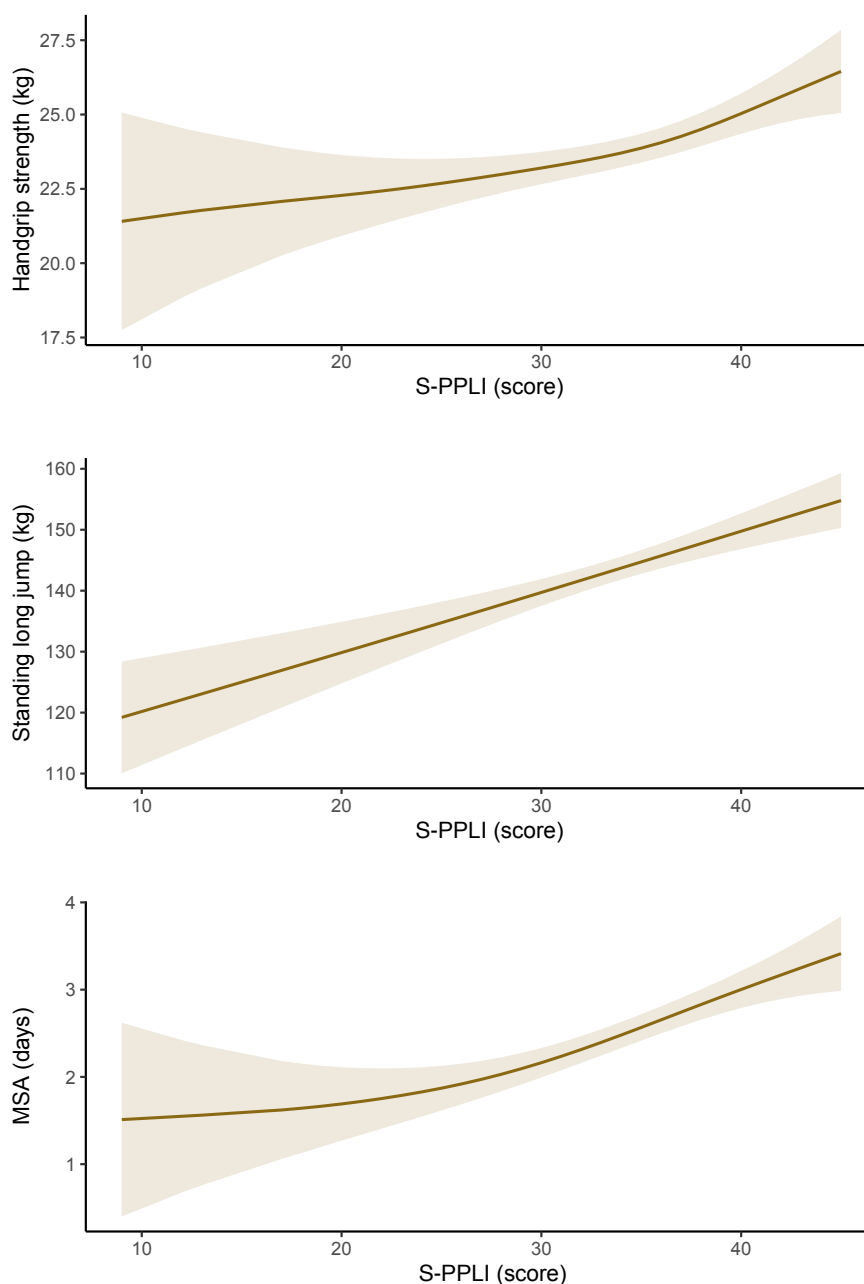
## RESULTS

The descriptive data of the sample of adolescents according to their PPL status are shown in table 1. The highest performance in terms of handgrip strength (kg), standing long jump (cm) and number of MSA days was found in those with high PPL (handgrip strength: median=23.2; IQR=9.8; standing long jump: median=152.0; IQR=49.0; MSA: median=3.0; IQR=3.0). Conversely, the lowest performance and MSA frequency were observed in adolescents with low PPL (handgrip strength: median=21.6; IQR=5.7; standing long jump: median=131.0; IQR=36.9; MSA: median=2.0; IQR=3.0).

Figure 1 displays the estimated marginal means and 95% CIs of handgrip strength, standing long jump, and MSA days in relation to the S-PPLI score through smoothed functions derived from GAMs. While the

approximate significance of the smoothing terms was statistically significant for all three outcomes ( $p < 0.001$ ), upon examining the figure and *edf*, we observed only a nonlinear relationship between the S-PPLI score and handgrip strength ( $F=2.28$ ;  $edf=2.24$ ;  $p < 0.001$ ) and MSA frequency ( $F=4.45$ ;  $edf=2.12$ ;  $p < 0.001$ ). After closely examining the figure and the *edf* for the standing long jump, we noticed that the *edf* value was close to 1, indicating that the association was linear ( $F=3.63$ ;  $edf=1.02$ ;  $p=0.001$ ). Secondary analyses stratified by sex are shown in online supplemental figure S1. Similarly, sensitivity analyses for the different S-PPLI domains (globally and by sex) are shown in online supplemental figure S2 and online supplemental figure S3, respectively.

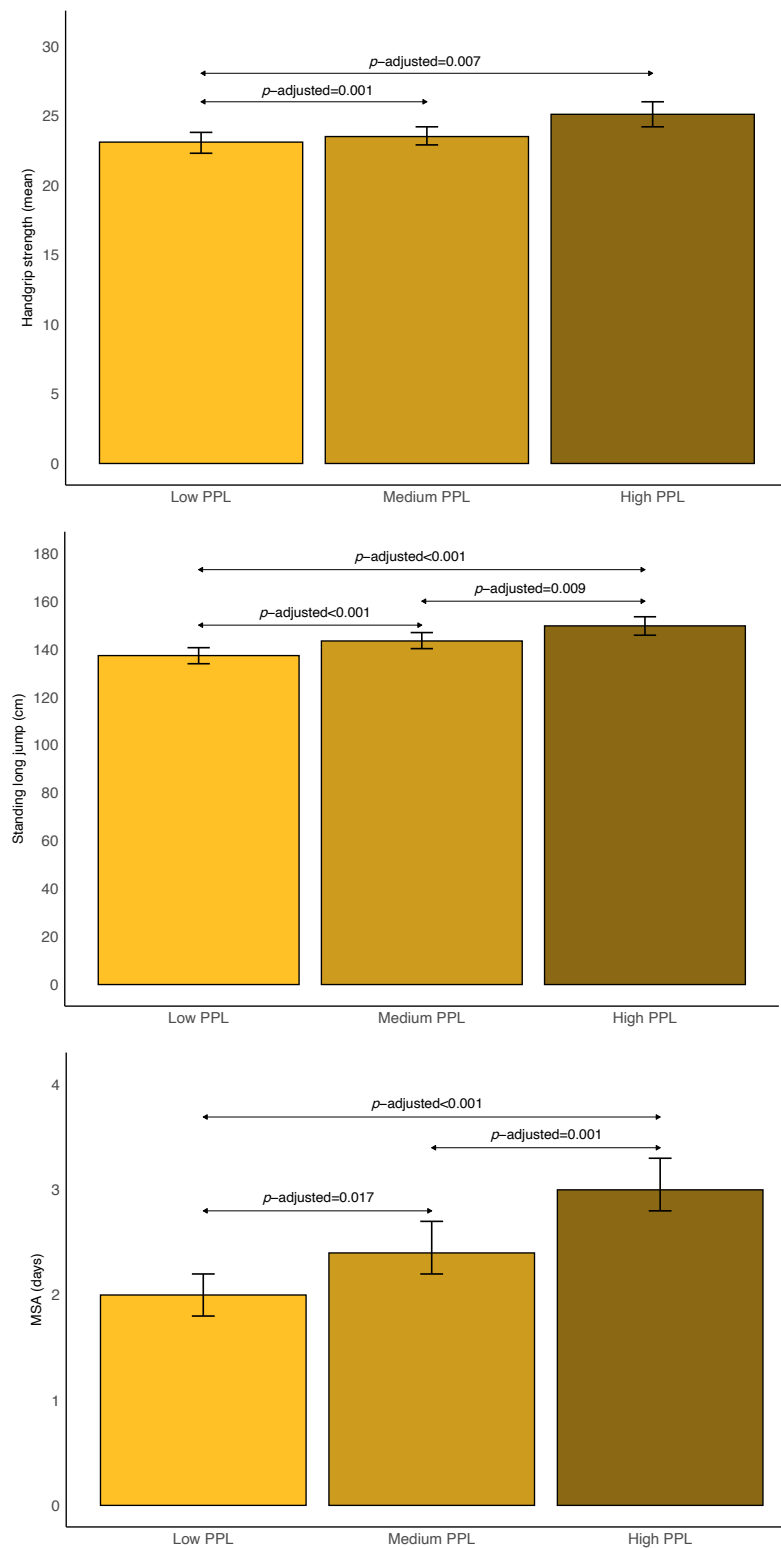
Figure 2 shows the estimated marginal means of handgrip strength, standing long jump, muscle-strengthening activities, and their BCa bootstrapped 95% CIs according to PPL status. Participants with high PPL had the highest handgrip strength (mean=25.1; BCa bootstrapped 95% CI 24.2 to 26.0) and standing long jump (mean=149.7; BCa bootstrapped 95% CI 145.8 to 153.5). Conversely, those adolescents with low PPL had the lowest handgrip strength (mean=23.1; BCa bootstrapped 95% CI 22.3 to 23.8) and standing long jump (mean=137.3; BCa bootstrapped 95% CI 133.9 to 140.6). For MSA, adolescents with high PPL had the highest mean of MSA days (mean=3.0; BCa bootstrapped 95% CI 2.8 to 3.3), while the lowest mean was observed for those with low PPL (mean=2.0; BCa bootstrapped 95% CI 1.8 to 2.2). Significant differences were found between high PPL and medium PPL for handgrip strength, standing long jump, and MSA days. Additionally, significant differences



**Figure 1** Relationships of perceived physical literacy with handgrip strength, standing long jump times and muscle-strengthening activities (MSA) in adolescents according to generalised additive models. The data are expressed as estimated marginal means (lines) and 95% CIs (shaded), adjusted for sex, age, socioeconomic status, adherence to the Mediterranean diet, energy intake, physical activity, sedentary behaviour, overall sleep duration and body mass index. S-PPLI, Spanish Perceived Physical Literacy Instrument.

were found between high PPL and low PPL for handgrip strength ( $p$ -adjusted=0.007), standing long jump ( $p$ -adjusted<0.001), and MSA days ( $p$ -adjusted<0.001). Similarly, significant differences were detected between high PPL and medium PPL for standing long jump ( $p$ -adjusted=0.009) and MSA days ( $p$ -adjusted=0.001). Moreover, significant differences were observed between medium PPL and low PPL for handgrip strength ( $p$ -adjusted=0.001), standing long jump ( $p$ -adjusted<0.001), and MSA days ( $p$ -adjusted=0.017). Finally, the highest

predicted probability of meeting the MSA recommendations was observed for adolescents with high PPL (63.7%, 95% CI 62.1% to 65.4%), followed by those with medium PPL (51.3%, 95% CI 49.8% to 52.8%), and those with low PPL (40.4%, 95% CI 38.7% to 42.0%) (data not shown in figure 2). Moreover, statistically significant differences were identified among adolescents with high PPL compared to those with low PPL, high PPL compared to medium PPL, and medium PPL compared to those with low PPL ( $p$ -adjusted<0.001 for all comparisons).



**Figure 2** Predicted mean values of handgrip strength, standing long jump and muscle-strengthening activities (MSA) among adolescents according to their physical literacy status. The data are expressed as estimated marginal means (bars) and bias-corrected and accelerated bootstrapped 95% CIs (lines), adjusted for sex, age, socioeconomic status, adherence to the Mediterranean diet, energy intake, physical activity, sedentary behaviour, overall sleep duration and body mass index. P values were adjusted using the correction for multiple comparisons proposed by Benjamini and Hochberg.<sup>38</sup> PPL, perceived physical literacy.

## DISCUSSION

This study examined the relationship between PL, MF and MSA in Spanish adolescents. As initially hypothesised, a high level of PL among Spanish adolescents was associated with higher levels of MF and MSA in both sexes. In recent years, the concept of the PL has gained attention due to its potential influence on daily physical activity in youth.<sup>38</sup> Initially introduced in education, particularly physical and sports education, PL has been recognised as a fundamental concept linking physical activity and health.<sup>21</sup> Cairney *et al.*<sup>39</sup> proposed a conceptual model that outlined the inter-relationship between PL, physical activity and health. Early empirical evidence has indicated that PL can serve as a pathway for developing and enhancing physical activity levels in adolescents.<sup>39</sup>

Since physical activity early in life is a predominant contributor to maintaining physical activity later in life, fostering the development of PL during childhood and adolescence can help to build a strong foundation for ongoing participation in physical activity and consequence maintenance of physical fitness throughout the life course.<sup>5</sup> It is essential to accurately understand the associations between physical fitness and physical activity and between physical fitness and the PL, as theoretically hypothesised by Cairney *et al.*<sup>39</sup> In our study, the highest measures of handgrip strength (kg) and standing long jump (cm) performance were found in adolescents with higher levels of PL as well as the highest number of MSA days. These data are consistent with a previous study of 85 French adolescents in which PL was associated with physical fitness (ie, CRF).<sup>39</sup> In a study by Nezonet *et al.*<sup>40</sup> which included adolescents, a significant positive association between the PPL Score and CRF was found with aerobic capacity as an indicator ( $r=0.40$ ;  $B=0.33$  95% CI: 0.13 to 0.53;  $p<0.05$ ), whereby for each additional point on the PPL Score aerobic capacity increased by 0.33 mL/kg/min<sup>-1</sup>. The authors noted that PL's influence on secondary school students' CRF was partly explained by the effect of weekly moderate-to-vigorous physical activity (MVPA).

In our study, the influence of PL on MF in adolescents could also be explained, at least in part, by the effect of weekly MVPA (measured in min per week). Adolescents with high PL status displayed greater Youth Activity Profile Physical Questionnaire (composite score) levels than those with low PPL status. Of note, in the study by Nezonet *et al.*<sup>40</sup> significant differences were observed in the PPL Score between male and female participants, which differ from our findings that demonstrated no interaction between sex and study variables. The differences could be due to the fitness performance of the boys in our study, who exhibited greater performance than the girls in the maximal aerobic speed test, maximal oxygen uptake and weekly MVPA.

Foundational movement competence development is hypothesised to vary according to culture and/or geographical location, and skill development may be hindered or enhanced by physical (ie, fitness, weight

status) and psychological (ie, perceived competence, self-efficacy) attributes.<sup>41</sup> Psychological elements, specifically self-efficacy (the belief in one's ability to achieve success) and perceived competence (the perception of actual capability), play a significant role in the formation of the broader construct known as 'self-concept' and are crucial factors influencing engagement in physical activities.<sup>42-43</sup> Notably, perceived competence has the greatest influence within the self-concept domain and is strongly associated with physical activity during childhood and adolescence.<sup>42</sup> Additionally, it has been observed that perceived competence acts as a mediator in the relationship between motor competence and physical activity among adolescents.<sup>44-45</sup> Thus, the development of PL allows for engagement in lifelong physical activity through improvements in motor skills and cognitive-emotional competencies,<sup>46</sup> integrating MF as a construct of 'motor skills' found in the definition and assessment of PL.<sup>47-48</sup>

In addition, previous research has indicated that self-concept and self-perception are related to an individual's level of engagement in physical activity.<sup>49-53</sup> Notably, youth who possess relatively low levels of self-concept at the start of an exercise programme may be more likely to show significant improvements compared with those who begin training with relatively high self-concept.<sup>54</sup> Notably, it has been reported that adolescent girls' physical self-perceptions improved following an 8-week resistance training programme.<sup>54</sup> Similarly, various self-concept measures have improved in adolescent boys and girls after 12 weeks of resistance training.<sup>55</sup>

Although the importance of PL is accepted, there is no global consensus about the most proper method of PL evaluation. As a result, authorities around the globe have developed unique PL concepts and, consequently, specific PL assessment tools.<sup>56-58</sup> For example, the Canadian Assessment of Physical Literacy and the Physical Literacy Assessment of Youth assessment tools are the most popular and commonly used in research. In the present study, the S-PPLI, which was previously validated for its applicability in Spanish youth, was used. The original PPLI comprises 18 items<sup>25</sup>; however, the version adapted for adolescents in this study was condensed into nine items, including self-perception and self-confidence, self-expression and interaction with others and knowledge and comprehension.

The PL domains (ie, motivation, confidence, physical competence, knowledge and understanding) are inter-correlated and essential for supporting participation in physical activity during adolescence and adulthood.<sup>59</sup> The attributes of physical competence in the multidimensional construct of PL have close connections with the domains of physical fitness. As such, the two constructs are connected through common underpinning components. Consistent with these findings, in our study, all categories were positively associated with greater MF and MSA in adolescents (boys and girls).

While the results obtained from this study are valuable, it is important to interpret them with caution due to certain limitations. Using a cross-sectional approach in this study means that establishing a direct cause-and-effect relationship based on the findings is not feasible. Further research employing different methodologies, such as interventions, is necessary to explore whether higher levels of PL are linked to increased MF or MSA days in youth. Additionally, relying on questionnaires to collect data on PL and other variables may introduce bias, as differences in willingness to disclose information or inaccuracies in recall details could impact the results. Also, based on our knowledge, since late childhood and early adolescence cannot be defined by fixed chronological boundaries, childhood can be defined as the first birthday to the onset of adolescence (which requires the identification of the onset of sexual maturation). Adolescence is a difficult period to define, and some suggest a range of 10–22 years in boys. WHO states adolescence begins with the onset of normal puberty and ends with adult identity, roughly 10–19 years of age.<sup>16</sup> However, significant interindividual variance exists for the level (magnitude of change), timing (onset of change) and tempo (rate of change) of biological maturation. The relative mismatch and wide variation in biological maturation between children of the same chronological age emphasises the limitations in using chronological age as a determinant.

However, a strength of this study lies in the objective assessment of MF through assessments that are widely accepted and validated in youth,<sup>26</sup> as well as the evaluation of PL using a previously validated tool in Spanish adolescents.<sup>24</sup> Furthermore, we used GAMs to capture non-linear and complex relationships between variables. This flexible approach improves the accuracy of exploring significant associations, providing a complete understanding of the association between PL and MF levels and MSA frequency. Finally, our analyses considered several sociodemographic and anthropometric variables, contributing to the reliability of our findings.

In conclusion, a high level of PL was associated with higher levels of MF and MSA among Spanish adolescents. These findings could be used to consider PL in interventions to increase MF and MSA frequency in adolescents. Further research in this area is warranted to fully understand how PL influences PA participation and health outcomes such as physical fitness in children and adolescents.

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