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Artistic swimming and school engagement: the mediating role of metacognition and technology

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This article presents a cross-sectional study that explores the association between artistic swimming and school engagement in a sample of 500 Italian adolescents. The study aimed to examine whether the practice of artistic swimming would foster strategic metacognitive skills. These skills, in turn, were hypothesized to positively influence school engagement and reduce recreational technology use, which could pose a risk to school engagement. The findings revealed that the relationship between artistic swimming and scholastic engagement, encompassing both cognitive and behavioral aspects, was entirely mediated by metacognitive strategies and reduced recreational technology usage. Moreover, students engaged in artistic swimming exhibited significantly higher levels of metacognitive strategies and scholastic engagement compared to their counterparts involved in other sports. The article also addresses the limitations inherent in the cross-sectional design and suggests potential avenues for future research.

KEYWORDS

engagement, metacognition, technology, artistic swimming, mediation

Introduction

Participation in physical activities (PA) is widely linked to good health and a lower chance of incurring health-threatening conditions. The positive physiological effects of physical activity tend to reduce, among others, problems related to blood pressure and cardiovascular disease, obesity, bone problems, and, more generally, are linked to a higher quality of life and a lower risk of mortality (Gutin et al., 2004; Bailey, 2006; Payne and Isaacs, 2020).

A vast amount of studies have shown that the positive effects of physical activity are particularly relevant during youth, especially when children aged 5 to 17 years participate in moderate to intense physical activities lasting about 60 min a day (Eime et al., 2013) due to increases in metabolism, oxygenation, and blood flow providing hormones that promote neurological health (Chaddock-Heyman et al., 2014). In addition to physiological modification, PA impacts on affectivity, lifestyle, and social and cognitive skills of young people (Bowker et al., 2003; Bailey, 2006; Bowker, 2006; Toriola et al., 2010; Collins et al., 2018).

A multitude of research endeavors have been undertaken to elucidate the influence that optimal levels of aerobic fitness can wield over academic performance and overall well-being. Interest in the benefits of PA and sports is particularly high in the wake of the

COVID-19 pandemic, given that sports can support the development of a more resilient, sustainable, and healthier society capable of better facing future global health and economic threats (European Commission, 2022).

Numerous research studies have focused on what types and modes of physical activity can lead to the best academic outcomes (Dwyer et al., 2001; Bailey, 2006; Chaddock-Heyman et al., 2014; McPherson et al., 2018). A recent meta-analysis (Bruner et al., 2021) explored the effect of sport-based interventions (SBI) on the promotion of positive youth development outcomes (PYD). Although the weakness of some studies included in the meta-analysis, authors found a statistically significant influence between PYD and some psychosocial categories such as competence, confidence, and life skills that can be useful also in educational contexts.

In their systematic review, Marques et al. (2018) highlighted a lack of consensus in this field of research about the relationship between physical activity and academic achievement. They identified a positive and significant association between cardiorespiratory fitness and academic achievement in all reviewed studies but this relationship was not found when physical activity was assessed with objective measures.

Although the impact of physical activity practiced in school on students' psychophysical development has been extensively researched, the effect of physical activity and sports undertaken outside of school on student development remains less clear. While previous studies have focused mainly on executive functions (e.g., Contreras-Osorio et al., 2022) and academic achievement, there is significant interest in exploring the impact on other variables, such as scholastic engagement, metacognitive skills, and the use of technologies for recreational purposes. The construct of school engagement has garnered much attention both because it predicts school achievement (Ladd and Dinella, 2009; Wang and Eccles, 2012) and because it acts as a protective factor against school dropout and behavioral problems (Li and Lerner, 2011; Wang and Fredricks, 2014). Metacognition is a much-debated construct whose usefulness has been widely discussed (Boer et al., 2018; Marulis et al., 2020). Metacognition can be considered a predictor of engagement since it compensates for students' lack of interest or self-control (Wang et al., 2021). Finally, there is general agreement that intensive use of technology for recreation may be a risk factor for growth and academic achievement (Adelantado-Renau et al., 2019) and that is related to physical activity (Ishii et al., 2020).

The present study proposes cross-sectional research in which levels of school engagement, metacognition, and use of technologies for recreational purposes will be compared between teenagers who practice artistic swimming and others who participate in other sports. Moreover, the study hypothesizes that the relationship between synchronized swimming and cognitive and behavioral engagement is mediated by metacognitive strategies and the number of hours of technology used for recreational purposes. The choice of artistic swimming is strategic since this sport has unique characteristics that distinguish it from others, and at the time of writing this article, the authors are not aware of any studies focused on the psychological impact of artistic swimming training on youth development.

Artistic swimming is a sports discipline that incorporates skills attributable to swimming, dance, and artistic gymnastics. These skills are very different from those required in other sports or general physical activity. Despite the fact that the roots of artistic swimming can be traced back to the late 19th century, its inclusion in the Summer Olympic Games is a relatively recent occurrence, with the sport making its debut in 1984 at the Helsinki Games. From a psychological point of view, artistic swimming arouses special interest since, compared with other sports or a generic physical activity, it brings together a set of skills that are very different from each other. Taking into consideration Schmidt and Lee (2011) classification, artistic swimming can be considered a sport that stimulates both so-called closed skills, skills not directly influenced by the surrounding environment typical of predictable situations (e.g., performing specific dance figures), and open skills in which athletes have to adapt their skills to an unpredictable environment (e.g., the continuous adaptation that a group performance requires to execute the planned pattern). Athletes practicing artistic swimming must rely on their awareness of signals from their muscles and skeletal structure to maintain body position underwater, as they cannot rely on real-time feedback from coaches. Additionally, they must work with their teammates to achieve synchronized patterns and figures while self-regulating and monitoring their progress toward the set goal.

In the following paragraphs, theoretical insights related to engagement, metacognition, and the use of technologies for recreation will be provided, and then the research and its results will be described in detail.

Student engagement

Astin's seminal work in the 1980s defined student engagement as "the amount of physical and psychological energy that the student devotes to the academic experience," which has since been a topic of interest for researchers and policymakers (Astin, 1984, p. 297). Actually, in subsequent definitions, the concept of engagement has become more complex and multifaceted, and even today there is no absolute agreement on its definition and components. While some authors have described student engagement in terms of institutional and socio-political factors, as well as the dynamic interaction between the student and educational practices, most engagement studies focus solely on psychological factors related to student engagement and rarely analyze engagement on a systemic level (Kahu, 2013; Picton et al., 2018).

Although some authors have proposed a two-dimensional model in which engagement is composed of behavior and emotion (Finn, 1989; Marks, 2000), most studies adopt a model in which three components are present: behavioral (positive conduct, absence of disruptive behavior, on-task attention, effort), emotional (quality of emotional relationships with teachers, peers, and school: enthusiasm, interest, absence of anger, anxiety, and boredom), and cognitive (being thoughtful, strategic, be capable of self-regulation and willing to learn) (Fredricks et al., 2004; Eccles, 2016). Reeve and Tseng proposed including the agentic dimension as a fourth dimension, defined as "the students' constructive contribution into the flow of the instruction they receive" (Reeve and Tseng, 2011, p. 258).

The engagement construct has achieved considerable academic success because it is a strong predictor of students' outcomes, progress, and achievement but also because engaged students are less at risk of boredom, alienation, problem behaviors, and dropout (Ladd and Dinella, 2009; Li and Lerner, 2011; Finn and Zimmer, 2012; Wang and Eccles, 2012; Wang and Fredricks, 2014).

Artistic swimming and engagement

Studies that evaluate the potential impact of sports participation on students' engagement, as far as the authors know, have yet to be proposed. The present study hypothesizes that those who practice artistic swimming might have higher levels of cognitive and behavioral engagement at school. Artistic swimming integrates several sports disciplines within it and, most importantly, adopts a training routine that is informally isomorphic to some of the best practices for stimulating metacognitive strategies, i.e., providing explicit prompts to assist practitioners in enhancing their self-regulation skills (Schraw, 1998), asking strategic questions before and after the execution of an athletic gesture (Kramarski and Mevarech, 2003), and using cooperative or collaborative learning situations (Kramarski and Mevarech, 2003; Teng and Reynolds, 2019; Teng, 2020).

As a consequence, the study hypothesized also that:

> H1. Artistic swimmers have higher levels of cognitive engagement in school than those who participate in other sports.

According to Reschly and Christenson (2012), cognitive engagement influences students' academic and behavioral engagement. Given H1, the present study expects that being strategic and self-regulated fosters the emission of behaviors consistent with academic success. For this reason, the present study hypothesizes that:

> H2. Artistic swimmers have higher levels of behavioral engagement in school than those who participate in other sports.

Metacognition

Metacognition is a multidimensional construct that has a plethora of theoretical conceptualizations and definitions that impede a unified theoretical definition (Azevedo, 2020). The various theoretical models generally share the original idea of Flavell that metacognition is a process that involves "thinking about thinking" (Flavell, 1979; Lai, 2011) and that it is composed of two components: metacognitive knowledge and metacognitive regulation (Muijs and Bokhove, 2020; Chen and McDunn, 2022). In the formulation of Schraw and Moshman (1995), knowledge of cognition is the awareness that a person has concerning his knowing, a cognition about cognition. Knowledge of cognition assumes that a person in the course of performing an activity knows which cognitive strategy to use (declarative knowledge), how to apply it (procedural knowledge), and when (conditional knowledge). The regulation of cognition is instead a set of activities that help people control their cognitive processes through planning, monitoring, and evaluation while performing a task.

Cornoldi (1987) introduced the concept of metacognitive attitude, which refers to a person's positive attitude towards their mind and the ability to understand and use it effectively. This attitude, also known as a general tendency to reflect on one's cognitive activity and think about ways to improve it, influences the ability to think about a task and use metacognitive knowledge (Cornoldi, 2010). Cornoldi identified metacognitive strategies as one of the most vital skills in educational contexts, as they entail accurately comprehending tasks, establishing relevant goals, and adapting necessary steps accordingly.

Given that artistic swimming training may foster these abilities, the present study postulates that they constitute some of the most stimulated skills in this type of training. Consequently, metacognitive strategies are among the variables included in this investigation.

Sport, artistic swimming, and metacognition

Although studies on the origin and development of metacognition are quite controversial (Gascoine et al., 2017), some authors (Whitebread et al., 2009; Whitebread and Basilio, 2012) provided evidence of verbal and non-verbal indicators of metacognitive and self-regulatory processes with subjects in the age range of 3 to 5 years, while there is some agreement that metacognitive skills in a narrow sense emerge around 8 years (Bartsch et al., 2003; Veenman et al., 2004).

Metacognitive skills are present from preschool age and become more refined and complex during students' formal education (Roebers and Spiess, 2017). According to some authors, these metacognitive skills could be learned within specific domains and then, especially during adolescence, be progressively integrated into a repertoire of skills that can be generalized to different domains (Veenman and Spaans, 2005; Van Der Stel and Veenman, 2014). According to Van Der Stel and Veenman (2014), during early adolescence (12–15 years old) metacognitive skills do not develop linearly, are independent of intellectual ability, and are predominantly general by nature over the years.

One of the ways to stimulate metacognitive skills is through sports. As stated by Augustyn and Rosenbaum (2005), "if intellectual and perceptual-motor skills rely on similar mechanisms, one would expect metacognition to apply to the guidance of perceptual-motor skills, just as it does to the guidance of intellectual skills" (p. 911). Metacognitive processes and inferences not only play an important role in the acquisition of sports skills (MacIntyre et al., 2014) but in turn have an impact on the mental abilities of its practitioners. Tomporowski et al. (2015) suggested that cognitive and metacognitive processes may play an important role in mediating the connection between physical activity and academic performance. The authors conducted a comprehensive review encompassing both quantitative interventions (which consider aspects such as intensity, duration, or frequency of physical activity) and qualitative interventions (which emphasize the cognitive engagement required during exercise). They argued that these interventions can potentially impact various facets of children's cognition and metacognition, although the precise effects on metacognition remain a topic of ongoing investigation. A systematic review of school-based physical activity interventions (Alvarez-Bueno et al., 2017) found that such programs have a positive impact on metacognitive skills in children and adolescents, with older participants showing a greater effect. The review only looked at structured physical activity programs in schools, but the authors believe that the positive effects on health and cognitive function would likely extend beyond the school setting.

It is important to note that not all exercise produces the same results (Alvarez-Bueno et al., 2017) and that research shows that certain types of exercise, such as those that involve complex movements and cognitive control, have a greater impact on executive functions than others (Best, 2010). As reported in the meta-analysis

carried out by Heilmann et al. (2022), it was found that athletes participating in open skills exercises exhibit moderate advantages in executive functions compared to their counterparts engaged in closed skills exercises. This underscores the significance of heightened cognitive demands during training in open skills exercises.

The hypothesis that artistic swimming may confer a strategic advantage is rooted in the aforementioned theoretical statements and the distinctiveness of the sport. Artistic swimming requires athletes to perform complex movements in unison with their teammates, while simultaneously remaining in an unfamiliar environment that is dissimilar to dry land. Furthermore, synchronized swimming also involves intricate choreography, which is performed to music. The success of a performance is thus contingent upon monitoring factors such as team formation, music, advancement of teammates' arrangements, execution of movements, and mimicry. The combination of swimming and artistic expression creates a sport that not only requires physical strength, but also creativity, flexibility, and precise timing.

Metacognitive strategies are crucial to achieving goals, as athletes must recognize that each step must be completed in a specific sequence to achieve the desired outcome. After executing the routine, the athlete must reflect on their performance and identify areas for improvement through self-evaluation and analysis, which can include reviewing videos and assessing strength and endurance during the exercise. The athlete bears the responsibility of deciding whether modifications are necessary for specific exercises to achieve their desired performance objectives.

> H3. Artistic swimmers have higher levels of metacognitive strategies than those who participate in other sports.

Use of technologies for recreational purposes and scholastic engagement

The use of technologies for recreational purposes has seen a significant increase in the past two years, surpassing the growth seen in the four years before the outbreak of the pandemic of COVID-19. Children between the ages of 8 and 12 years old use about five and a half hours of screen media per day, while 13 to 18 years old use about eight and a half hours of screen media (Rideout et al., 2022). These results differ by gender, ethnicity, and household income. Recent research conducted in the UK revealed that social media usage among adolescents in the 13–15 age group was more prevalent among girls, while boys demonstrated a greater propensity for gaming activities (Twenge and Farley, 2021). Adolescent females exhibit a higher tendency than their male counterparts to perceive excessive social media use, and they express greater hesitancy towards discontinuing their engagement with social media. It is pertinent to note the differential patterns of online presence across ethnic groups, with Black and Hispanic teens standing out by being online more frequently than their White peers. A substantial proportion of Black and Hispanic teens claim to be online almost constantly, more than White teens. Furthermore, age plays a role in this context, with older teens, particularly those aged 15 to 17, exhibiting a higher likelihood of nearly constant internet usage. In addition, slight differences emerge based on household income: teens residing in households with an annual income exceeding $75,000 manifest a greater likelihood of possessing access to gaming consoles and to desktop or laptop computers (Vogels et al., 2022).

Approximately 30% of 8 and 9-year-olds possess their phones, while 70% of 12–13 year-olds and almost 90% of 14 and older also have one (Rideout et al., 2022).

The investigation of the relationship between technology use and school engagement is an area that has received limited attention in the past. Based on recent studies (Tafesse, 2020; Su and Huang, 2021), it appears that school engagement serves as a mediator between technology use and academic achievement. While Su and Huang (2021) found no significant direct effect of social media use by college students on their academic performance, Tafesse (2020) found that a direct negative impact of high social networking site usage on college students' academic performance is mediated by student engagement.

Although this topic is of particular interest, we are not aware of any other significant studies on the subject. The majority of studies focus on the relationship between technology use and academic performance which has been the subject of extensive controversial research in recent years considering the reported negative, positive, and null associations (Adelantado-Renau et al., 2019; Mundy et al., 2020; Cardoso-Leite et al., 2021; Morgan et al., 2021; Sampasa-Kanyinga et al., 2022; Tafesse, 2022).

Sport, artistic swimming, and use of technologies

Teenagers' intense use of technology for recreation can have negative repercussions on participation in physical activities and overall health status but physical activity can be a protective factor. A recent study with Japanese elementary school students (Mineshita et al., 2021) has highlighted that students with normal body weight, higher physical activity, better grades, and high sleep quality were those who had shorter screen time. Similar results are described by Bravo-Sánchez et al. (2021) who subjected a sample of 501 high school students to a series of physical tests prescribed by the Eurofit protocol to assess their flexibility, strength, and durability. Students with the highest mobile phone usage, regardless of gender, performed worse in physical fitness and academics compared to those in the low and medium mobile phone usage groups highlighting a positive relationship between physical fitness and academic performance. More in general, engaging in physical activity or sports, especially at a competitive level, has been found to have better academic outcomes than those who are sedentary (Muñoz-Bullón et al., 2017) and lead to better results in terms of adiposity, life satisfaction, happiness, stress levels, emotional health, and sleep quality (Wilhite et al., 2022).

Sports can thus provide a much-needed break from screens and technology, allowing people to disconnect and engage in face-to-face interactions and experiences. Additionally, physical activity has been shown to provide numerous physical and mental health benefits, which may also lead to a reduction in technology use for leisure as individuals may be more likely to prioritize physical activity over sedentary leisure activities.

Mediating role of metacognition and use of technologies

The mediation hypothesis suggests that there is a relationship between artistic swimming and cognitive engagement, but this relationship is not direct. Rather, it is proposed that the relationship is partially explained by the mediating variables of the use of technologies and metacognition.

As previously mentioned, high usage of leisure technology may jeopardize academic outcomes. A potential explanation for this phenomenon is rooted in the time displacement theory (Robinson et al., 2002), which posits that time allocated to an activity, like technology usage, necessitates a reallocation from other activities, consequently diminishing or supplanting them. Sports, particularly artistic swimming, demanding extended and consistent training, reduce the available daily time budget for leisure technology use. This could be a potentially protective factor against a range of sedentary lifestyle-related issues, such as obesity, poor posture, and eye strain (Adelantado-Renau et al., 2019; Mundy et al., 2020; Sampasa-Kanyinga et al., 2022; Tafesse, 2022). The in-depth immersion in technology use and its multifarious functionalities can deplete the level of scholastic engagement, thereby endangering students' executive function capacities (Doleck et al., 2018). The mediation hypothesis suggests that sports, specifically artistic swimming, might influence student academic engagement by reducing the hours spent on leisure technology.

The second mediator in the relationship between artistic swimming and scholastic engagement involves metacognitive strategies. Artistic swimming athletes must possess the ability to control their movements and timing, synchronize with their teammates, and perform intricate maneuvers with precision. These skills necessitate the constant application of metacognitive strategies, which are continually honed during training. Given that metacognitive processes may play an important role in mediating the connection between physical activity and academic performance (Tomporowski et al., 2015), and athletes engaging in open skills exercises exhibit moderate advantages in executive functions compared to their counterparts engaged in closed skills exercises (Heilmann et al., 2022), the second mediation hypothesis suggests that metacognitive skills stimulated through sports may prove beneficial in other domains of their lives like school engagement.

> H4. Metacognitive strategies and the number of hours employed using the technologies for recreational purposes mediate the relationship between artistic swimming and cognitive engagement in school.

> H5. Metacognitive strategies and the number of hours employed using the technologies for recreational purposes mediate the relationship between artistic swimming and behavioral engagement in school.

Materials and methods

All clubs listed on the website of the Italian Swimming Federation (FIN) were contacted via email asking those responsible to forward to their artistic swimming athletes a questionnaire. The present study considers a subject belonging to the group of artistic swimmers if ordering the sports the person indicated in the questionnaire for the level of participation (competitive > amateur) and the number of years of participation (in descending order), the artistic swimming is in the first position. Moreover, a further criterion is being a member of the FIN at the time of filling in the questionnaire.

Non-artistic swimming practitioners/athletes were recruited through their secondary schools. The study randomly selected 35% of secondary schools from each region in Italy, totaling 2,108 schools, using a list provided by the Italian Ministry of Education. The headmasters of these schools were contacted via email and asked to distribute a questionnaire to their students.

Sensitivity power analysis indicated that an independent samples t-test with 190 participants per group ($N = 380$) would be sensitive to the effect of Cohen's $d = 0.37$ with 95% power ($\alpha = 0.05$, two-tailed). A Monte Carlo power analysis simulation was conducted to estimate the statistical power of detecting indirect effects in mediation analysis, using a sample size of $N = 500$, 1,000 replications, and a confidence level of 95%. The analysis revealed that the first indirect effect (metacognitive strategies) was estimated to have a power of 0.94, indicating a high likelihood of detecting a true effect with the given sample size. Similarly, the power for the second indirect effect (use of technologies for leisure) was estimated to be 0.78, suggesting that the sample size of 500 is sufficient for detecting a true effect of this size with reasonably high power.

Participants were informed that the questionnaire's answers were anonymous and that there were no right or wrong answers. Data were collected only after participants got their informed consent. A privacy policy at the beginning of the questionnaire described to the participants the purposes and methods of treatment operated by the data controller on the personal data collected. The research was submitted to the ethics committee of the University Polyclinic "Paolo Giaccone" of Palermo and obtained a favorable opinion for its development (record number 02/2022 issued February 15, 2022). Data were collected from March to May 2022 and it is available at the URL: https://figshare.com/articles/dataset/Data/22210969.

Participants

A total of 514 subjects were involved in the study. Surprisingly, the number of individuals who report not playing sports is very low ($n = 14$). 189 subjects practice artistic swimming as their primary discipline while 311 perform other sports.

The mean age of the artistic swimming group was 14.0 years (SD = 1.03), and the mean age of the group engaged in other sports was 14.3 years (SD = 0.822). After excluding cases who did not play sports, a Pearson's chi-squared test was conducted to compare the frequency of males and females in the sample. The observed chi-squared value was 134.70, which was statistically significant ($p = 0.00$). The proportion of males and females between groups is different because artistic swimming is practiced almost exclusively by women while the other sports are practiced also by boys. These differences will be discussed as a limitation of the study.

Instruments

Sociodemographic questionnaire

The sociodemographic questionnaire included questions about gender, age, hours spent using technology for studying and for leisure, sports practice, how many sports, at what level, and for how many years.

Student engagement scale

The questionnaire investigates student engagement through three scales: affective, behavioral, and cognitive (Mameli and Passini, 2017). The present study considered only the behavioral and cognitive scales. For the first subscale, students were asked to indicate their level of agreement on a 7-point Likert scale (from 1 = strongly disagree to 7 = strongly agree) in items such as "As I study, I keep track of what I understand, not just whether I am getting the right answers" and "When I study, I try to connect what I am learning with my own experiences." For the cognitive engagement scale, a 7-point Likert scale of frequency was used (from 1 = never to 7 = always). Some examples of this scale are: "The first time my teacher talks about a new topic, I listen very carefully," and "I listen carefully in class." The internal consistency was satisfactory ($\alpha = 0.90$).

Questionario Metacognitivo sul metodo di studio (QMS)

QMS questionnaire, developed by the MT Group (Cornoldi et al., 2020), represents a validated instrument to evaluate students' study skills in lower secondary schools. This questionnaire examines 21 factors that underlie study skills, organized into four macro-areas. Specifically, this study focused on the subscale "Strategies for preparing for a test," which is part of the "metacognition and study" area, consisting of 12 items. QMS includes items like the following: "I try to anticipate the nature of the upcoming task," "I consistently ensure my comprehension of the study material by questioning myself or engaging in exercises," "While studying independently, I consistently dedicate a portion of my time to assessing my knowledge." The questionnaire employs a three-point Likert scale (1 = "A little," 2 = "Somewhat," 3 = "A lot") to measure the degree of agreement. The internal consistency of the subscales was deemed acceptable ($\alpha = 0.72$).

Results

Preliminary analysis

Table 1 presents the descriptive analysis of socio-demographic variables for two groups of participants: those who engage in other sports activities ($N = 311$) and those who engage in artistic swimming ($N = 189$). The table provides information on the distribution of sex, age, hours spent using technology for study and leisure, and the number of years engaged in sports for both groups.

Table 2 presents the descriptive statistics for sports other than artistic swimming. The sports undertaken by individuals who are not involved in artistic swimming exhibit considerable heterogeneity, and this diversity will be explored as a research limitation. The predominant sports disciplines involve two opposing teams vying to either gain control of a specified area or defend it, as exemplified by sports like soccer (20.90%) and basketball (5.79%). Additionally, there is a notable presence of competitive sports and athletic activities requiring participants to travel to different locations, as observed in swimming (22.83%). Finally, many subjects engaged in rhythmic or aesthetic sports such as artistic gymnastics (7.07%) or dance (6.11%).

TABLE 1 Descriptive analysis of socio-demographic variables.

	Other sportspeople ($N = 311$)	Artistic swimming ($N = 189$)	Overall ($N = 500$)
Sex			
Other	1 (0.3%)	3 (1.6%)	4 (0.8%)
Female	157 (50.5%)	186 (98.4%)	343 (68.6%)
Male	153 (49.2%)	0 (0%)	153 (30.6%)
Age			
Mean (SD)	14.3 (0.822)	14.0 (1.03)	14.2 (0.920)
Median [Min, Max]	14.0 [13.0, 16.0]	14.0 [13.0, 16.0]	14.0 [13.0, 16.0]
Hours technology for study			
Mean (SD)	1.90 (1.35)	1.91 (1.43)	1.90 (1.38)
Median [Min, Max]	2.00 [0, 8.00]	2.00 [0, 8.00]	2.00 [0, 8.00]
Hours technology for leisure			
Mean (SD)	3.62 (1.73)	2.68 (1.38)	3.27 (1.67)
Median [Min, Max]	3.00 [1.00, 8.00]	3.00 [0, 7.00]	3.00 [0, 8.00]
Nr. years competitive sport			
Mean (SD)	5.67 (4.92)	7.09 (4.51)	6.20 (4.82)
Median [Min, Max]	6.00 [0, 27.0]	7.00 [0, 30.0]	7.00 [0, 30.0]
Nr. years sports			
Mean (SD)	9.33 (4.67)	11.1 (4.89)	9.98 (4.82)
Median [Min, Max]	9.00 [1.00, 28.0]	10.0 [2.00, 30.0]	9.00 [1.00, 30.0]

Groups comparisons

The Shapiro–Wilk and Levene tests were conducted to evaluate the normality of the distribution and the homogeneity of the variances of the variable to be compared. Independent t-tests and Mann–Whitney U Tests were applied according to the result of this check. The comparison between sportspeople and artistic swimmers indicated that the latter scored higher in cognitive ($t(498) = 3.54$, $p = 0.00$, $d = 0.33$), and behavioral ($t(498) = 3.00$, $p = 0.00$, $d = 0.28$) engagement. Moreover, they reported higher scores in the metacognitive strategies ($W = 35{,}742$, $p = 0.00$, $d = 0.39$). Finally, they reported fewer hours per day of the use of technologies for leisure ($W = 20{,}262$, $p = 1.00$, $d = -0.60$).

Considering that the sample of artistic swimmers is almost exclusively composed of female subjects and that males and females may differ in cognitive abilities and academic performance, the comparison between individuals engaged in artistic swimming and those who are not has been repeated, with male subjects excluded from the sample to mitigate the potential influence of gender. The findings indicate that significant differences between the two groups persist, albeit with a slight reduction in the effect size observed in some comparisons (means, standard deviations, and medians of all comparisons are reported in Table 3).

TABLE 2 Descriptive statistics for non-artistic swimming sports.

Sport	Freq.	Freq. rel.
Swimming	71	22,8%3
Soccer	65	20,90%
Volleyball	26	8,36%
Artistic gymnastics	22	7,07%
Dance	19	6,11%
Basketball	18	5,79%
Rhythmic gymnastics	11	3,54%
Tennis	11	3,54%
Horseback riding	7	2,25%
Skating	6	1,93%
Skiing	6	1,93%
Karate	4	1,29%
Water polo	4	1,29%
Boxing	3	0,96%
Cycling	3	0,96%
Jujutsu	3	0,96%
Athletics	2	0,64%
Canoeing	2	0,64%
Fencing	2	0,64%
Handball	2	0,64%
Judo	2	0,64%
Parkour	2	0,64%
Rugby	2	0,64%
Snowboarding	2	0,64%
Beach tennis	1	0,32%
Biathlon	1	0,32%
Crossfit	1	0,32%
Javelin throwing	1	0,32%
Kick boxing	1	0,32%
Kung fu	1	0,32%
Latin American dance	1	0,32%
Motorcycling	1	0,32%
Mountain biking	1	0,32%
Pole acrobatics	1	0,32%
Running	1	0,32%
Sailing	1	0,32%
Shooting	1	0,32%
Twirling	1	0,32%
Yoseikan budo	1	0,32%
Zumba	1	0,32%

In conclusion, a comparative analysis was conducted between males and females to eliminate any potential gender-related impact on technology usage. The results indicated that there was no significant difference in the daily use of technology between males and females ($W = 25{,}464$, $p > 0.05$).

Mediation analysis

The mediation analysis was carried out using the PROCESS script for R Version 4.2 beta, developed by Andrew F. Hayes. The correlations between the primary study variables are presented in Table 4, while Table 5 provides the specifics of the mediation models.

Mediation of cognitive engagement by metacognitive strategies and the use of technology for leisure through artistic swimming

A significant positive relationship between artistic swimming and cognitive engagement was found ($\beta = 0.30$, $p < 0.001$), as demonstrated by the direct path coefficient from the predictor to the criterion in the absence of mediators. To explore the relationship between artistic swimming and cognitive engagement, a multiple mediation analysis was conducted using two mediators: metacognitive strategies and leisure time spent using technology. The results indicate that the model accounts for a significant amount of variance in the outcome variable ($R^2 = 0.24$, $p < 0.001$). A fully mediated relationship between artistic swimming and cognitive engagement was identified. The direct effect of artistic swimming on cognitive engagement was not statistically significant ($\beta = 0.12$, $p > 0.05$) in the presence of the mediators. Specifically, artistic swimming was found to have a positive association with metacognitive strategies ($\beta = 0.32$, $p < 0.001$) and a negative association with leisure time spent using technology ($\beta = -0.56$, $p < 0.001$). In addition, higher levels of metacognitive strategies ($\beta = 0.43$, $p < 0.001$) were associated with higher levels of cognitive engagement, while reduced leisure time spent using technology ($\beta = -0.11$, $p < 0.001$) was associated with lower levels of cognitive engagement.

The results of the mediation analysis (Figure 1) revealed significant indirect effects of artistic swimming on cognitive engagement through both metacognitive strategies (indirect effect = 0.14, 95% CI = [0.06, 0.22]) and leisure time spent using technology (indirect effect = 0.06, 95% CI = [0.01, 0.13]). This suggests that the effects of artistic swimming on cognitive engagement are entirely indirect, operating through the mediators. It is important to note that these effects were determined through bootstrapping with a 95% level of confidence and 10,000 bootstrap samples.

Mediation of behavioral engagement by metacognitive strategies and the use of technology for leisure through artistic swimming

The direct path coefficient from the predictor to the criterion in the absence of mediators demonstrated a significant positive association ($\beta = 0.16$, $p < 0.001$) between artistic swimming and behavioral engagement. An investigation of the relationship between artistic swimming and behavioral engagement was carried out using a multiple mediation analysis that incorporated two mediators: metacognitive strategies and leisure time spent using technology. Approximately 19% of the variance in the dependent variable can be accounted for by the independent variables included in the model ($p < 0.001$). The results showed that artistic swimming had a fully mediated relationship with behavioral engagement (Figure 2), as the direct effect of artistic swimming on behavioral engagement was not statistically significant in the presence of the mediators ($\beta = 0.07$, $p > 0.05$).

TABLE 3 Mean and median differences between students practicing artistic swimming and not.

	Artistic swimmers (n = 189)			Other sports (n = 311)				Other sports (only females, n = 157)			
Measure	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.	Effect Size	Mean	Median	Std. Dev.	Effect Size
Cognitive engagement	61.25	62	10.11	57.70	57	11.35	0.33***	58.11	58	11.58	0.29***
Behavioral engagement	53.42	54	6.38	51.54	51	7.02	0.28**	52.48	52	6.34	0.15**
Metacognitive strategies	26.47	27	3.45	25.07	25	3.63	0.39***	25.64	26	3.60	0.25***
Technology for leisure (hours per day)	2.68	3	1.38	3.62	3	1.73	−0.60***	3.72	3	1.79	−0.64***
Technology for study (hours per day)	1.91	2	1.43	1.90	2	1.35	0.01	2.08	2	1.38	0.11

TABLE 4 Means, standard deviations, and correlations with confidence intervals.

Variable	M	SD	1	2	3	4	5	6	7
1. Cognitive engagement	4.92	0.92							
2. Behavioral engagement	4.35	0.57	0.44**						
			[0.36, 0.51]						
3. Metacognitive strategies	2.11	0.34	0.47**	0.41**					
			[0.39, 0.53]	[0.33, 0.48]					
4. Hours technology for leisure	3.27	1.67	−0.23**	−0.25**	−0.23**				
			[−0.31, −0.15]	[−0.33, −0.16]	[−0.32, −0.15]				
5. Hours technology for study	1.90	1.38	0.09	0.11*	0.09*	0.10*			
			[−0.00, 0.17]	[0.03, 0.20]	[0.01, 0.18]	[0.01, 0.18]			
6. Artistic swimming	0.38	0.49	0.16**	0.13**	0.16**	−0.27**	0.00		
			[0.07, 0.24]	[0.05, 0.22]	[0.07, 0.24]	[−0.35, −0.19]	[−0.08, 0.09]		
7. Nr. years competitive sport	6.20	4.82	0.01	0.02	−0.00	−0.12**	−0.04	0.14**	
			[−0.08, 0.10]	[−0.06, 0.11]	[−0.09, 0.08]	[−0.20, −0.03]	[−0.13, 0.04]	[0.06, 0.23]	
7. Nr. years sport	9.98	4.82	0.04	0.10*	0.06	−0.06	0.09	0.17**	0.56**
			[−0.04, 0.13]	[0.01, 0.18]	[−0.03, 0.14]	[−0.15, 0.02]	[−0.00, 0.17]	[0.09, 0.26]	[0.49, 0.61]

M and SD are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < 0.05$. ** indicates $p < 0.01$.

Instead, artistic swimming was found to be positively associated with metacognitive strategies ($\beta = 0.32$, $p < 0.001$) and negatively associated with leisure time spent using technology ($\beta = -0.56$, $p < 0.001$). Additionally, the analysis showed that increased levels of metacognitive strategies were positively associated with higher levels of behavioral engagement ($\beta = 0.36$, $p < 0.001$), whereas decreased leisure time spent using technology was negatively correlated with behavioral engagement ($\beta = -0.15$, $p < 0.001$). These findings suggest that the effects of artistic swimming on behavioral engagement are entirely indirect, operating through the mediators of metacognitive strategies (indirect effect = 0.11, 95% CI = [0.05, 0.19]) and leisure time spent using technology (indirect effect = 0.08, 95% CI = [0.03, 0.14]). These effects were determined using bootstrapping with a 95% level of confidence and 10,000 bootstrap samples.

Discussion

The present cross-sectional study compared cognitive and behavioral engagement, metacognitive strategies, and leisure time spent using technology in artistic swimmers and people practicing other sports. Additionally, a mediation analysis was conducted to investigate the mediating effects of metacognitive strategies and leisure time spent using technology on the relationship between artistic swimming and engagement. The data obtained in the research provided support for the formulated hypotheses. Specifically, the findings indicated that individuals who engage in artistic swimming exhibited significantly greater levels of metacognitive strategies, cognitive and behavioral engagement, and a decreased tendency to utilize technology for recreational purposes. Furthermore, it was found that the impact of artistic swimming on engagement is

TABLE 5 Standardized direct, indirect, and total effects for the mediation models.

Model pathways	Standardized estimated effects	95% CI		*p*
		Lower 2.5%	Upper 2.5%	
Cognitive engagement				
Direct effect artistic swimming → cognitive engagement	0.12	−0.04	0.26	0.16
Indirect effect metacognitive strategies → cognitive engagement	0.14	0.06	0.22	<0.001
Indirect effect use of technology for leisure → cognitive engagement	0.06	0.01	0.13	<0.001
Behavioral engagement				
Direct effect artistic swimming → behavioral engagement	0.07	−0.05	0.14	0.41
Indirect effect metacognitive strategies → behavioral engagement	0.12	0.05	0.19	<0.001
Indirect effect use of technology for leisure → behavioral engagement	0.08	0.03	0.14	<0.001

primarily mediated by the indirect effects of metacognition and technology usage.

The benefits of physical activity interventions on child development have been the subject of growing interest in the scientific community. The importance of exercise and its effects on health and well-being is widely discussed (Gutin et al., 2004; Bailey, 2006; Payne and Isaacs, 2020), and an increasing body of evidence suggests that physical activity can also have positive effects on cognitive function (Chaddock-Heyman et al., 2014; Bruner et al., 2021; Contreras-Osorio et al., 2022). However, it is important to note that not all types of exercise are created equal in terms of their cognitive benefits. Animal studies have demonstrated that complex and random activities, as opposed to simple and repetitive actions, can result in greater neural growth in key brain regions associated with cognitive function, such as the hippocampus, cerebellum, and cerebral cortices (Carey et al., 2005). This suggests that exercises that require more complex and adaptive cognitive and motor processes may be more beneficial for cognitive function. Specifically, the results provide support for the notion that engaging in a complex sports discipline, such as artistic swimming, can be particularly effective in enhancing metacognitive skills, which may extend to performance in educational settings.

Tomporowski's model (Tomporowski et al., 2015) proposes a plausible link between physical activity, cognition, metacognition, and academic achievement. It is reasonable to hypothesize that exercise interventions that are qualitatively stimulating, promote the development of procedural and declarative skills, and foster the formulation of strategies may influence metacognitive processes that build upon basic executive functions. The interconnection between the aforementioned components implies that certain skills acquired in a sporting setting have the potential to generalize to other domains.

However, from an evolutionary standpoint, there has been considerable debate over the occurrence and mechanisms of skill generalization. This has been a long-standing topic of discourse for scholars, highlighting the need for further research in this area to better understand the conditions that foster the transfer of skills across domains. For example, a recent meta-analysis (Heilmann et al., 2022) has suggested that training in sports or cognitive tasks may lead to an improvement in performance in related yet untrained tasks. This theory is supported by recent studies, which have demonstrated that expert athletes in open-skill sports exhibit superior executive function compared to those in closed-skill sports. Nonetheless, the overall effect size was found to be low and not statistically significant.

The constraints of cross-sectional research preclude the determination of causality, but the present study offers evidence that select training modalities may influence overall abilities. This finding is consistent with the theoretical construct put forth by Van der Stel and Veenman (2014) regarding metacognitive development, which posits that metacognitive skills tend to exhibit a general, non-linear growth trajectory that persists over time.

The study suggests also that reduced leisure time spent using technology is associated with higher levels of engagement and metacognitive strategies. This finding aligns with the body of research demonstrating the adverse impact of high technology usage on the health status and academic performance of students research has consistently demonstrated that prolonged screen time and a sedentary lifestyle associated with technology use can contribute to physical health issues, such as obesity, poor posture, and eye strain (Adelantado-Renau et al., 2019; Mundy et al., 2020; Sampasa-Kanyinga et al., 2022; Tafesse, 2022). Additionally, high use of technology has been linked to mental health problems, including anxiety, depression, and sleep disturbances, which can further hinder academic performance (Gutin et al., 2004; Bailey, 2006; Payne and Isaacs, 2020). Furthermore, the constant distraction and multitasking often associated with technology use can impair cognitive processes such as attention, memory, and learning, all of which are essential for academic success. Regular participation in sports has been shown to offer numerous physical and mental health benefits, making it an effective means of promoting healthy behavior and reducing the negative impact of high technology use. Sports provide a break from screen time and offer opportunities for face-to-face interactions and experiences, which can counteract the negative effects of technology on social skills and well-being (Wilhite et al., 2022).

The findings of the study reveal that the relationship between artistic swimming and engagement is primarily mediated by metacognitive strategies and leisure technology usage. Specifically, participating in artistic swimming can foster stronger metacognitive skills, resulting in better cognitive and behavioral engagement at school. Moreover, in the context of synchronized swimming training, particularly at a competitive level, the time commitment can be quite substantial. As with other activities that encroach on a student's leisure time, the student is likely to have fewer opportunities for recreational engagement with information technologies, which can act as a protective factor against their high use.

Further investigation is warranted to gain a comprehensive understanding of the intricate relationship between artistic swimming,

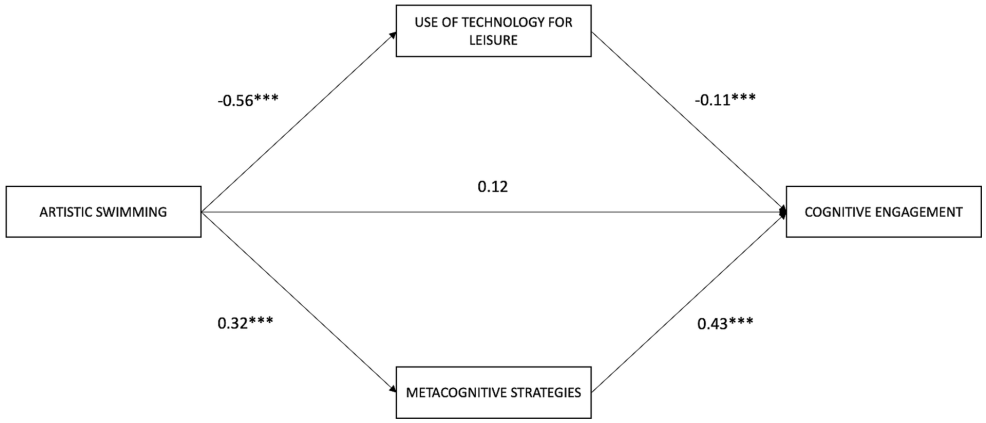

FIGURE 1
The multiple mediation model of artistic swimming on cognitive engagement. * $p < 0.05$; ** $p < 0.01$, *** $p < 0.001$. All of the parameter coefficients are standardised results.

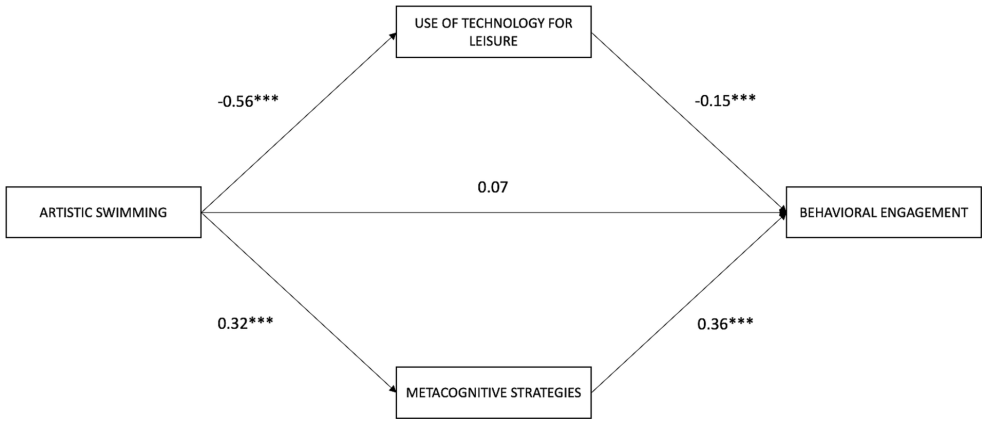

FIGURE 2
The multiple mediation model of artistic swimming on behavioral engagement. * $p < 0.05$; ** $p < 0.01$, *** $p < 0.001$. All of the parameter coefficients are standardised results.

physical activity, and engagement. Future research could involve comparing the effects of other sports with similar characteristics to artistic swimming, using longitudinal research designs. This approach would provide a better understanding of the unique benefits of artistic swimming in promoting engagement, and whether these benefits extend to other forms of physical activity.

In summary, the findings of this study have the potential to lay the foundation for a more comprehensive approach to educational and sports programs. This research field, focused on evaluating the impacts of diverse forms and methods of physical activity on cognitive and metacognitive skills, holds the promise of guiding, in the near future, parents, educators, and policymakers in the integration of tailored physical activities in each student's developmental curriculum, taking into account their individual characteristics.

Limitations

While the present study provides valuable insights into the potential impact of artistic swimming on students' engagement, it is important to acknowledge its limitations. First, the cross-sectional design of the study means that it cannot establish causal relationships between variables. Therefore, it is not possible to determine whether engagement is increased because of participation in artistic swimming or whether individuals who are already more engaged are more likely to participate in this activity. Second, the study involved a sample predominantly comprised of female artistic swimmers accounting for 98.4% of the total. This introduces a potential issue, as gender-related factors may impact the observed outcomes. However, this limitation was addressed by conducting a re-analysis of the data, specifically considering only the female participants engaged in other sports, which yielded results consistent with those obtained from the entire sample. While this outcome may suggest the lack of a direct influence of gender on the measured variables, aligning with previous studies that offer limited support for substantial gender or sex-based disparities in executive functions (Hyde, 2016; Grissom and Reyes, 2019; Gaillard, et al., 2021), it is imperative to exercise caution in automatically extrapolating these results to male students. Indeed, an imbalanced sample can compromise statistical power, diminishing the capacity to identify significant differences between the groups, should

they exist. Third, the group of sports chosen for comparison in terms of the dependent variable exhibits a considerable degree of heterogeneity, which limits our ability to fully comprehend the similarities and distinctions between sports that may stimulate similar cognitive processes but in unique ways. While the data analysis revealed that practitioners of artistic swimming displayed advantages in the measured variables, it is important to emphasize that the authors do not propose this sport as the exclusive remedy for addressing low levels of school engagement or ineffective utilization of metacognitive strategies. This study serves as an initial exploration of the potential influence of sports on the development of cognitive and metacognitive skills during the formative years of young individuals. As an exploratory preliminary investigation, the authors deliberately employed a broad level of granularity, also designed to facilitate the sampling phase. In subsequent research, the authors intend to categorize various sports according to a defined framework (e.g., one developed by O'Connor et al., 2022) and enhance the representation of different sports categories to conduct a more in-depth exploration of common psychological elements among specific types of sports. This approach will help determine whether these sports share common effects on the cognitive development of individuals.

Furthermore, the use of self-reported data may have introduced bias, particularly if participants over- or under-reported their engagement, technology use, or level of sports participation, particularly in the realm of physical activity domain where disparities between objective and subjective measurement methods are recognized (Marques et al., 2018). An ideal approach would involve combining subjective assessments with objective measurements, possibly obtained through ecological data collection, to mitigate measurement-related biases.

Additionally, the study did not differentiate between various types of technology used for leisure, and different media may have different effects on engagement. For example, a recent metanalysis (Adelantado-Renau et al., 2019) showed that when exploring the relationship between specific screen-based activities and academic performance, it was observed that television viewing was inversely related to language and mathematics performance. Similarly, playing video games exhibited an inverse association with composite scores. Furthermore, when subgroup analyses were conducted separately for children and adolescents, it became evident that the duration of these screen-based activities might exert a more substantial impact on the academic performance of adolescents compared to children. Moreover, factors related to the home environment and parental attributes, such as socioeconomic status and parental support, may exert a more substantial influence on scholastic engagement and academic performance when contrasted with the quantity of screen media usage.

Further research with larger and more diverse samples, as well as using longitudinal designs, could help to overcome some of the limitations of this study and shed more light on the complex mechanisms underlying the relationship between artistic swimming and engagement.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by University Polyclinic "Paolo Giaccone" of Palermo (record number 02/2022 issued February 15, 2022). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

Author contributions

GM: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. LJ: Conceptualization, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Adelantado-Renau, M., Moliner-Urdiales, D., Cavero-Redondo, I., Beltran-Valls, M. R., Martínez-Vizcaíno, V., and Álvarez-Bueno, C. (2019). Association between screen media use and academic performance among children and adolescents: a systematic review and meta-analysis. *JAMA Pediatr.* 173, 1058–1067. doi: 10.1001/jamapediatrics.2019.3176

Alvarez-Bueno, C., Pesce, C., Cavero-Redondo, I., Sanchez-Lopez, M., Martínez-Hortelano, J. A., and Martinez-Vizcaino, V. (2017). The effect of physical activity interventions on children's cognition and metacognition: a systematic review and meta-analysis. *J. Am. Acad. Child Adolesc. Psychiatry* 56, 729–738. doi: 10.1016/j.jaac.2017.06.012

Astin, A. W. (1984). Student involvement: a developmental theory for higher education. *J. Coll. Stud. Pers.* 25, 297–308. https://psycnet.apa.org/record/1985-18630-001

Augustyn, J. S., and Rosenbaum, D. A. (2005). Metacognitive control of action: preparation for aiming reflects knowledge of fitts's law. *Psychon. Bull. Rev.* 12, 911–916. doi: 10.3758/BF03196785

Azevedo, R. (2020). Reflections on the field of metacognition: issues, challenges, and opportunities. *Metacogn. Learn.* 15, 91–98. doi: 10.1007/s11409-020-09231-x

Bailey, R. (2006). Physical education and sport in schools: a review of benefits and outcomes. *J. Sch. Health* 76, 397–401. doi: 10.1111/j.1746-1561.2006.00132.x

Bartsch, K., Horvath, K., and Estes, D. (2003). Young children's talk about learning events. *Cogn. Dev.* 18, 177–193. doi: 10.1016/S0885-2014(03)00019-4

Best, J. R. (2010). Effects of physical activity on children's executive function: contributions of experimental research on aerobic exercise. *Dev. Rev.* 30, 331–351. doi: 10.1016/j.dr.2010.08.001

Boer, H., de Donker, A. S., Kostons, D. D., and Werf, G. P. (2018). Long-term effects of metacognitive strategy instruction on student academic performance: a meta-analysis. *Educ. Res. Rev.* 24, 98–115. doi: 10.1016/j.edurev.2018.03.002

Bowker, A. (2006). The relationship between sports participation and self-esteem during early adolescence. *Canadian J. Behav. Sci.* 38, 214–229. doi: 10.1037/cjbs2006009

Bowker, A., Gadbois, S., and Cornock, B. (2003). Sports participation and self-esteem: variations as a function of gender and gender role orientation. *Sex Roles* 49, 47–58. doi: 10.1023/A:1023909619409

Bravo-Sánchez, A., Morán-García, J., Abián, P., and Abián-Vicén, J. (2021). Association of the use of the mobile phone with physical fitness and academic performance: a cross-sectional study. *Int. J. Environ. Res. Public Health* 18:1042. doi: 10.3390/ijerph18031042

Bruner, M. W., McLaren, C. D., Sutcliffe, J. T., Gardner, L. A., Lubans, D. R., Smith, J. J., et al. (2021). The effect of sport-based interventions on positive youth development: a systematic review and meta-analysis. *Int. Rev. Sport Exerc. Psychol.* 1–28, 1–28. doi: 10.1080/1750984X.2021.1875496

Cardoso-Leite, P., Buchard, A., Tissieres, I., Mussack, D., and Bavelier, D. (2021). Media use, attention, mental health and academic performance among 8 to 12 year old children. *PLoS One* 16:e0259163. doi: 10.1371/journal.pone.0259163

Carey, J. R., Bhatt, E., and Nagpal, A. (2005). Neuroplasticity promoted by task complexity. *Exerc. Sport Sci. Rev.* 33, 24–31. Available at: https://pubmed.ncbi.nlm.nih.gov/15640717/.

Chaddock-Heyman, L., Hillman, C. H., Cohen, N. J., and Kramer, A. F. (2014). III. The importance of physical activity and aerobic fitness for cognitive control and memory in children. *Monogr. Soc. Res. Child Dev.* 79, 25–50. doi: 10.1111/mono.12129

Chen, S., and McDunn, B. A. (2022). Metacognition: history, measurements, and the role in early childhood development and education. *Learn. Motiv.* 78:101786. doi: 10.1016/j.lmot.2022.101786

Collins, N. M., Cromartie, F., Butler, S., and Bae, J. (2018). Effects of early sport participation on self-esteem and happiness. *Sport J.* 20, 1–20. Available at:https://thesportjournal.org/article/effects-of-early-sport-participation-on-self-esteem-and-happiness/

Contreras-Osorio, F., Guzmán-Guzmán, I. P., Cerda-Vega, E., Chirosa-Ríos, L., Ramírez-Campillo, R., and Campos-Jara, C. (2022). Effects of the type of sports practice on the executive functions of schoolchildren. *Int. J. Environ. Res. Public Health* 19:3886. doi: 10.3390/ijerph19073886

Cornoldi, C. (1987). Memory in the child. In B. Inhelder, CapronaD. De and A. Cornu-Wells (Eds.), *Piaget today* (pp. 183–201). Hillsdale, NJ: Erlbaum.

Cornoldi, C. (2010). Metacognition, intelligence, and academic performance. In: Metacognition, Strategy Use, and Instruction. Eds. H. S. Waters and W. Schneider. The Guildford Press, 257–277. Available at: https://psycnet.apa.org/record/2009-18875-011

Cornoldi, C., De Beni, R., and Gruppo, M. (2020). *Imparare a studiare: Strategie, stili cognitivi, metacognizione e atteggiamenti nello studio* Edizioni Centro Studi Erickson.

Doleck, T., Bazelais, P., and Lemay, D. J. (2018). Social networking and academic performance: a generalized structured component approach. *J. Educ. Comput. Res.* 56, 1129–1148. doi: 10.1177/0735633117738281

Dwyer, T., Sallis, J. F., Blizzard, L., Lazarus, R., and Dean, K. (2001). Relation of academic performance to physical activity and fitness in children. *Pediatr. Exerc. Sci.* 13, 225–237.

Eccles, J. S. (2016). Engagement: where to next? *Learn. Instr.* 43, 71–75. doi: 10.1016/j.learninstruc.2016.02.003

Eime, R. M., Young, J. A., Harvey, J. T., Charity, M. J., and Payne, W. R. (2013). A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. *Int. J. Behav. Nutr. Phys. Act.* 10, 1–21. doi: 10.1186/1479-5868-10-98

European Commission (2022). Next generation EU: How can the sport sector benefit? -background paper-. Available at: https://sport.ec.europa.eu/sites/default/files/2022-08/SHARE%20LAB%20-%20Next%20Generation%20EU%20guidance%20-%20FINAL.pdf.

Finn, J. D. (1989). Withdrawing from school. *Rev. Educ. Res.* 59, 117–142. doi: 10.3102/00346543059002117

Finn, J. D., and Zimmer, K. S. (2012). "Student engagement: what is it? Why does it matter?" in *Handbook of research on student engagement* (Boston, MA: Springer US), 97–131.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: a new area of cognitive–developmental inquiry. *Am. Psychol.* 34, 906–911. doi: 10.1037/0003-066X.34.10.906

Fredricks, J. A., Blumenfeld, P. C., and Paris, A. H. (2004). School engagement: potential of the concept, state of the evidence. *Rev. Educ. Res.* 74, 59–109. doi: 10.3102/00346543074001059

Gaillard, A., Fehring, D. J., and Rossell, S. L. (2021). A systematic review and meta-analysis of behavioural sex differences in executive control. *Eur. J. Neurosci.* 53, 519–542.

Gascoine, L., Higgins, S., and Wall, K. (2017). The assessment of metacognition in children aged 4–16 years: a systematic review. *Rev. Educ.* 5, 3–57. doi: 10.1002/REV3.3077

Grissom, N. M., and Reyes, T. M. (2019). Let's call the whole thing off: evaluating gender and sex differences in executive function. *Neuropsychopharmacology* 44, 86–96. doi: 10.1038/s41386-018-0179-5

Gutin, B., Barbeau, P., and Yin, Z. (2004). Exercise interventions for prevention of obesity and related disorders in youths. *Quest* 56, 120–141. doi: 10.1080/00336297.2004.10491818

Heilmann, F., Weinberg, H., and Wollny, R. (2022). The impact of practicing open-vs. closed-skill sports on executive functions—a meta-analytic and systematic review with a focus on characteristics of sports. *Brain Sci.* 12:1071. doi: 10.3390/brainsci12081071

Hyde, J. S. (2016). Sex and cognition: gender and cognitive functions. *Curr. Opin. Neurobiol.* 38, 53–56. doi: 10.1016/j.conb.2016.02.007

Ishii, K., Aoyagi, K., Shibata, A., Javad Koohsari, M., Carver, A., and Oka, K. (2020). Joint associations of leisure screen time and physical activity with academic performance in a sample of japanese children. *Int. J. Environ. Res. Public Health* 17:757. doi: 10.3390/ijerph17030757

Kahu, E. R. (2013). Framing student engagement in higher education. *Stud. High. Educ.* 38, 758–773. doi: 10.1080/03075079.2011.598505

Kramarski, B., and Mevarech, Z. R. (2003). Enhancing mathematical reasoning in the classroom: the effects of cooperative learning and metacognitive training. *Am. Educ. Res. J.* 40, 281–310. doi: 10.3102/00028312040001281

Ladd, G. W., and Dinella, L. M. (2009). Continuity and change in early school engagement: predictive of children's achievement trajectories from first to eighth grade? *J. Educ. Psychol.* 101, 190–206. doi: 10.1037/a0013153

Lai, E. R. (2011). Metacognition: a literature review. *Always Learn.* 9, 330–334. doi: 10.12691/education-9-6-1

Li, Y., and Lerner, R. M. (2011). Trajectories of school engagement during adolescence: implications for grades, depression, delinquency, and substance use. *Dev. Psychol.* 47, 233–247. doi: 10.1037/a0021307

MacIntyre, T. E., Igou, E. R., Campbell, M. J., Moran, A. P., and Matthews, J. (2014). Metacognition and action: a new pathway to understanding social and cognitive aspects of expertise in sport. *Front. Psychol.* 5:1155. doi: 10.3389/fpsyg.2014.01155

Mameli, C., and Passini, S. (2017). Measuring four-dimensional engagement in school: a validation of the student engagement scale and of the agentic engagement scale. *TPM* 24, 527–541. doi: 10.4473/TPM24.4.4

Marks, H. M. (2000). Student engagement in instructional activity: patterns in the elementary, middle, and high school years. *Am. Educ. Res. J.* 37, 153–184. doi: 10.3102/00028312037001153

Marques, A., Santos, D. A., Hillman, C. H., and Sardinha, L. B. (2018). How does academic achievement relate to cardiorespiratory fitness, self-reported physical activity and objectively reported physical activity: a systematic review in children and adolescents aged 6–18 years. *Br. J. Sports Med.* 52:1039. doi: 10.1136/bjsports-2016-097361

Marulis, L. M., Baker, S. T., and Whitebread, D. (2020). Integrating metacognition and executive function to enhance young children's perception of and agency in their learning. *Early Child. Res. Q.* 50, 46–54. doi: 10.1016/j.ecresq.2018.12.017

McPherson, A., Mackay, L., Kunkel, J., and Duncan, S. (2018). Physical activity, cognition and academic performance: An analysis of mediating and confounding relationships in primary school children. *BMC Public Health.* 18, 1–9. doi: 10.1186/s12889-018-5863-1

Mineshita, Y., Kim, H.-K., Chijiki, H., Nanba, T., Shinto, T., Furuhashi, S., et al. (2021). Screen time duration and timing: effects on obesity, physical activity, dry eyes, and learning ability in elementary school children. *BMC Public Health* 21, 1–11. doi: 10.1186/s12889-021-10484-7

Morgan, P. L., Wang, Y., and Woods, A. D. (2021). Risk and protective factors for frequent electronic device use of online technologies. *Child Dev.* 92, 704–714. doi: 10.1111/cdev.13532

Muijs, D., and Bokhove, C. (2020). *Metacognition and self-regulation: evidence review*. London: Education Endowment Foundation. Available at: https://educationendowmentfoundation.org.uk/evidence-summaries/evidence-reviews/metacognition-and-self-regulation-review/.

Mundy, L. K., Canterford, L., Hoq, M., Olds, T., Moreno-Betancur, M., Sawyer, S., et al. (2020). Electronic media use and academic performance in late childhood: a longitudinal study. *PLoS One* 15:e0237908. doi: 10.1371/journal.pone.0237908

Muñoz-Bullón, F., Sanchez-Bueno, M. J., and Vos-Saz, A. (2017). The influence of sports participation on academic performance among students in higher education. *Sport Manag. Rev.* 20, 365–378. doi: 10.1086/693117

O'Connor, J., Alfrey, L., and Penney, D. (2022). Rethinking the classification of games and sports in physical education: a response to changes in sport and participation. *Phys. Educ. Sport Pedagog.* 1-14, 1–14. doi: 10.1080/17408989.2022.2061938

Payne, V. G., and Isaacs, L. D. (2020). Growth and maturation. In human motor development (pp. 159–194). Routledge. Available at: https://www.taylorfrancis.com/chapters/edit/10.4324/9780429327568-9/growth-maturation-gregory-payne-larry-isaacs

Picton, C., Kahu, E. R., and Nelson, K. (2018). 'Hardworking, determined and happy': first-year students' understanding and experience of success. *High. Educ. Res. Develop.* 37, 1260–1273. doi: 10.1080/07294360.2018.1478803

Reeve, J., and Tseng, C.-M. (2011). Agency as a fourth aspect of students' engagement during learning activities. *Contemp. Educ. Psychol.* 36, 257–267. doi: 10.1016/j.cedpsych.2011.05.002

Reschly, A. L., and Christenson, S. L. (2012). "Jingle, jangle, and conceptual haziness: evolution and future directions of the engagement construct" in *Handbook of research on student engagement*. (Boston, MA: Springer US), 3–19.

Rideout, V., Peebles, A., Mann, S., and Robb, M. (2022). *Common sense census: Media use by tweens and teens, 2021*. Common sense. Available at: https://www.commonsensemedia.org/sites/default/files/research/report/8-18-census-integrated-report-final-web_0.pdf.

Robinson, J. P., Kestnbaum, M., Neustadtl, A., and Alvarez, A. (2002). Information technology and functional time displacement. *IT Soc.* 1, 21–36.

Roebers, C. M., and Spiess, M. (2017). The development of metacognitive monitoring and control in second graders: a short-term longitudinal study. *J. Cogn. Dev.* 18, 110–128. doi: 10.1080/15248372.2016.1157079

Sampasa-Kanyinga, H., Hamilton, H. A., Goldfield, G. S., and Chaput, J.-P. (2022). Problem technology use, academic performance, and school connectedness among adolescents. *Int. J. Environ. Res. Public Health* 19:2337. doi: 10.3390/ijerph19042337

Schmidt, R. A., and Lee, T. D. (2011). "Motor control and learning: A behavioral emphasis (6th ed.)" in *Human kinetics*.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instr. Sci.* 26, 113–125. doi: 10.1023/A:1003044231033

Schraw, G., and Moshman, D. (1995). Metacognitive theories. *Educ. Psychol. Rev.* 7, 351–371. doi: 10.1007/BF02212307

Su, X., and Huang, J. (2021). Social media use and college students' academic performance: student engagement as a mediator. *Soc. Behav. Personal. Int. J.* 49, 1–8. doi: 10.2224/sbp.10797

Tafesse, W. (2020). The effect of social networking site use on college students' academic performance: the mediating role of student engagement. *Educ. Inf. Technol.* 25, 4747–4763. doi: 10.1007/s10639-020-10162-y

Tafesse, W. (2022). Social networking sites use and college students' academic performance: testing for an inverted u-shaped relationship using automated mobile app usage data. *Int. J. Educ. Technol. High. Educ.* 19, 1–17. doi: 10.1186/s41239-022-00322-0

Teng, M. F. (2020). Effects of cooperative–metacognitive instruction on EFL learners' writing and metacognitive awareness. *Asia Pacific J. Educ.* 42, 179–195. doi: 10.1080/02188791.2020.1835606

Teng, F., and Reynolds, B. L. (2019). Effects of individual and group metacognitive prompts on EFL reading comprehension and incidental vocabulary learning. *PLoS One* 14:e0215902. doi: 10.1371/journal.pone.0215902

Tomporowski, P. D., McCullick, B., Pendleton, D. M., and Pesce, C. (2015). Exercise and children's cognition: the role of exercise characteristics and a place for metacognition. *J. Sport Health Sci.* 4, 47–55. doi: 10.1016/j.jshs.2014.09.003

Toriola, A. L., Amusa, L. O., Patriksson, G., and Kougioumtzis, K. (2010). Physical education as a tool for developing health and social skills: results of a pilot study in South Africa and Sweden. *Afric. J. Phys. Health Educ. Recreat. Dance* 16, 327–342. doi: 10.4314/ajpherd.v16i3.60908

Twenge, J. M., and Farley, E. (2021). Not all screen time is created equal: associations with mental health vary by activity and gender. *Soc. Psychiatry Psychiatr. Epidemiol.* 56, 207–217. doi: 10.1007/s00127-020-01906-9

Van Der Stel, M., and Veenman, M. V. (2014). Metacognitive skills and intellectual ability of young adolescents: a longitudinal study from a developmental perspective. *Eur. J. Psychol. Educ.* 29, 117–137. doi: 10.1007/s10212-013-0190-5

Veenman, M. V., and Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: age and task differences. *Learn. Individ. Differ.* 15, 159–176. doi: 10.1016/j.lindif.2004.12.001

Veenman, M. V., Wilhelm, P., and Beishuizen, J. J. (2004). The relation between intellectual and metacognitive skills from a developmental perspective. *Learn. Instr.* 14, 89–109. doi: 10.1016/j.learninstruc.2003.10.004

Vogels, E. A., Gelles-Watnick, R., and Massarat, N. (2022). *Teens, social media and technology 2022*. Available at: https://www.pewresearch.org/internet/2022/08/10/teens-social-media-and-technology-2022/.

Wang, M.-T., Binning, K. R., Del Toro, J., Qin, X., and Zepeda, C. D. (2021). Skill, thrill, and will: the role of metacognition, interest, and self-control in predicting student engagement in mathematics learning over time. *Child Dev.* 92, 1369–1387. doi: 10.1111/cdev.13531

Wang, M.-T., and Eccles, J. S. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *J. Res. Adolesc.* 22, 31–39. doi: 10.1111/j.1532-7795.2011.00753.x

Wang, M.-T., and Fredricks, J. A. (2014). The reciprocal links between school engagement, youth problem behaviors, and school dropout during adolescence. *Child Dev.* 85, 722–737. doi: 10.1111/cdev.12138

Whitebread, D., and Basilio, M. (2012). The emergence and early development of self-regulation in young children. Profesorado, Revista de Currículum y Formacíon Del Profesorado, 16(1), 15–34. Available at: https://www.semanticscholar.org/paper/The-emergence-and-early-development-of-in-young-Whitebread-Basilio/63015de23ad3f0461e39cc5fcbf864f6a851c93a

Whitebread, D., Coltman, P., Pasternak, D. P., Sangster, C., Grau, V., Bingham, S., et al. (2009). The development of two observational tools for assessing metacognition and self-regulated learning in young children. *Metacogn. Learn.* 4, 63–85. doi: 10.1007/s11409-008-9033-1

Wilhite, K., Booker, B., Huang, B.-H., Antczak, D., Corbett, L., and Parker, P. (2022). Combinations of physical activity, sedentary behavior, and sleep and their associations with physical, psychological, and educational outcomes in children and adolescents: a systematic review. *Am. J. Epidemiol.* 192, 665–679. doi: 10.1093/aje/kwac212