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*Procesos metacognitivos y niveles de actividad física en estudiantes universitarios**

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ABSTRACT

Background: Cognitive processes are associated with Systematic Physical Activity (SPA). However, few studies have evaluated the relation between SPA and Metacognition (MC). Objectives: (1) to study the effect of the SPA levels on MC, and (2) to explore the covariance of gender. Method: Through a Non-Experimental design and with intentional sampling, 270 university students participated (M_{age}= 25.3, SD= 1.5, min= 18, max= 51), 209 men (77.4%), and 61 women (22.6%). The International Physical Activity Questionnaire-Short Form (IPAQ-SF) and The Metacognitive Awareness Inventory were completed. The MANOVA showed that SPA levels significantly affected MC. The MANCOVA did not show a gender effect. Results: The main effects indicated that moderate and vigorous SPA levels favor MC. Differences were observed between the low vs vigorous SPA levels (p= .035, 95% CI [-1.49, -0.03]) in the knowledge of cognition factor. Similarly, there are differences in the regulation of cognition between low vs moderate SPA levels (p= .013, 95% CI [-1.86, -0.16]), and low vs vigorous (p= .044, 95% CI [-1.72, -0.15]). Conclusions: Moderate and vigorous SPA levels favor CM, mainly the regulation of cognition. In contrast, the vigorous SPA level favors the Knowledge of Cognition.

Keywords: psychology of physical activity, education, student, knowledge, cognitive process, declarative knowledge, procedural knowledge, metacognition (Thesaurus PsycInfo).

RESUMEN

Antecedentes: Los procesos cognitivos se relacionan con la Actividad Física Sistemática (AFS). Sin embargo, pocos estudios han evaluado la relación entre la AFS y la Metacognición (MC). Objetivos: (1) estudiar el efecto de los niveles de la AFS sobre la MC, y (2) explorar la covarianza del género. Método: A través de un diseño No-Experimental y con un muestreo intencional participaron 270 universitarios (M_{age}= 25.3, SD= 1.5, min=18 y max= 51), 209 hombres (77.4%), y 61 mujeres (22.6%). Se completó el International Physical Activity Questionnaire-Short Form (IPAQ-SF), y The Metacognitive Awareness Inventory. El MANOVA mostró que los niveles de la AFS afectaron significativamente la MC. El MANCOVA no mostró un efecto del género. Resultados: Los efectos principales indicaron que los niveles de AFS moderados y vigoroso favorecen la MC. Se observaron diferencias entre el nivel de AFS bajo vs vigoroso (p= .035, 95%CI [-1.49, -0.03]) en el factor Conocimiento sobre la Cognición. Similarmente, hay diferencias en la Regulación de la Cognición entre niveles AFS bajo vs moderado (p= .013, 95%CI [-1.86, -0.16]), y bajo vs vigoroso (p= .044, 95%CI [-1.72, -0.15]). Conclusión: Los niveles de AFS moderados y vigorosos favorecen la MC, principalmente la Regulación de la Cognición. Mientras que el nivel AFS vigoroso favorece el Conocimiento de la Cognición.

Palabras clave: psicología de la actividad física, estudiantes, educación, conocimiento, procesos cognitivos, conocimiento declarativo, conocimiento procesual, metacognición (Thesaurus PsycInfo).

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Introduction

Systematic Physical Activity (SPA) and Physical Exercise are recommended for the wellbeing and quality of life of people, according to the World Health Organization, WHO (2018, 2010). Likewise, there is more and more evidence that supports the effects of the SPA in the face of different psychological and neurocognitive processes throughout the life cycle in healthy samples. (Etnier *et al.*, 2019; McSween *et al.*, 2019; Pontifex *et al.*, 2019; Stern *et al.*, 2019).

Different systematic reviews and meta-analysis have indicated that SPA at moderate intensities improves cognition (Fernandes *et al.*, 2018); likewise, it improves several cognitive domains (e.g., working memory, inhibition, cognitive flexibility, etc.) and metacognitive domains (Álvarez-Bueno *et al.*, 2017). Even neuroimaging techniques indicate that SPA facilitates neuroplasticity processes and changes in the brain (Gunnell *et al.*, 2018); as well as effects on hippocampal structures (Erickson *et al.*, 2009; Voss *et al.*, 2019) and, consequently, a better capacity of an individual to respond to environmental demands (Hoetting & Roeder, 2013). In elite athletes, favorable changes also seem to be observed since it selectively accelerates motor synchronization (Sysoeva *et al.*, 2013). The SPA with high-intensity interval training (HIIT) methods has positive effects on inhibition in children, adolescents, and adults; and working memory in children (Gejl *et al.*, 2018; Hillman *et al.*, 2019; Hsieh, Chueh, Huang, *et al.*, 2020). Similarly, greater cardiorespiratory fitness is associated with a better performance in inhibitory control tasks (Hsieh, Chueh, Morris, *et al.*, 2020).

Along these lines, promising results for SPA have also been seen in clinical areas. One clear example is in the geriatric population under neurodegenerative conditions where SPA seems to show favorable effects on the different cognitive process (Cassilhas *et al.*, 2016). Furthermore, in patients who consume heroin, a reduction in consumption and an improvement in inhibitory control have been observed (Wang *et al.*, 2020).

Given the above considerations, school environments are promising for promoting SPA (Donnelly *et al.*, 2013, 2016). Interventions and curricular physical education programs appear to be the most effective Metacognition (MC) processes (Álvarez-Bueno *et al.*, 2017). Regarding the SPA in a school environment, Mavilidi *et al.* (Mavilidi *et al.*, 2015) have compared three conditions of learning-teaching in schoolchildren, showing that the physical exercise condition achieved to improve learning; the physical exercise condition was compared with the condition of gesturing movements and conventional learning strategies. Also, descriptive data have been shown in academic communities of higher education, indicating that those who self-reported a high frequency of SPA are better in inhibitory control, working memory and anticipation capacities (Aguirre-Loaiza, Parra, *et al.*, 2019).

However, the research that has explored the effect of SPA on cognitive processes have focused their hypotheses on clinical models (Bherer *et al.*, 2013; Jia *et al.*, 2019; Lautenschlager *et al.*, 2008; Reimers *et al.*, 2012; Spartano *et al.*, 2019), with relative evidence if the number of research studies that study neurotypical or apparently healthy groups and clinical cases are compared. Even more scarce is the literature regarding the relationship between SPA and Metacognition (MC). Despite this, metacognitive skills can be influenced by environmental factors such as SPA and schooling, in such a way that, if both converge, integral abilities in the human being can be potentiated.

The approach to MC should be considered as a model of cognition, metacognitive knowledge and metacognitive skills (Flavell, 1979). MC is considered very important to self-regulation, i. e, the ability to successfully control thoughts and actions in accordance with the demands of a task (Efklides, 2014). Recently, studies that highlight the importance of the metacognitive process in sports, specifically in endurance performance, have been found. (Brick *et al.*, 2015; 2020). These findings revealed that metacognitive strategies – such as planning, monitoring, reviewing, and evaluating – and metacognitive experiences were fundamental to cognitive control and cognitive strategy use in elite endurance runners (Brick *et al.*, 2020).

It seems that there are differences in the use of MC in both academic and psychomotor tasks (Martini & Shore, 2008); nevertheless, more research on this issue is needed. In this line, the study of the use of metacognition by children with different levels of abilities (experts vs novice) is still a current topic.(Brick *et al.*, 2020). On the other hand, metacognitive skills have been standardized with the use of the MAI - Metacognitive Awareness Inventory (see definition of the construct in the section on techniques and instruments) with factorial structures of knowledge and regulation of cognition (Gutierrez & Montoya, 2020; Schraw & Dennison, 1994).

Regarding with the literature reviewed, the hypothesis that we assume indicates that the levels of SPA show differences in the MC factors. Thus, this work had a twofold purpose: first, to study the effect of SPA levels on metacognition; second, to explore the covariance of gender and age in the interaction of the SPA levels and metacognition.

Method

Design

A cross-sectional design was carried out (Stockemer, 2019).

Participants

Through an intentional sampling, n = 270 university students (M_{age} = 25.3, SD = 1.5, min = 18, and max = 51) of both genders participated: 209 (77.4%) men, (M_{age} = 22.6, SD = 4.8), and 61, (22.6%) *women* (M_{age} = 22.8, SD = 3.9). The inclusion criteria were: (i) Over 18 years of age. (ii) Are pursuing a university degree. This criterion allowed the control of the level of education as a possible confounding variable (Me = 5 semester).

Measure and instruments

Physical Activity: The International Physical Activity Questionnaire-Short Form (IPAQ-SF) is recognized as the most widely used questionnaire in the assessment of PA (Forsén *et al.*, 2010; Van Poppel *et al.*, 2010). The IPAQ is designed to facilitate the follow-up on measures of physical activity from self-report (Craig *et al.*, 2003). The IPAQ-SF has shown evidence of construct validity and internal consistency of the scores (Dinger *et al.*, 2006; Forsén *et al.*, 2010; Sanda *et al.*, 2017). These measures are in line with the global recommendations of the WHO (2018, 2010). The IPAQ-SF questions are related to the last seven days (e.g., "*How much time in total did you usually dedicate to moderate physical activity on one of those days*?"), with a response format of the number of hours/day and minutes/day. The unit of measure MET (metabolic equivalent of task minutes per week) is estimated; in turn, it is classified into three categories.

- ***Vigorous:*** three days adding ≥ 1500 METs, minutes/week; or seven days adding a minimum total physical activity of at least 3000 MET minutes/week.
- ***Moderate:*** activity of moderate intensity and activity of vigorous-intensity adding a total minimum PA of ≥600 MET-minutes/ week, which could be vigorous-intensity at

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least 20 minutes per day, for ≥3 days; o moderate physical intensity and/or walking at least 30 minutes per day, ≥5 days.
- ***Low:*** those records were not classified into the moderate or vigorous categories.

Metacognitive: The Metacognitive Awareness Inventory (MAI) evaluates people's self-understanding or awareness of their metacognitive processes (Schraw & Dennison, 1994). It is composed of 55 items with a Likert scale format, 1= strongly disagree, 2= disagree, 3= neither agree nor disagree, 4= agree, and 5= strongly agree. The items contain statements such aa: "I set specific objectives before starting a task" or "I am clear about what type of information is most important to learn"). The MAI is divided into two second-order factors (Schraw, 1998): (1) knowledge about cognition and (2) regulation of one's cognition; and eight first-order factors (see Table 1). The MAI contains several pieces of evidence of construct validity and psychometric reviews that have confirmed its factorial structure (Gutierrez & Montoya, 2020; Schraw, 1998; Schraw & Dennison, 1994). For our data, the reliability coefficient of the MAI has been estimated as (ω= .85, 95%CI [.83, .88]); likewise, for the second-order factors, satisfactory coefficients were estimated (see Table 1).

Table 1. Factorial Structure first and second order, definition, and coefficient of internal consistency of MAI

First order factors	First order factors operational definition	(# of items) Item identification	Second order factors (ω) 95%CI [LL, UL]
Declarative knowledge	Knowledge that a subject has of his learning, its abilities and the use of his cognitive abilities	(8) 5, 10,12, 16, 17, 20, 32, 46	Knowledge of cognition (ω= .73) [.69, .78]
Procedural knowledge	Knowledge that a subject has about the use of his learning strategies	(4) 3,14, 27, 33	
Conditional knowledge	Knowledge that a subject has about when and why he uses it	(5) 15, 18, 26, 29, 35	
Planification	Planning by the subject of study times, fixation of learning goals and resource selection	(6) 4, 6, 8, 22,23, 42, 45	Regulation of cognition (ω= .81) [.79, .85]
Organization	Process accomplished by the subject that allows him to organize the activities around learning	(11) 9, 13, 30, 31, 37, 39, 41, 43, 47, 48	
Monitoring	Supervision exercised by the subject of the learning process during the development of task	(6) 1, 2, 11, 21, 28, 34, 49	
Debugging	Process accomplished by the subject that allows him to identify skills in learning and adjust strategies to improve his performance	(5) 25, 40, 44, 51, 52	
Evaluation	Analysis by the subject of the effectiveness implemented strategies	(6) 7, 19, 24, 36, 38, 50	

Note: ω= McDonald Omega coefficient, 95%CI = Confidence Interval of the coefficient ω, LL= Lower Limit, UP= Upper Limit.

Source: authors

Procedure and ethical considerations

A pilot test of *n*= 15 university students was carried out to examine the understanding of the measurement protocol. Next, permission was requested from the university directives and teachers for the hetero-application of the measured protocol: (a) Informed consent, (b) IPAQ-SF, and (c) MAI. Two of the authors of this study were present in the fieldwork. The data collection process was taken between February and April 2019. All participants were guaranteed the principles of autonomy and confidentiality of study participation. They were ensured that the data obtained would only be for academic and research purposes. Each participant signed the informed consent, and the entire procedure of this research was aligned with national and international investigative principles (*Deontología y Bioética Del Ejercicio de La Psicología En Colombia*, 2012) and international ones such as the Helsinki declaration (World Medical Association, 2013).

Statistics and data analysis

The data were processed and digitized into an Excel data matrix. To correct typing errors, 10% of the responses of the participants were randomly examined. Answers that were consistent with the evaluation protocol were checked. Cleaning and exploring the data allowed the identification of five outlier cases which were >Q3 or <Q1, then observed in a box and whisker plot. Outlier data were removed due to possible social desirability responses or randomized responses. The sample size was n= 270. Descriptive measures of the mean (M) and Standard Deviation (SD) were estimated, as well as the registry of the Confidence Interval (CI) Upper and Lower Limits (UL-LL). Inference analysis were carried out. The multivariate analysis (MANOVA) treated the second-order factors of the MAI (Knowledge of Cognition and Regulation of Cognition) as dependent variables. The independent variables were SPA levels (low, moderate, and vigorous) and gender. The normality assumptions (Kolmogorov-Smirnov) of the two first-order factors were checked: knowledge of cognition (K-S = 0.046, p= 0.200) and regulation of cognition (K-S = 0.040, p= 0.200). Likewise, the assumption of sphericity of the variances was satisfied with the Box's test= 10.483, p= .810. The effect size was estimated with partial eta squared (p. 2), and the interpretation of magnitude is: <.01 small; .06, medium; and >.14 large (Cohen, 1988; Ellis, 2010). The comparison of measurements was made with the Bonferroni post-hoc analysis and 95% CI report. For the MANCOVA analysis, the same procedure for the dependent and independent variables was maintained as gender covariates. Inferential analysis was calculated with SPSS-IBM v.24. Statistical Power (1-β) was calculated with G*Power (Faul *et al.*, 2009). The internal consistency of second-order factors and the total score of the MAI were estimated through the Omega coefficient (ω) of McDonald (2013) and the confidence intervals of each coefficient (see Table 1). This procedure was carried out through JASP software (JASP Team, 2020).

Results

The descriptive data of the metacognitive second-order factors according to the levels of AFS, are observed in table 2.

Table 2. Comparison between metacognition factors

Levels Physical Activity	Knowledge of cognition			Regulation of cognition		
	M	SD	95% CI [LI, LS]	M	SD	95% CI [LI, LS]
Low (n= 88)	22.3	1.9	[21.9, 22.7]	26.5	2.3	[26.0, 27.0]
Moderate (n= 89)	22.9	2.1	[22.5, 23.3]	27.5	2.3	[27.0, 27.9]
Vigorous (n=93)	23.0	1.9	[22,7, 23,5]	27.3	2.4	[26.8, 27.7]

Source: authors

The Multivariate analysis (MANOVA) showed that the SPA levels affect the second order metacognitive factor, Wilks' Λ= 959, F=(4, 722)= 2.83, p= .024, ηp^2= *.021, 1-β=.79*, while MANCOVA showed that gender did not affect, Wilks 'Λ = 992, F=(4, 265)= 1.06, p= .348, ηp^2= .008. The inter-subject analysis, indicates an effect of SPA on the knowledge of cognition factor, F=(2, 266)= 3.53, p= .031, ηp^2= *.0.26, 1-β*=.96, and on regulation of cognition factor, F=(2, 266)= 4.78, p= .009, ηp^2= .0.35 (see, table 3).

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Table 3. Comparative between metacognition factors

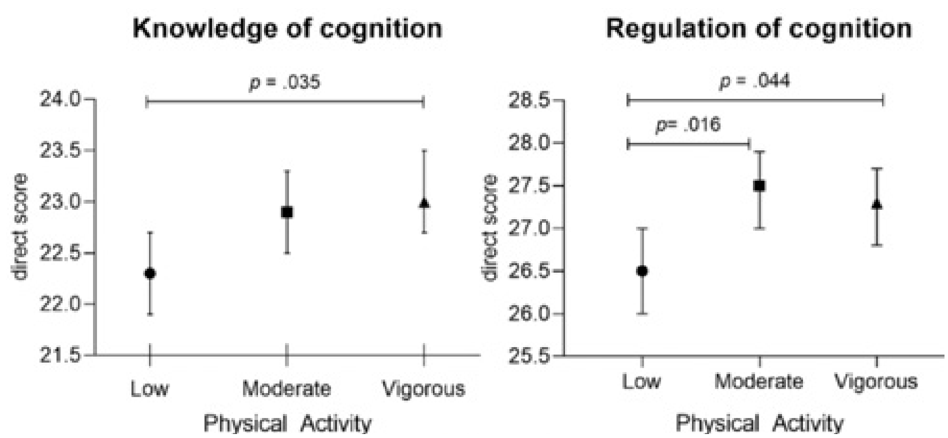
Variables	Test of between-subjects effects				
	SS	MS	F	p	ηp2
Levels Physical Activity					
Knowledge of cognition	28.21	14.10	3.53	.031	.026
Regulation of cognition	52.78	26.3	4.78	.009	.035
Gender					
Knowledge of cognition	1.04	1.04	0.26	.610	.001
Regulation of cognition	10.04	10.04	1.81	.178	.007

Note: SS=sum of squares, MS= mean square

Source: authors

The comparison of means and the post-hoc analysis (see, figure 1) showed that in the knowledge of cognition factor the low level of SPA (M= 22.3, DE=1.9) is significantly different regarding with vigorous level (M= 23.0, DE=1.9), p= .035, 95%CI [-1.49, -0.03]. Regarding the regulation of cognition factor, the low SPA level differed with moderate level (M=27.5. DE= 2.3), p= .013, 95%CI [-1.86, -0.16], and vigorous (M=27.3. DE= 2.4), p= .044, 95%CI [-1.72, -0.15].

Figure 1. Comparison between means of the systematic physical activity levels and metacognition factor. Analysis post-hoc corrected with Bonferroni



Source: authors

Discussion

The purpose of this paper is to study the effect of SPA levels on metacognition; the hypothesis that SPA levels show differences in MC factors was confirmed. The main results indicated that SPA levels significantly affected MC, while gender has no effect according to the analysis of covariance. The main effects indicated that the vigorous level of SPA, compared to the low level of SPA, were significantly better in knowledge of cognition. Similarly, the low levels differ significantly regarding with the moderate and vigorous SPA levels in the regulation of cognition.

This study contributes to the evidence about the effect of SPA on cognitive and metacognitive processes (Álvarez-Bueno *et al.*, 2017; Kramer *et al.*, 2006). These data also indicate that moderate and vigorous SPA levels may have positive effects on metacognitive processes, as has also been indicated by other reports that have systematized effects of the SPA on emotional recognition variables (Aguirre-Loaiza, Arenas, *et al.*, 2019; Brand *et al.*, 2019), psychological processes (Päivärinne *et al.*, 2018), and neurobiological substrates of people (Erickson *et al.*, 2015; Esteban-Cornejo *et al.*, 2019; Mandolesi *et al.*, 2018).

Studying the modulating role of SPA regarding cognition and MC concerning dose-response is one of the important questions in the research line of psychology of physical activity for health (Chang *et al.*, 2015; Chen *et al.*, 2018; Engeroff *et al.*, 2019; Naderi *et al.*, 2019). Likewise, linking other analysis in different population groups (e.g., children, older adults, etc), including comparisons between neurotypical groups and clinical cases (McSween *et al.*, 2019). Thus, moderate and vigorous SPA levels are desired for the improvement of the physical, cognitive and emotional people's welfare (Hillman *et al.*, 2019; Hillman & Biggan, 2017; Tsukamoto *et al.*, 2016). Additionally, more complex processes such as MC also indicate that these vigorous and moderate SPA levels may be more favorable than low ones (Browne *et al.*, 2017). Consequently, the SPA shows a benefit on the quality of life and healthy lifestyles (Barbosa-Granados & Aguirre-Loaiza, 2020; Päivärinne *et al.*, 2018).

The linkage between SPA and MC is of interest of the scientific community. In turn, it is promising when educational sectors can be promoters of SPA. In fact, we express that skills such as planning, organization, monitoring, debugging, evaluation, and other learning strategies could also be modulated through the SPA. Under those circumstances, embodied cognition is a theoretical and methodological proposal that complies with these new demands to consider the body as an element of cognition and MC (Schmidt *et al.*, 2019; Shapiro & Spaulding, 2019).

This work has some limitations. The use of self-report instruments can lead to biased results. Likewise, the sample collected comes from a single university. Finally, it is a cross-sectional and observational design. As mentioned earlier, future works in this line should consider the manipulation and control of the SPA as an independent variable (experimental or quasi-experimental designs). Although a wide variety of people are found in universities, it is appropriate to include other educational centers, including colleges and schools at the primary and secondary level. Subsequently, the use of physical fitness measures and evaluation of endurance, strength, flexibility, etc., as well as MC measures with achievement tasks can yield data with better quality evidence.

However, before the previous limitations, this work has several implications, from which mainly two stand out. On the one hand, theoretically, it is one of the pioneering studies that relates SPA and MC, adding evidence of the favorable effects that SPA has on metacognition. On the other hand, on a practical level, it highlights the importance of SPA on teaching and learning processes throughout the educational platform. However, this study asks for caution in the generalization of its interpretations if the opportunity that the different educational levels have to promote SPA from their curricular structures is confirmed. Sports are also a field to explore in coherence with education and cognitive and metacognitive process. For example, intervention applied of sport psychology in students-athletes (Herrera Velásquez & Gómez-Maquet, 2020). Recently, a study analyzed social cognition in athletes (Aguirre-Loaiza *et al.*, 2020), and social cognition is very important in cognitive processes and MC. Despite this topic is related to physical activity, we think that athletes can be a model, and new studies on sports will help to understand MC applied in other fields.

Conclusions

In conclusion, this study indicates that SPA levels have an effect on MC, with moderate and vigorous levels being favorable. Specifically, the vigorous level shows a better score than the low level in knowledge of cognition. Also, moderate and vigorous levels showed a better score than the low level, in the regulation of cognition.

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