




# Physical activity, physical fitness and academic achievement in adolescents: A self-organising maps approach


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## TITLE PAGE

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## ABSTRACT

The relationship among physical activity, physical fitness and academic achievement in adolescents has been widely studied; however, controversy concerning this topic persists. The methods used thus far to analyse the relationship between these variables have included mostly traditional lineal analysis according to the available literature. The aim of this study was to perform a visual analysis of this relationship with self-organising maps (SOM) and to monitor the subject's evolution during the four years of secondary school. Four hundred forty-four students participated in the study. The physical activity and physical fitness of the participants were measured, and the participants' GPAs were obtained from the 5 participant institutions. Four main clusters representing two primary student profiles with few differences between boys and girls were observed. The clustering demonstrated that students with higher energy expenditure and better physical fitness exhibited lower Body Mass Index (BMI) and higher academic performance, whereas those adolescents with lower energy expenditure exhibited worse physical fitness, higher BMI and lower academic performance. With respect to the evolution of the students during the four years, approximately 25% of the students originally clustered in a negative profile moved to a positive profile, and there was no movement in the opposite direction.

# INTRODUCTION

Regular physical activity has been associated to many health benefits. These benefits are particularly applicable in childhood and adolescence [1] because these are stages of life in which healthy habits should be acquired to prevent diseases such as obesity, diabetes, and hypertension [2]. In addition, the prevention of such diseases, the increase of moderate or vigorous physical activity in childhood and adolescence has a positive effect on mental and physical health that enhances opportunities to improve academic performance [3–5]. Thus, many institutional campaigns based on the promotion of physical activity have been instituted in the schools in an effort to improve health and academic results [6–9]. Furthermore, with respect to the consequences of obesity and physical inactivity, there are many studies focused on the relationship between childhood obesity and academic achievement [10–12], although the results are inconclusive and the relationship remains clear.

Most of the studies performed in the last years indicate that students with a more active lifestyle [3,13–16] or those who exhibit better physical fitness [17–20] obtain better academic results than those students with more sedentary lifestyles. Additionally, the relationship between physical activity or physical fitness and the different components of academic achievement has been studied. Some authors indicate that physical activity and physical fitness are significantly correlated with mathematical performance but not with other subjects [21], whereas most articles note that physical activity and physical fitness are also correlated with performance in other subjects, such as language ability [17,22] or social sciences [6]; nevertheless, math or numeracy scores seem to exhibit the highest correlation with physical activity [17,22,23].

A recent review [24], although supporting these results, reported a deficit in the number of articles of high methodological quality. Nevertheless, some studies have not reported significant differences in the academic performance of active children and those who are less active [25–27], concluding, that more time expended in physical activity may not exert positive effects on cognition and academic achievement; however, negative effects have never been reported.

Most studies examining the relationship among physical activity, physical fitness and academic achievement exhibit a cross-sectional design, and in some cases, promotional campaigns have been performed. Nevertheless, only few reports of longitudinal studies exist [8,11,24,28,29] that would allow researchers to observe the evolution of the relationship between physical activity and academic performance over time.

The aim of this study is to examine the relationship among the physical activity level, physical fitness and academic performance with Self-Organising Maps (SOM) analysis throughout the secondary school stage. Thus far, this issue has been addressed using traditional lineal analyses; however, some evidence indicates that the relationship among these variables may be no-lineal [14]. SOM analysis is used to classify and display the lineal and non-lineal relationships among variables. Moreover, one of the most important points of this study is to classify the students to identify different behavioural patterns and to supervise behavioural evolution over time. There is insufficient information available in the literature to predict the evolution of student behaviour throughout the secondary stage.

Our working hypothesis has been that students with a higher level of physical activity and better physical fitness should cluster with better academic performance.

## MATERIALS AND METHODS

*Study design and participants*

The present study used a longitudinal design in which physical activity, physical fitness, body composition and academic performance (GPA grade point average) were recorded over four academic years (2007-2008; 2008-2009; 2009-2010; 2010-2011).

The sample selection process was as follows: 1) Among all of the high schools in Barcelona city, we selected schools with similar socioeconomic and demographic characteristics. 2) After contacting with the administrators of these centres, 5 high schools agreed to take part in the study. 3) All of the students enrolled in the first year of secondary education in these centres were considered eligible. 4) Several briefings were help in which the exclusion criteria were explained to the teachers and involved students. Thus, students with physical or psychological disabilities were discarded, as were those who had been injured for more than one month during the previous academic year and students with high truancy (i.e., more than 30% absences). Additionally, we excluded students who had repeated a grade once and/or students whose ages did not correspond with their assigned grade level. Finally, 700 adolescents begin the study. 5) Four hundred forty-four students (218 boys and 226 girls) completed the four years of the study; 36.5% of the original participant sample left the research due to various reasons (e.g., dropping out of the school, change residence, sport injuries during the test period, etc.). It is necessary to note that in Catalonia (Spain), the curriculum of all public schools is common (the outline of the educational program of the subjects followed in our study is presented is the supplementary material). Furthermore, the profile of teachers is homogeneous (i.e., civil servant), and all teachers have equivalent academic backgrounds and have been selected through the same process.

All students and students' parents or legal tutors signed an informed consent form for their children's participation in the study. Educational authorities and the Ramon Llull University's Research Ethics Committee in Barcelona approved the development of this study.

*Outcome measures*

The academic achievement was obtained from the student's transcripts using the grade point averages (GPAs). The procedure was as follows: The mean value of 10 academic topics corresponding to an academic year (GPA grade point average) was obtained for each of the four years that the students spent at secondary school. The score of the mean value ranged from 0 (worst rating) to 10 (best rating). The mark required for passing an academic topic was 5. The mean mark during each school year (i.e., of the ten topics) was taken for posterior analysis. There were no significant differences between the schools with respect to the average GPA ($p > 0.05$).

Through a qualitative questionnaire [30], the students were asked about the practice of formal physical activity after school, understood as any practice of physical activity in a formal context with a stipulated schedule after school, i.e., sports, dance, or any other activity practiced on a scheduled basis. The participants could choose between three options (1 = yes, I practice formal physical activity; 2 = I practice formal physical activity only occasionally; or 3 = I don't practice formal physical activity).

The physical activity performed was assessed using the International Physical Activity Questionnaire (IPAQ) [31] in its abbreviated form, using the adaptations for adolescents used in the HELENA study [32]. The IPAQ records all of the physical activity performed in the previous week. The results were converted into units of Metabolic Equivalent of Task (METs) following the IPAQ specifications.

The body mass index (BMI=kg/m$^2$) was calculated by measuring weight (kg) and height (m). The weight was measured with a digital weight scale, the SECA 714 (Seca, Hamburg, Germany), whereas the height was obtained with a height rod from the SECA 217 (Seca, Hamburg, Germany).

The jump power was measured from the data obtained in a countermovement jump (CMJ) in a contact platform with the Chronojump software (Chronojump Boscosystem, Barcelona, Spain) validated by De Blas [33]. All subjects performed a warm-up consisting of 5 min of running, stretching and calisthenics. Before each jump, 3-4 practice jumps were performed; finally, the best jump of the two trials was recorded.

Aerobic power was measured using the Cooper test. This test was performed by taking into account the aspects described by McArdle et al., [34] over a distance of 200 m with markings every 50 m. All subjects were familiarised with the test protocol and performed a light warm-up of 2 min running and 3 min stretching.

The handgrip isometric strength was measured with a Takei dynamometer model 1875 (Takei Kiki Kogyo, Tokyo, Japan) that assessed the strength in each hand for 5 sec; the best result of the strongest hand was recorded. All of the measurements were supervised by the same researcher.

*Data analysis*

In the present study, we applied a Self-Organising Map (SOM). This analytical method employs competitive non-supervised neural networks. The principal goal of the SOM is to transform an incoming signal pattern of arbitrary dimension into a two-dimensional discrete map, performing this transformation in a topologically ordered fashion [35]. This type of analysis is a common tool used to classify or identify relationships between the different variables that describe a given problem. Although this classification was the main objective of this analysis, SOM also allows the researcher to observe the patterns of changes in the data across different periods of time. Furthermore, the SOM can represent the movement of the subject's data within the map. SOM was performed with the Matlab R2008a program (MathWorks Inc., Natick, USA) and the SOM toolbox (version 2.0 beta) for Matlab [36].

The process begins with the construction of a neuron or node network, whose size depends on the number of cases included in the analysis. The data matrix used as the input had a length of 1776 cases (i.e., 444 subjects x 4 years). To track the progress of each subject during the four-year period (temporal trajectories), an identifier was assigned to each adolescent where the year in which the data had been taken was specified following the guidelines of Delmelle et al., [37].

In our study, the network had a rectangular shape with a size of 18 x 12 neurons in height and width, respectively. The neurons shape was hexagonal, such that each neuron had 6 neighbouring neurons.

After determining the size and shape of the lattice, a value was assigned for each input variable to each of the nodes or neurons (i.e., initialisation). SOM initialisation was performed in two different ways, as explained below. In the randomised initialisation, small random values were assigned to each neuron's weight vector. In the linear initialisation, weight vectors were initialised in an orderly fashion along the linear subspace spanned by the two principal eigenvectors of the input data set.

The initially assigned weights were modified during the training process. Two different training algorithms were applied in this study (i.e., sequential and batch). In the training phase, each neuron of the grid competed to win each of the input vectors ($x$) or cases of the sample. The winner neuron was the one that exhibited the minor Euclidean distance between its weight vector and the input vector. It should be highlighted that the input vectors or cases were normalised (taking values between 0 and 1) before starting the training process; in this way, the variable scale did not affect the SOM training.

This competitive process led to an adaptive process; once an input data vector was assigned to a neuron, the weights of the winning neuron and its neighbour neurons changed and were topologically ordered at the same time (i.e., ordering and convergence phases).

In particular, equation 1 was used to perform the calculation during the neural network training.

$$w_j(n+1) = w_j(n) + \eta(n) h_{j,i(x)}(n)(x - w_j(n)) \qquad \text{Eq. 1}$$

where $w_j$ is the weight vector of the j$^{th}$ neuron, $\eta$ is the learning ratio, $h_{j,i(x)}$ is the neighbourhood function, and $x$ is the input vector. As seen, the weights were modified after each iteration based on the differences between the starting weights and the input vector, the neighbourhood function and the learning ratio. The neighbourhood function was used so that the winning neuron and its nearest neighbours could adjust their weights to resemble the input vector more than the neurons distant to the winning neuron. For the present study, four different neighbourhood functions were tested: i) Gaussian, ii) cut Gaussian, iii) Epanechicov and iv) Bubble.

The learning ratio had a high value during the first iterations and gradually decreased to very low values. Thus, at the beginning of the training, large changes in the neuron weight were produced and were modified more discreetly as the process progressed.

The process described was repeated 100 times because the final analysis result depended on some randomised processes (e.g., initialisation and entry order of the input vector). By repeating the process 100 times, the odds of finding the best solution to the problem were increased. Because we used two different training methods, four neighbourhood functions and two initialisation methods, 1600 SOM were obtained (i.e., 100 x 2 x 4 x 2). The map with the least error when multiplying the quantisation and topographical errors was selected. The quantisation error expressed the accuracy of the value assigned to the neuron regarding the values of each participant who had been included in that neuron. The topographic error was related with the position and the value of the neurons. This error was low when the nearest neurons resembled each other more than those further away.

Among the measured variables, the formal physical activity was not included in the analysis. This variable was used to label the winning neurons by the percentage of subjects belonging to each category. Although the SOM aimed to cluster cases with similar characteristics for different neurons (i.e., each neuron represents a cluster itself), occasionally a cluster analysis was performed to establish larger groups of people. We used a k-mean method, setting 4 clusters for posterior analysis. These clusters are presented in figure 1 overlying the component planes to facilitate understanding. Lastly, the correlation matrix between variables was calculated through a Pearson r to reinforce the visual analysis. For this calculation, we took the value of each neuron.

Moreover, with the aim of assessing the subject's mobility, the number of subjects that started their secondary school in one cluster and changed to another cluster at the end of this educational period was computed. Thus, the percentage of subjects that experienced a change of cluster was established. The type I error was established as less than 5% ($\alpha<0.05$).

## RESULTS

Before describing the results, it is necessary to explain some aspects of the analysis that will help the reader to better interpret the SOMs: i) At the time the analysis algorithm finishes, all sample subjects (input) are placed in a given neuron (output). Effectively, the subjects are grouped in the same neuron with those colleagues with whom they share more characteristics. Therefore, regardless of the visualisation system used or of the variable being observed, subjects will always be placed in the same place (i.e., the same neuron). ii) The second critical point is related to the distances between the neurons. A priori, subjects in a given neuron will have similar values to the colleagues located in the same neuron and less similar to those placed in distant neurons.

In figure 1, bottom right corner, the number of subjects "trapped" in each neuron can be observed (HITS plane). Most of the subjects in our study are located in the peripheral areas of the map. In the central area, in the horizontal axis, several neurons are unpopulated. Although in the other maps of the figure these neurons are coloured, the colours do not represent any subject, and the associated value is merely an approximation. In the same HITS map, the four identified clusters appear numbered and are surrounded by a thick border. The areas 1 and 3 are the low academic achievement areas, and the areas 2 and 4 are the high academic achievement areas, as seen in the academic performance map.

In figure 1, the *component planes* are also shown. This display form gives an idea of the values achieved by the subjects placed in a given neuron in each analysed variable separately. The upper left corner demonstrates that boys and girls have been clustered on opposite sides (top girls and bottom boys).

When examining the remaining component planes, two opposite behaviour patterns can be observed, with slight differences observed between boys and girls. The first profile can be observed on the left side of the maps (areas of interest 1 and 3). In this area, the adolescents have a BMI>23 and exhibit a low energy expenditure due to physical activity (approximately 1000 METs/week). These students have a low academic performance below 5 out of 10 points (i.e., they fail at least one academic topic). Additionally, these students exhibit low values in the physical fitness test (endurance, CMJ and handgrip). As mentioned above, there are slight differences between boys and girls; the girls exhibit slightly better academic performances, higher BMIs and lower physical fitness.

Areas 2 and 4 contain students with a high academic performance, a BMI<21 and a high energy expenditure due to physical activity >2000 METs/week. With respect to their physical fitness, these students exhibited higher values in endurance, CMJ and handgrip strength than the profile located on the opposite side. As was observed with profiles 1 and 3, the behaviours linked to gender exhibited slight differences.

In figure 2, the variable “formal physical activity” (Label plane) is represented. It is important to note this qualitative variable was not introduced in the analysis; instead, once the subjects were assigned to the different neurons, the behaviour reigning was calculated. In the high academic performance areas in both girls and boys (areas 2 and 4), most persons practiced formal physical activity regularly or occasionally. Looking the map located immediately on the right (Pie plane), the percentage of persons with a specific behaviour can be observed (blue=regular formal physical activity; green=occasional formal physical activity; red=no formal physical activity). By contrast, on the left side (areas 1 and 3), the students exhibited lower academic achievement and were associated with the behaviours “not performing formal physical activity” and “performing formal physical activity only occasionally”.

Although the main aim of the SOM is to perform an exploratory analysis for detecting behaviour patterns by considering all variables, table 1 presents the numerical data of each measured variable. This table summarises the values characterising the four clusters studied. In table 2, the correlation matrix between the variables analysed can be observed.

Finally, a key aspect in this work is that the subjects were monitored for four years. In figure 3, the trajectories followed by the students during the years of secondary school can be observed. It can be appreciated that only some subjects placed in the clusters 1 and 3 exhibited crossed clusters, reaching the opposite side after four years. Specifically, 36 girls from cluster 1 (27.9% of the cluster subjects) reached cluster 2, and 23 boys from cluster 3 (21.2% of the cluster subjects) finished their fourth year in the opposite cluster. However, students in areas 2 and 4 did not abandon the cluster where they began. In other words, the students with a high academic performance and good physical fitness maintained these behaviours over the years.

## DISCUSSION

The main contribution of this study is the SOM analysis of the interactions among physical activity, physical fitness and academic performance, which allows a non-lineal visual interpretation of this relationship as well as the changes of profiles experienced by the participants during the time elapsed in the secondary school. Concretely, this analysis enables researchers to detect specific profiles of students and check the effects of the secondary school on changes in the profiles of the participants, as has been suggested previously [38]. Thus, we observed 4 clusters that can be summarised into two main profiles: low performance and high performance. Moreover, changes in the profiles were detected in the participants who exhibited poor performance during the first year of secondary school. Approximately 25% of these subjects moved to the high performance profile, possibly due to the educational intervention performed during these four years. The main characteristics of this educational intervention can be found in the supplementary material.

Nevertheless, before discussing these findings, it is important to analyse the values obtained for the input variables as well as the relationship between these variables. The values of the different variables (BMI, energy consumption, academic achievement, aerobic capacity, CMJ and handgrip values) confirm our initial hypothesis and are consistent with the data obtained in other studies involving similar populations with respect to physical activity [14], IMC [39] or the physical condition test such as handgrip values [40,41] or the cooper test [42].

As mentioned in the results, four profiles were identified, including two with low performance scores (areas 1 and 3) and two with high performance scores (areas 2 and 4). Area 1 included girls with high BMI values, low energy expenditure and low academic performance. The adolescents located in this area exhibited the worst results on the physical fitness tests.

Profiles in areas 1 and 3 are very similar. The latter profile included boys with low academic performances, high BMI values and low energy expenditure. Additionally, adolescents located in this area exhibited low values on the physical fitness tests.

Area 2 contained girls with medium-high academic performance, low BMI and high energy expenditure. These girls also exhibited good physical fitness, as evidenced by high values on the fitness tests.

Finally, area 4 included boys with medium-high academic performance, low BMI and high energy expenditure. The students placed in this area also exhibited good values on the physical fitness tests.

This clustering analysis demonstrates that students with higher energy expenditure and better physical fitness also exhibit lower BMI and higher academic performance, whereas those adolescents with lower energy expenditure also exhibit the worst physical fitness, higher BMI and lower academic performance. These profiles are confirmed by the correlations calculated after performing the SOM.

There are two main theories to explain how physical activity can be beneficial for cognitive processes and how may it be associated with academic achievement: i) Studies have attempted to explain this relationship from the neurophysiological point of view, suggesting for example that academic achievement is caused by improved blood flow in brain that leads to an improvement in cognitive functions such as memory or attention. ii) Other studies explain this relationship from the psychosocial perspective, suggesting that participation in physical activity and sports with peers improves social skills such as cooperation and respect for the rules and may have a positive influence on academic performance.

Many studies have explained the relationship between physical activity and cognitive performance from a neurophysiological perspective [43–45]. The main argument of this research is that physical exercise produces favourable changes in the hippocampus [13], such as heightening neurogenesis [44], enhancing neural transmission [46,47] and increasing the creation of neuroprotective factors such as brain-derived neurotrophic factor (BDNF) [48], which may improve memory and learning processes.

On the other hand, some studies indicate that the increase in physical activity and the improvement of physical fitness is positively associated with mental health components, self-esteem, emotional wellbeing and self-concept [49,50].

Additionally, the variable formal physical activity may also help to improve academic performance; Morales et al., [51] indicate that participation in extracurricular physical activities improves academic results due to the increased opportunity from participants to socialise. The variable formal physical activity was not introduced in the SOM analysis and therefore has not contributed to the subjects' distribution; however, the variable supports the arguments espoused thus far.

However, despite the evidence presented, some studies have failed to identify any relationship between physical activity and academic achievement [25–27], possibly because the relationship between these two variables is not exactly linear. This relationship suggests that energy expenditure does not improve academic achievement if the threshold of a (moderately high) physical activity is surpassed. Nevertheless, students increasing physical activity to higher levels may not obtain better academic results than their peers with moderately high activity levels [14].

With respect to the differences between the genders, boys exhibited better performances on physical fitness tests as reported previously due to physiological differences, whereas girls exhibited better academic results than boys. Our study is not the first study reporting these differences in academic performance between the genders [52].

The analysis of the maps suggests that the academic community should devote more attention and effort to the low academic performance profiles. In this study, students were followed for four years, and we observed that approximately 25% of the students placed in low performance areas during the first year finished the secondary stage in the high performance clusters. Therefore, both boys and girls in low performance profiles at the beginning of secondary school can progress and change to a high performance profile. Nevertheless, the boys and girls that began secondary school in the high performance cluster did not redistribute to the low performance profile after the 4-year period. This fact could be explained by the effectiveness of the educational procedures that were applied during the four years of secondary school. During this period of time, the subjects received an educational intervention that promoted the high performance profiles. Another possible explanation for the maintenance of the high performance profiles over the four–year period may be familial and social pressure; students with good academic results may become more self-demanding and self-confident, making it essential for them to maintain or improve their academic performance.

*Limitations*

Finally, it should be noted that the methodology used in this study allows the data to be analysed in a non-linear fashion, thereby obtaining visual information about how students can be clustered. Nevertheless, there are also some limitations to this methodology, including the impossibility of establishing differences as in the traditional lineal analysis. This limitation could be seen as an impediment to establishing direct relationships among physical activity, physical fitness and academic performance. Therefore, for future research, it would be interesting to perform an experimental intervention that increases the time of physical activity in low performance profiles and investigate whether the habit changes are sufficient to produce a positive change in the long-term academic performance. Moreover, it would be interesting to examine the changes in the relationship between academic performance and physical activity/fitness using other longitudinal analysis techniques. Finally, our study did not allow us to determine the underlying mechanisms by which physical activity correlated with the academic performance. Future studies should address this issue.

*Practical applications*

Among many other variables, physical activity and physical fitness have been linked to academic performance in the scientific literature. Our work contributes to the study of this topic. The use of advanced mathematical models (i.e., neuronal networks) has enabled us to establish well-defined student profiles that were previously unknown. These profiles very clearly demonstrate that physically active and fit students exhibit better academic performance. Nevertheless, one of the main contributions of our study is the ability to observe changes in some adolescents over the four–year study period. The results of this work demonstrate that students with low performance profiles can develop more positive behaviours.

These findings are useful from a descriptive or exploratory perspective, but the findings are also particularly relevant for sports medicine and social sciences from a practical point of view. In fact, future plans against academic failure may include physical activity as an important factor for achieving academic success. Moreover, the increase in physical activity practice in schools could contribute to fight sedentary lifestyles and their public health consequences.

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# TABLES

**Table 1. Descriptive statistics of the neurons values**

| | | BMI (n.u.) | PHYSICAL ACTIVITY Kcal (day) | COOPER (m) | CMJ (cm) | HANDGRIP (kg) | ACADEMIC PERFORMANCE (score) |
|---|---|---|---|---|---|---|---|
| Cluster 1 (n=52) | $\bar{x}$ | 24.68 | 1309.98 | 1416.85 | 27.47 | 27.67 | 5.43 |
| | $\sigma$ | 2.19 | 280.14 | 214.14 | 2.60 | 2.05 | 0.37 |
| | 95% CI | [24.06 , 25.29] | [1231.98 , 1387.97] | [1357.23 , 1476.47] | [26.74 , 28.19] | [27.10 , 28.24] | [5.32 , 5.53] |
| Cluster 2 (n=60) | $\bar{x}$ | 21.03 | 2044.41 | 2017.43 | 31.38 | 31.08 | 6.40 |
| | $\sigma$ | 1.73 | 297.80 | 162.71 | 2.06 | 1.87 | 0.51 |
| | 95% CI | [20.58 , 21.48] | [1967.48 , 2121.34] | [1975.39 , 2059.46] | [30.84 , 31.91] | [30.60 , 31.57] | [6.27 , 6.53] |
| Cluster 3 (n=49) | $\bar{x}$ | 23.89 | 1257.12 | 1418.17 | 29.30 | 28.56 | 4.48 |
| | $\sigma$ | 2.11 | 220.32 | 264.32 | 2.29 | 2.06 | 0.61 |
| | 95% CI | [23.28 , 24.50] | [1193.84 , 1320.40] | [1342.24 , 1494.09] | [28.64 , 29.95] | [27.97 , 29.15] | [4.31 , 4.66] |
| Cluster 4 (n=55) | $\bar{x}$ | 19.82 | 2362.79 | 2396.10 | 34.50 | 35.40 | 6.28 |
| | $\sigma$ | 1.20 | 372.93 | 248.96 | 2.20 | 2.83 | 0.44 |
| | 95% CI | [19.49 , 20.14] | [2261.98 , 2463.61] | [2328.80 , 2463.40] | [33.91 , 35.10] | [34.64 , 36.17] | [6.16 , 6.40] |

*95% CI=95% Confidence Interval*

**Table 2. Pearson correlation coefficients between physical activity, physical fitness and academic performance**

| | BMI (n.u.) | PHYSICAL ACTIVITY Kcal (day) | COOPER (m) | CMJ (cm) | HANDGRIP (kg) | ACADEMIC PERFORMANCE (score) |
|---|---|---|---|---|---|---|
| BMI | 1 | | | | | |
| PHYSICAL ACTIVITY | -0.66* [-0.73 , -0.58] | 1 | | | | |
| COOPER | -0.77* [-0.81 , -0.70] | 0.94* [0.93 , 0.95] | 1 | | | |
| CMJ | -0.88* [-0.91 , -0.85] | 0.63* [0.55 , 0.71] | 0.78* [0.72 , 0.82] | 1 | | |
| HANDGRIP | -0.81* [-0.85 , -0.76] | 0.76* [0.7 , 0.81] | 0.84* [0.79 , 0.87] | 0.91* [0.89 , 0.93] | 1 | |
| ACADEMIC PERFORMANCE | -0.56* [-0.64 , -0.46] | 0.80* [0.74 , 0.84] | 0.78* [0.72 , 0.82] | 0.47* [0.36 , 0.56] | 0.49* [0.39 , 0.59] | 1 |

*Data are correlations coefficients [95% Confidence Intervals]; * indicates significant correlation to 0.01 level (bilateral).*

## FIGURE LEGENDS

**Figure 1. Component planes of the recorded variables**

*From left to right and from top to bottom: the component planes of the variables sex (male=1; female =2), Body Mass Index (kg·m$^{-2}$), Physical Activity (METs·week$^{-1}$), Cooper (m), Counter Movement Jump (cm), Handgrip (kg) and Academic Performance (score). Bottom right corner: Hit Map, where the four clusters (numbers 1 to 4) are marked. These areas are overlapped on all maps in the figure for clarification.*

**Figure 2. Formal physical activity**

*The label map is placed on the left side and presents the winning value of each neuron (Y= regular formal physical activity; O=occasional formal physical activity; N=no formal physical activity). The right side presents the pie plane representing the percentage of participants practicing physical activity on each neuron (blue= regular formal physical activity; green=occasional formal physical activity; red=no formal physical activity). The four areas of interest are overlapped with a thicker line.*

**Figure 3. Distance travelled by the subjects during the four years recorded**

*The lines indicate the neurons through which the subjects have moved.*

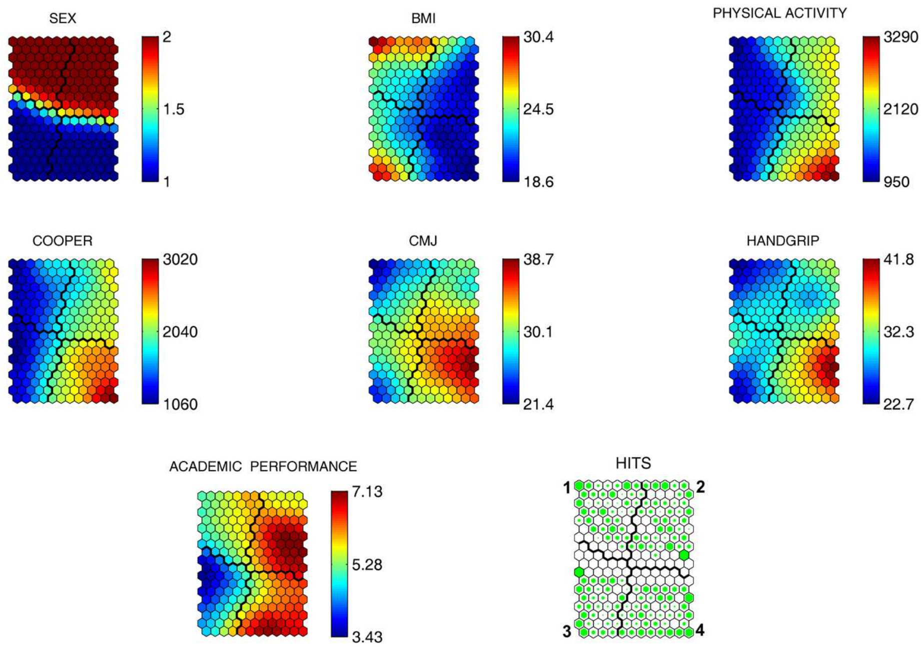


Figure 1. Component planes of the recorded variables
From left to right and from top to bottom the component planes of variable sex (male=1; female =2), Body Mass Index (kg·m-2), Physical Activity (METs·week-1), Cooper (m), Counter Movement Jump (cm), Handgrip (kg) and Academic Performance (score). Bottom right corner Hit Map, where the four inters areas (numbers 1 to 4) are marked. These areas are overlapped in all maps in the figure for clarification matters.

158x107mm (300 x 300 DPI)

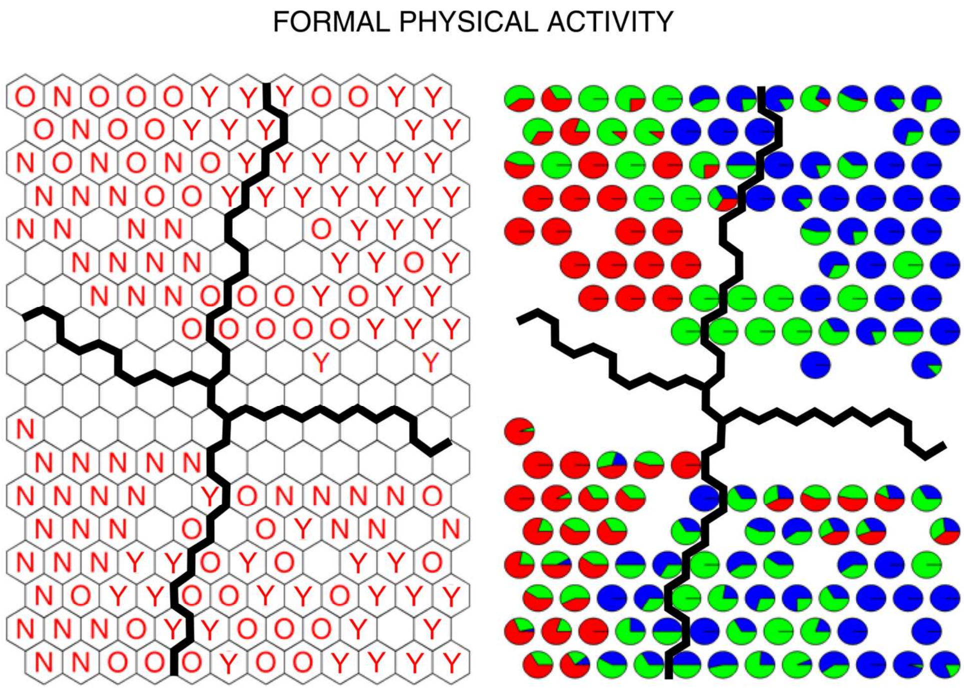


Figure 2. Formal physical activity
The label map is placed on the left side and presents the winning value of each neuron (Y= regular formal physical activity; O=occasional formal physical activity; N=no formal physical activity). The right side presents the pie plane representing the percentage of participants practicing physical activity on each neuron (blue= regular formal physical activity; green=occasional formal physical activity; red=no formal physical activity). The four areas of interest are overlapped with a thicker line.
137x95mm (300 x 300 DPI)

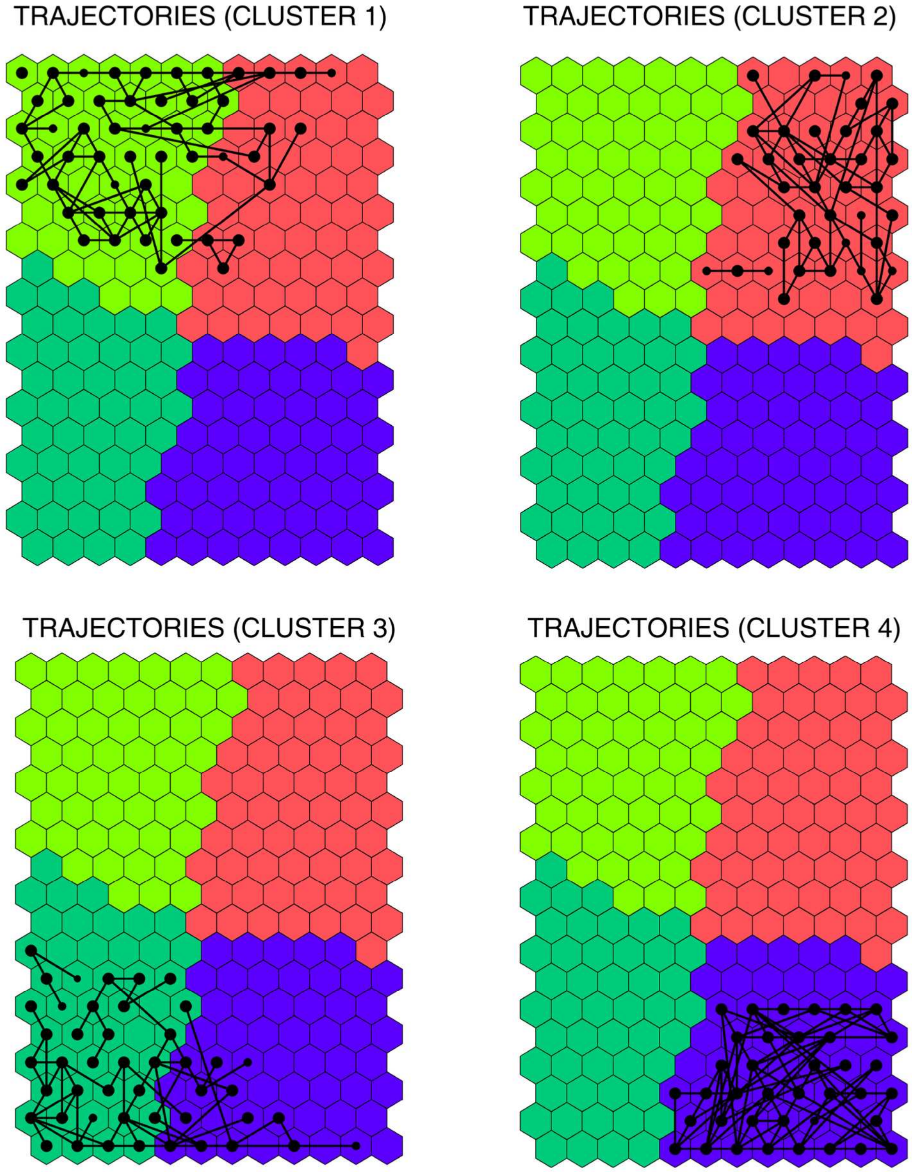


Figure 3. Distance traveled by the subjects during the four years recorded
The lines show the neurons through which the subjects have moved.

153x193mm (300 x 300 DPI)

# SUPPLEMENTARY MATERIAL

## CHARACTERISTICS OF THE SPANISH EDUCATION SYSTEM

The main feature of the Spanish education system is the convergence on the educational objectives set by the European Union. Thus, the legal framework imposes minimum requirements that produce a high degree of homogeneity among all autonomous communities that make up the Spanish State.

The public education system in Spain is characterised by the equality of access to opportunities by all students without any discrimination by sex, race or culture. The admission process of students and teachers is controlled by the administration, ensuring equal opportunities for everyone.

Entry to the teaching profession is achieved through a public examination involving a homogeneous degree requirement and an equal access exam.

For all students with the same opportunities within the system, a number of mechanisms are established to ensure the quality of the whole process:

- The promotion from one course to another takes place when the student is actually prepared, establishing evaluation mechanisms to corroborate this preparation.
- The administration establishes general mechanisms for evaluating schools. At the end of 2nd year and 4th year, identical diagnostic tests for all public schools are established to set the level of each school and establish mechanisms to correct problems if necessary.

The education system invests many resources in the awareness of diversity, setting some mechanisms to balance the level of all of the students:

- It is possible to establish flexible groups, where students can change groups in consideration of their needs for each subject.
- The possibility of reinforcements with teachers in the groups that require such reinforcement is contemplated.
- Specific methodologies are used according to the needs of students. Additionally, the contents of the materials can be arranged differently if necessary.
- The educational administration allows, in very particular cases, significant curriculum changes after a study case by case.

The tutorial action has a very important role during this stage and involves two hours each week dedicated to individual attention to each student and their parents.

The Spanish education system has two compulsory stages:

- Primary: 6 years (between ages 6-11)
- Secondary: 4 years (between ages 12-16)

A post-compulsory stage BACHELOR: 2 years (between ages 16-18).

The secondary stage is divided in 2 cycles: 1º and 2º of compulsory secondary education (ESO) and 3º and 4º of ESO.

| **Subject/Year** | **1º** | **2º** | **3º** | **4º** |
|---|---|---|---|---|
| Spanish language | 3 | 3 | 3 | 3 |
| Catalan Language | 3 | 3 | 3 | 3 |
| English Language | 3 | 3 | 3 | 3 |
| Mathematics | 3 | 3 | 3 | 3 |
| Sciences | 3 | 3 | 4 | - |
| Social sciences | 3 | 3 | 3 | 3 |
| Physical education | 2 | 2 | 2 | 2 |
| Technology | 2 | 2 | 2 | - |
| Visual and plastic education | - | 3 | 1 | - |
| Music | 3 | - | 1 | - |
| Attention to diversity* | 5 | 5 | 5 | 13 |
| TOTAL | 30 | 30 | 30 | 30 |

**The attention to diversity includes specific and elective subjects and tutorages depending on the student's need.*

Physical education includes the following contents:

• Physical and health condition.

• Games and sports.

• Body language.

• Activities in the natural environment.

Each school specify the activities from these blocks of contents, choosing the sports and activities in nature that are best suited to their environment.