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## Pilot evaluation of the effectiveness of an ergonomics awareness educational programme addressed to middle-school children

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### Abstract:

**Background:** Ergonomics programmes addressed to children fit the health-promoting schools (HPS) framework. Beyond the integration of ergonomics in curricula, an important aspect is the effectiveness of the programme. This pilot study aims to evaluate the effectiveness of the programme proposed to a sample of middle-school children (aged 10–13 years) of the metropolitan city of Cagliari.

**Methods:** The programme was designed along the lines of the INAIL (Italian National Institute for Insurance against Accidents at Work) scheme and proposed to 260 children. It consisted of three phases: 1) assessment of students' background with a pre-intervention questionnaire (completed by 142 students); 2) teaching of the ergonomics training modules and evaluation of the weight of a sample of 160 backpacks, and of students' perception to be able to sit by putting their feet on the ground; 3) evaluation of conceptual understanding of ergonomics concepts with a post-intervention questionnaire (completed by 107 students out of the 142 students who completed phase 1).

**Results:** There was a substantial improvement in the percentage of correct responses post-intervention, confirmed by the chi-square test, regarding concepts about ergonomics, backpack weight and handling. Most of the backpacks exceeded the maximum allowed value, and 20% of students were perceived to be unable to sit putting their feet on the ground.

**Conclusions:** The practical application of ergonomics pedagogy proved effective in the school setting and should be integrated into school curricula. The prevention technicians can offer a holistic approach, while the teachers are essential to implement the programme on a large scale. Effectiveness evaluation is necessary to guide resource allocation and implement and sustain the HPS approach. A tailored programme has a greater chance of reaching its target audience and maximizing effectiveness.

**Keywords:** ergonomics, educational programmes, school community, health promotion, empowerment

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## Introduction

Schools are considered a vital resource for influencing the health and well-being of students and the school community. Combining education and health would facilitate schools in achieving their educational and social goals: healthy staff work better, with greater job satisfaction, and healthy

students learn better (1). A critical aspect of school-aged children's health is back health: musculoskeletal discomfort and back pain are not uncommon from an early age in modern society (2,3). In Italy, school children spend a significant amount of time in prolonged static positions, often carrying heavy backpacks and using improper lifting techniques. Different factors may worsen these issues: i) ill-fitting

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chairs and desks, and a schedule that does not guarantee the opportunity to move around and exercise; ii) the lack of ergonomics awareness educational programmes addressed to children and the school community. These programmes fit in the health-promoting schools (HPS) (4) approach, which needs to be fostered by national and regional policies, strategies, and resource allocation, as postulated by the World Health Organization (WHO), UNESCO and UNICEF (5) following the Ottawa Charter (6).

Schools have a role in forming healthy, educated, and socially and civilly engaged citizens. This goal aligns with the evolution of safety legislation attributing the role of safety employee to the worker. This aspect is of particular importance if we theorize parallelism between students and workers in terms of time spent at school/workplace. Nowadays, the worker has a central role in taking care of safety in the workplace (7), and often emphasized is the importance of promoting activities to spread concepts about health, prevention, and safety culture at the earliest possible stage, with programmes tailored for educational settings (7). These concepts may strengthen from childhood the ability to make informed decisions and favour children's empowerment, preparing them to have an active role in changing their surroundings (8). Perceiving risks and adopting safe attitudes from childhood can have a long-term positive impact on working life in Italy; occupational injuries, illnesses, and deaths all carry high costs for individuals and society (9,10).

Legal obligations finely regulate correct work systems, working postures, and maximum permitted loads. Paradoxically, in the educational field, the attention reserved to compliance with the norms is not the same. There are regulatory standards issued to formalize the principles of ergonomics, which are provided and approved by national and international organizations such as CEN (European Committee for Standardization), CENELEC (European Committee for Electrotechnical Standardization) and ISO (International Organization for Standardization). In Italy, the UNI (Italian National Unification Body) specifies dimensions and sizes of chairs and tables for educational institutions (11). However, in the Italian school context, it is common that the furnishings deviate from the quality ergonomic standards proposed by the legislation.

The stage of physical development of school-aged

children exposes them to effects linked to mismatched furnishings, wrong postures, prolonged static positions, and handling of heavy loads (4). Back pain and spine alterations in school-aged children and the school ergonomics risk factors are the subjects of several investigations (12–17). Various studies focus on ergonomics educational programmes addressed to children (18–22), and some reported positive responses to the interventions (23–25). Despite this evidence, ergonomics is still taught piecemeal at schools (4,26–29), and it is not included by default in students' curricula.

In the present study, we proposed to local schools an ergonomics awareness educational programme addressing aspects that may be changed with conscious individual behaviours. In 2011, the INAIL (Italian National Institute for Insurance against Accidents at Work) published an educational programme (4) divided into five training modules aimed to provide primary school teachers (working with children ages 6–10 years) with engaging teaching tools to improve students' awareness of the primary prevention of musculoskeletal disorders and pathologies linked to postures and loads. This programme had two objectives: i) preventing, in the short term, musculoskeletal disorders and ensuring the best psycho-physical development of students; ii) providing concepts about prevention that will be useful in the long term to promote healthy lifestyles and work safety. The awareness ergonomics programme we present was designed along the lines of the INAIL educational scheme (4) but addresses middle-school students (aged 10–13) and is carried out by a prevention technician. The latter is a professional figure with a degree in Prevention Techniques for the Environment and the Workplace and specific competence prevention, training, verification and control activities regarding hygiene and safety of places of life and work.

Beyond ergonomics integration in school curricula, important aspects for all stakeholders are the programme's appropriateness to the context and effectiveness. In the present study, we aimed to evaluate the effectiveness of the programme taught to middle-school children of the metropolitan area of Cagliari from March 2021 to March 2022. For this purpose, we compared the results of the questionnaires administered to students before and after the educational programme. We also checked

the furnishings' ergonomic suitability and the backpacks' weight compliance with EU standards.

## Materials and methods

### *Participants*

Two schools from the metropolitan city of Cagliari joined the initiative. The schools were recruited through direct engagement with the principals. A detailed description of the programme (activities, duration, commitment required), objectives and benefits for children and school community was provided. The principals discussed with teachers and representatives of parents about joining the initiative. The adhesion forms were collected with internal procedures by the schools. The ergonomics educational programme was taught from March 2021 to March 2022 to 260 middle-school children aged 10–13 years of the 6th- and 7th-grade classes (corresponding to the 1st and 2nd of the three middle-school years in the Italian school system). The age range is 10–11 years in the 6th grade, 11–12 in the 7th grade and 12–13 in the 8th grade. Children of 13 were included in the programme when belonging to 7th-grade classes. One hundred and forty-two students filled out the pre-intervention questionnaire, and 107 among them also completed the post-intervention questionnaire.

### *Procedure*

The project was divided into three phases: 1) assessing students' background by proposing a pre-intervention questionnaire (a week before phase 2); 2) teaching of the training modules by the prevention technician; 3) assessing understanding and acquisition of concepts presented by proposing a post-intervention questionnaire (same day of the intervention). During phase 2 the prevention technician also inspected school furnishings for proper size and shape and measured some parameters: i) the weight of 160 backpacks; ii) how many students perceive to be able to sit by putting their feet on the ground. Phases 2 and 3 were carried out in a day established in accordance with the school major and teachers for each class. The activities took about 3h in total. Two hundred and sixty school children participated in phase 2 only, 142 out of the 260 completed the pre-intervention questionnaire

(phases 1 and 2) and 107 out of these 142 completed the post-intervention questionnaire (all three phases). Although the 107 participants who filled out the questionnaire of step 3 had previously completed step 1, we could not match each subject's pre and post performance due to anonymity. Therefore, the statistical analysis was performed on two groups made by not-matched results of the pre- and post-intervention questionnaires.

### *Instrumentation*

#### Questionnaires

The two questionnaires were originally developed by the INAIL in 2011 (4) and slightly adapted to address the purpose of the project. No amendments were made to the original items, but the questionnaires were shortened (links to original questionnaires are in the Supplemental materials online). The INAIL granted its approval for modifying and using the questionnaires for our purposes. (See the topic of each question in Table 2 (questionnaires' full content and English translation are in the Supplemental materials)). The pre-intervention questionnaire was administered to students a week before the intervention and completed under the supervision of the teachers. The post-intervention questionnaire was administered after the intervention, on the same day, under the supervision of the prevention technician and in the presence of the teachers. There was no time limit for the compilation (average time 15 min). The supervisors explained how to compile the questionnaire and were open to questions and clarification.

#### *Training modules*

All four modules were taught in person with multimedia material, physical objects and hands-on demonstrations. To follow, a final oral evaluation was completed through a trivia game on the topics covered.

1) *Spine and back pain*. Students were asked to share personal experiences linked to back pain. Starting from their stories, the prevention technician identified the three main causes of the disorder: injuries, overload, and incorrect posture. With the aid of building blocks and rubber balls, the operator provided elementary notions of the structure and

functioning mechanism of the vertebrae and inter-vertebral discs.

2) *The backpack.* The professional provided notions useful to choose a backpack with good ergonomics characteristics: padded shoulder straps, padded and semi-rigid backrest, handle for lifting from the ground, and others. It was shown how to use the backpack properly by involving the students in hands-on activities: filling, lifting, wearing and carrying the backpack. Finally, the weight of some backpacks was checked to verify whether the weight was safe comparing with the owner's approximate weight.

3) *Sitting posture.* Involving the students, the professional showed the proper posture for a correct sitting position and invited the students to assume it, observe, and give each other advice.

4) *Exercises.* The professional engaged students in gymnastic exercises that can be done in class and while sitting. These exercises allowed reactivating the muscles more involved in keeping the sitting posture.

#### *Furnishing inspection*

The prevention technician checked the height, width and depth of the desks and the height and backrest angle of the chairs. The shape (rounded edges) and proportion between the desks and chairs were also checked.

#### *Backpacks weight measurement*

During the meetings with the students, the weight of 160 backpacks was measured with a weighing scale.

#### *Sitting-posture evaluation*

The supplied chairs must allow the students to completely rest their feet on the ground while sitting. To verify this aspect and stimulate students to focus on posture awareness, they were asked by show of hands how many perceived not to be able to put their feet entirely on the ground. To be considered accurate, the claim made by the children had to be visually confirmed, so the prevention technician proceeded to check the students' postures individually.

#### *Data analysis*

The filled-in questionnaires were translated into digital by entering the answers into online forms (links in Supplemental materials) created with the Google Forms tool (Google Drive office suite). Question 1 was excluded from the analysis because it differed in the pre and post versions of the questionnaire in both the original and the modified version (see Supplemental material).

The results were downloaded from Google Forms in .csv format. Descriptive and inferential analysis was performed with Microsoft Excel (30): i) the chi-square test ( $\chi^2$ ) was performed for each pair of questions (matched pre/post-intervention) to determine whether there was a relationship between the answers given and programme participation; ii) the chi-square distribution and *p*-value were calculated to verify significance.

The chi-square test was applied after excluding the questionnaires with no answers given for each specific question, with a consequent reduction in the initial number. In the present analysis, we considered significant *p*-values <0.01 to avoid spurious positives deriving from the number of comparisons performed.

The operator noted the number of students who could not rest their feet on the ground while sitting at the desk after visual confirmation. The arithmetic mean of the weights of the backpacks was calculated and plotted with Microsoft Excel (30).

## **Results**

### *Ergonomics educational programme*

The 249 questionnaires collected belonged to two groups: a) pre-intervention: completed by 142 students; b) post-intervention: completed by 107 students. The distributions by age and sex were homogeneous in the two groups (Table 1). The chi-square test and *p*-value results for each question considered are summarized in Table 2, along with a summary of the questions' topics. Four out of nine questions showed a significant difference between the pre- and post-intervention groups, with a performance improvement (correct answers given) following the intervention: the answers to questions 2.1 (backpack safety), 2.2 (backpack filling), 2.3 (backpack weight) and 5

(school ergonomics meaning) (see Table 2). Five out of nine questions showed no significant differences between the pre- and post-intervention groups: the answers to 3 (right sequence to wear the backpack), 4.1 (chair swinging), 4.2 (space for leg movement; footrest), 4.3 (sitting postures) and 6 (wrong postures) questions. Among these, however, subgroup 4.(1, 2, 3) had a high percentage of correct answers even before the intervention. The percentages of correct answers to questions 3 and 6 were the lowest recorded in both pre- and post-intervention (Table 2).

### Furnishing inspection

According to the prevention technician, all desks and chairs were the same size (among three that

would be appropriate for the age range) and in compliance with regulations regarding shape and proportion between chair and desk.

### Backpack weight

The arithmetic average of the weights of the 160 backpacks was 8.5 kg (SD=1,1; Figure 1). The school protocol of the institutes involved in the project did not allow asking for the school children's anthropometric data. For the purposes of the study, we took as reference the growth data (the closest to our sample's age) published by the WHO (31). Based on the WHO percentiles, the indicative weight range is 20–60 kg, and we considered the mean weight of 31 kg (males and females). According to Italian Ministry of Education, University and Research (MIUR) guidelines (32), a student weighing 31 kg could carry a backpack weighing 4.65 kg (max. 15% of the body weight). We could conclude that most of the 160 backpacks measured exceed the maximum allowed value.

### Sitting-posture evaluation

As verified by the prevention technician, almost 20% of the students were unable to completely rest their feet on the ground while sitting. It should be noted that these children did not necessarily belong to the lower end of the participants' age range and

**Table 1.** Participants details.

Participants	Pre-intervention questionnaire		Post-intervention questionnaire	
	Mean	SD	Mean	SD
Number	142		107	
Age	11.55	0.719	11.57	0.715
Sex	M	F	M	F
	51%	49%	49%	51%

M: male; F: female

**Table 2.** Topics of the questions; percentage of correct answers, and chi-square test and p-value results for each question.

Question	Topic	Pre	Post	Pre	Post	Pre vs. post
		Number of answers	Number of answers	% Correct answers	% Correct answers	Chi-square; significance
2.1	Backpack safety	142	107	66%	85%	$\chi^2 (2)=15.12; p=0.00$
2.2	Backpack filling	140	107	51%	73%	$\chi^2 (2)=12.17; p=0.00$
2.3	Backpack weight	142	107	37%	94%	$\chi^2 (2)=86.69; p=0.00$
3	Right sequence to wear the backpack	141	106	47%	54%	$\chi^2 (1)=1.17; p=0.28$
4.1	Chair swinging	140	105	92%	94%	$\chi^2 (1)=0.43; p=0.51$
4.2	Space for leg movement; footrest	139	105	92%	97%	$\chi^2 (1)=2.83; p=0.09$
4.3	Sitting postures	139	105	69%	82%	$\chi^2 (1)=5.20; p=0.02$
5	What is school ergonomics?	134	105	62%	82%	$\chi^2 (2)=12.41; p=0.00$
6	Wrong postures	134	107	37%	49%	$\chi^2 (4)=4.65; p=0.33$

Significant values ( $p < 0.01$ ) are in bold.

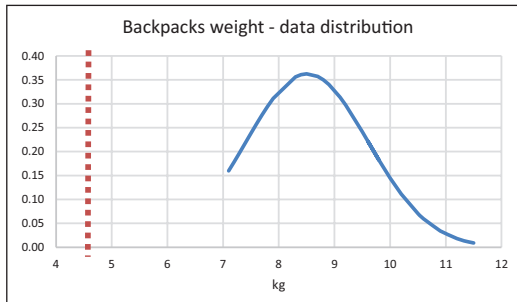


Figure 1. Backpack weight – data distribution.

that their height seemed to fall under the normal height variability for their age.

## Discussion

The structure of problems linked to ergonomics is multivariant: macro-ergonomics issues relate to ergonomics pedagogy and curriculum design; micro-ergonomics issues pertain mainly to the mismatch between the anthropometrics of students and the shape and size of furnishings, and backpacks' weight (26).

Several elements may contribute to causing back pain in children (12–16,19), such as mismatched school furnishings, poor sitting postures, prolonged stationary positions, and carrying, lifting and handling heavy school backpacks (17). School-aged children are in a crucial stage of physical development, and the cited aspects affect spine and low-back biomechanics, representing modifiable risk factors for back pain. Currently, the recommended weight for school backpacks varies between 10% and 15% of the body weight (32). There is a need to include the correct backpack weight management within broader health education and to promote a pragmatic approach to school equipment organization (e.g., books) among teachers and school publishers (32). Another critical element is represented by the size and proportionality between chairs and desks specified by UNI to favour the correct posture of the students.

Regarding micro-ergonomics issues, we found that most of the backpacks measured exceeded in weight the maximum value recommended by the competent authority, representing a risk factor for an excess of musculoskeletal load. Furthermore, the sizes of desks and chairs were the same for all the students, regardless of their height. The latter

explains why 20% of the students were unable to put the entire soles of their feet on the ground while sitting.

Typically, less attention is paid to macro-ergonomics issues (20,26), especially in terms of practical applications of ergonomics pedagogy, which results in a current inadequate state of knowledge. Smith (27) strongly supported applying ergonomics to educational settings, and Woodcock (28) supported introducing ergonomics fundamentals in designing educational curricula. Back in 2008, most of the Nordic countries were planning to develop ergonomics modules and training courses for teachers and approach each respective Ministry of Education (29). Heyman and Dekel (18) presented an educational programme taught by physical education students in elementary schools and reported positive feedback from the school community. However, this approach was not implemented on a large scale in all European countries.

The lack of attention to ergonomics may result in worse learning performance of school children and should be a priority in schools' agenda. Nevertheless, based on our pre-intervention questionnaire results, it could be argued that ergonomics has not been given sufficient attention in standard programmes of Italian schools. The pre-intervention percentage of correct answers is, in fact, appreciably lower than the post-intervention one across all the topics. The greatest increases in correct answers occurred in questions about backpacks' safety, filling and handling, and the concept of school ergonomics. Questions that show pre- and post-intervention continuity, in terms of the percentage of correct answers, can be divided into two categories: *a*) questions to which the students already answered well (4.1, 4.2, 4.3); *b*) questions to which students often answered incorrectly, both before and after the intervention (3,6).

In our opinion, questions of group *a* relate to basic rules given by parents before the start of lessons about postures commonly considered appropriate and preferable. These concepts, which involve rocking back and forth with the chair, resting the chin on the hand, and placing the elbows on the desk and both feet on the ground, are probably familiar to most students. Not surprisingly, the post-intervention increase in correct answers is not significant, as confirmed by the *p*-value. On the other hand, group *b* questions have the lowest

percentage of correct answers both in pre- and post-intervention questionnaires, with no significant difference pre versus post. The evaluation of the programme's effectiveness brought us to a necessary re-evaluation of the questions proposed in terms of topics, form and clearness. In question 3, students were asked to identify the correct sequence to wear the backpack (numbering boxes); in question number 6, they were asked to detect the wrong postures depicted in a drawing with seven different scenarios (marking with a cross). The prevention technician had positive observational feedback after showing the correct sequence and involving the students in the practical execution of the actions they had to order in question 3.

Furthermore, the students performed well in most of the written questions about posture, in some cases even in the pre-intervention questionnaire (e.g. 4.1, 4.2, 4.3). That is why, in the case of questions 3 and 6, we should consider a potential problem in the written explanation of the actions listed as answers, in the graphic depiction of the postures, or in students' ability to pair verbal expressions with explanatory figures. Following these considerations, for future application of the questionnaires, rewording, re-elaboration of the graphical elements, and a repeated pairing of verbal expressions with figures would be needed. Such an approach would help us improve the understandability of the questionnaires and verify the origin of bad performances related to specific questions. The high percentage of incorrect answers might derive from i) poorly-posed questions or graphic representation defects; ii) students' difficulties with a specific type of question (e.g., matching verbal description and graphic representation); iii) a lack in the awareness programme or a failure in delivering some concepts; iv) a combination of these factors.

Considering all the limits of the case, this pilot study delivered positive results, with an overall improvement in the percentage of correct answers in the post-intervention questionnaire and a starting point for the questionnaire revision and the improvement of the programme. Furthermore, during the whole programme, students and school community showed curiosity and interest in the subject and a very attentive approach.

Our pilot study demonstrated that the practical applications of ergonomics pedagogy are effective in the school setting when introduced with suitable tools. The prevention technician offered a holistic

and efficient approach to the multivariant structure of ergonomics problems. However, it should be noted that teachers, by virtue of their competence and professional position, are suitable and essential resources to implement the programme on a large scale (4). Following a multidisciplinary approach, the two figures should be seen as complementary. Training the teachers in modules and interactive activities to be offered to children might boost the inclusion of ergonomics in school curricula. In this regard, the prevention technicians are appropriate figures to train and support teachers in this educational path.

### *Limitations*

A natural limitation of this pilot study is the small sample (pre- and post-intervention questionnaires filled respectively by 142 and 107 students), from which may derive low statistical power. An important aspect is the short-term re-testing (post-intervention questionnaires) to verify understanding and acquisition of the concepts presented. In this regard, we should also consider a possible positive short-term effect of the trivia game. Re-testing the students on the same day of the intervention fails to measure learning retention, understood as the ability to transfer the ergonomics concepts learned in the long-term memory to be recalled and used in the future. Furthermore, it was impossible to match pre- and post-intervention questionnaires from each subject, which limited the kind of analysis we could perform.

Following this pilot study, we plan to validate our findings by proposing the programme to a broader number of school children, with all the due improvements to the structure of questionnaires and teaching style. We also plan to match pre- and post-intervention questionnaires and re-test participants after a period to be defined to verify learning retention and implementation of the ergonomics concepts stressed during the project.

### **Conclusions**

A correct evaluation of awareness programmes' effectiveness is needed to guide resource allocation, which is essential to implement and sustain the HPS approach. Participation and engagement of students and school community are fundamental requisites for the effectiveness of any educational programme.

This pilot study engaged students and school community and demonstrated that, when introduced with appropriate methods, the practical applications of ergonomics pedagogy are effective in the school setting. Our results suggest that it is essential to tailor and continually adapt programmes addressed to children and school communities to their specific social, environmental and cultural contexts to maximize effectiveness. We plan to confirm our hypothesis by proposing to a larger sample of school children an adapted version of the ergonomics programme based on the results of the pilot study.

Considering children, and students in general, comparable to workers in their school environment, promoting and funding activities that spread concepts about health, prevention, and safety culture is crucial. Our ergonomics programme covers just one of many aspects relating to students' health but incorporates basic universal concepts of safety culture. Getting used to them from childhood strengthens the ability to perceive the risks in the surrounding environment and make informed decisions. Furthermore, adopting safe attitudes might have a long-term positive impact on working life, translating into fewer occupational injuries, diseases, deaths, and related costs.

#### *Authors' contributions*

Sara Maria Pani: conceptualization (lead); formal analysis; writing – original draft; writing – review and editing (equal). Fabrizio Gaccetta: investigation; methodology; writing – review and editing (equal). Federica Cadoni: conceptualization (supporting); writing – review and editing (equal). Andrea Della Salda: conceptualization (supporting); writing – review and editing (equal). Arianna Liori: conceptualization (supporting); writing – review and editing (equal). Paolo Contu: project administration; supervision; writing – review and editing (equal). All authors contributed to the interpretation of study results and have reviewed and approved the final manuscript.

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The authors have no conflicts of interest to declare.

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#### *Human subjects statement*

Preparation of this paper did not involve primary research or collecting individually identifiable data deriving from human subjects; therefore, no institutional review board

examination or approval was required. After obtaining parents' adhesions to the project (information gathering comprised), we collected data through anonymous questionnaires addressed to children.

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