Original Article

doi: https://doi.org/10.1590/1983-1447.2023.20220344.en

Playful activity with robot for hand hygiene of elementary school students: quasi-experimental study

Atividade lúdica com robô para higienização das mãos de estudantes do ensino fundamental: estudo quase-experimental

Actividad lúdica con robot para la higiene de manos de estudiantes de educación primaria: estudio cuasi experimental

Michael Gabarron Costa[a]
Paulo Roberto Rocha Júnior[a]
Maria Angélica Spadella[b]
Melissa Vitória Xavier Pinho[c]
Eduardo Federighi Baisi Chagas[b,d]
Osni Lázaro Pinheiro[a]

How to cite this article:
Costa MG, Rocha Júnior PR, Spadella MA, Pinho MVX, Chagas EFB, Pinheiro OL. Playful activity with robot for hand hygiene of elementary school students: quasi-experimental study. Rev Gaúcha Enferm. 2023;44:e20220344. doi: https://doi.org/10.1590/1983-1447.2023.20220344.en

ABSTRACT

Objective: To evaluate the effectiveness of the hand hygiene process after elementary school students participated in an educational activity using an automated digital technology called Tutor Robot.

Method: Quasi-experimental study developed in 2019 with elementary school students (n=203). Hand hygiene was performed with a fluorescent solution before and after participating in an educational activity with a tutor robot. The images were recorded in a dark chamber and the data related to area of residence, grade, gender, hand position and laterality were analyzed by Anova and Holm-Sidak Post-Hoc ($p \leq 0,05$).

Results: All conditions studied improved the hand hygiene process after activity with the tutor robot. There was no association between grade, gender, and dominant hand and the performance in the hand hygiene process, however, students from urban areas performed better than those from rural areas.

Conclusion: The activity with the tutor robot represented an important resource for conducting health education actions on hand hygiene and can also be tested in other settings and populations.

Descriptors: Hand hygiene. Students. Health education.

RESUMO

Objetivo: Avaliar a efetividade do processo de higienização das mãos após a participação de estudantes do Ensino Fundamental em uma atividade educativa, com uso de uma tecnologia digital automatizada, denominada robô tutor.

Método: Estudo quase-experimental desenvolvido em 2019 com estudantes do Ensino Fundamental I (n=203). Foi realizada higienização das mãos com solução fluorescente antes e após a participação em atividade educativa com um robô tutor. As imagens foram registradas em câmara escura e os dados relacionados à área de residência, série, sexo, posição das mãos e lateralidade foram analisados por Anova e Post-Hoc de Holm-Sidak ($p \leq 0,05$).

Resultados: Todas as condições estudadas melhoraram o processo de higienização das mãos após atividade com o robô tutor. Não houve associação entre série, sexo e mão dominante e o desempenho no processo de higienização das mãos, porém, estudantes da área urbana apresentaram desempenho melhor do que os provenientes de área rural.

Conclusão: A atividade com o robô tutor representou um recurso importante para a realização de ações de educação em saúde a respeito da higienização das mãos, e pode também ser testada em outros cenários e populações.

Descritores: Higiene das mãos. Estudantes. Educação em saúde.

RESUMEN

Objetivo: Evaluar la eficacia del proceso de higiene de manos tras la participación de estudiantes de educación primaria en una actividad educativa, utilizando una tecnología digital automatizada denominada Tutor Robot.

Método: Estudio cuasi-experimental desarrollado en 2019 con estudiantes de primaria (n=203). Se realizó higiene de manos con una solución fluorescente antes y después de participar en una actividad educativa con un robot tutor. Las imágenes se grabaron en un cuarto oscuro y los datos relacionados con la zona de residencia, el grado, el sexo, la posición de la mano y la lateralidad se analizaron mediante Anova y Post-Hoc de Holm-Sidak ($p \leq 0,05$).

Resultados: Todas las condiciones estudiadas mejoraron el proceso de higiene de manos después de la actividad con el robot tutor. No hubo asociación entre el grado, el sexo y la mano dominante y el desempeño en el proceso de higiene de manos, sin embargo, los estudiantes de la zona urbana se desempeñaron mejor que los de la zona rural.

Conclusión: La actividad con el robot tutor representó un recurso importante para la realización de acciones de educación sanitaria sobre higiene de manos, puede también ser testeada en otros escenarios y poblaciones.

Descriptores: Higiene de las manos. Estudiantes. Educación en salud.

[a] Faculdade de Medicina de Marília (Famema), Programa de Pós-Graduação em Ensino em Saúde, Mestrado Profissional. Marília, São Paulo, Brasil.

[b] Faculdade de Medicina de Marília (Famema), Programa de Pós-Graduação em Saúde e Envelhecimento, Mestrado Acadêmico. Marília, São Paulo, Brasil.

[c] Faculdade de Medicina de Marília (Famema). Marília, São Paulo, Brasil.

[d] Universidade de Marília (UNIMAR), Programa de Pós-Graduação em Interações Estruturais e Funcionais em Reabilitação.Marília, São Paulo, Brasil.

INTRODUCTION

Hand hygiene is a simple but very effective process for preventing infectious diseases. However, little progress has been made in the last two decades regarding the population's adherence to this practice, and even to the proper procedure, which motivated the creation of World Hand Hygiene Day, on May 5, 2022, by the World Health Organization[1].

In a study involving around 80 countries, the frequency of hand hygiene among adolescents aged 12 to 15 years was evaluated. The results showed a low prevalence of good hand hygiene practices, especially in less economically developed countries. Hand hygiene before meals, after using toilets and using soap during this procedure were rarely mentioned by poorer populations. The authors highlighted the importance of conducting educational activities to improve these rates[2].

Good hand hygiene practice also involves the correct use of the technique, following each of the steps involved. In a study conducted in Pakistan, elementary school students initially performed hand hygiene, according to their own knowledge. The scores were recorded by an evaluator and then, the students participated in an activity on the hand hygiene technique according to the World Health Organization. After a few weeks of the educational activity, this process was repeated and the post-intervention scores recorded were significantly better[3].

In a study conducted with students aged 13 to 18 years, using soap with a fluorescent marker, it was also verified that the students' previous knowledge was not enough for the correct use of the hand hygiene technique, with the absence of the fluorescent substance in some regions. However, after performing the educational intervention, there was an improvement in hygiene, with better distribution of fluorescence on hands[4].

It should be highlighted that the school is a place where students spend a big part of the day, exposed to infections, which was verified in the flu pandemic caused by the H1N1 virus in 2009, showing that infectious diseases can quickly spread in school settings[5–7].

The importance of schools in controlling the transmission of diseases has been widely discussed, especially due to the new pandemic caused by the coronavirus (SARS-CoV-2), which causes Covid-19[8,9]. Current evidence points out that the virus that causes COVID-19 is transmitted through respiratory droplets or by contact, when contaminated hands touch the mucous membranes of the mouth, nose or eyes. The virus can also be transferred from one surface to another through contaminated hands, which facilitates its indirect transmission to other people. Consequently, hand hygiene is important to prevent the spread of the virus that causes COVID-19[10–12].

Conducting educational practices regarding hand hygiene with students can have a great impact on their own health, as well as that of their families and the community in which they live. However, the choice of the educational approach is important and should consider the strategies with the greatest reach for the target audience. In this case, of elementary and high school students, it is important to use playful resources, as they have the potential to spark the interest of this population[13,14].

A recent scoping review investigated the digital technologies used as tools for intervention or monitoring of handwashing practices in children in educational settings. In this study, it was found that computer games, videos and video cameras were used in hand hygiene activities in children aged less than 12 years. These technologies were used both to monitor the hand hygiene process and to promote this practice among children. The review showed that studies that used computer games were effective in improving children's knowledge about hygiene, with repercussions on the handwashing process[15].

The data presented shows that hand hygiene is an important aspect in disease prevention, however, turning it into a habit and correctly using hand hygiene technique are still considered challenges to be overcome. The school is an important scenario for conducting health actions and playful activities should be considered in situations where children represent the target audience.

The objective of the present study was to evaluate the effectiveness of the hand hygiene process after elementary school students participated in an educational activity of a playful nature, using an automated digital technology called tutor robot.

METHOD

This is a quasi-experimental study, therefore without sample randomization, in which each student participated twice in data collection, one before and other after the educational intervention for hand hygiene using the tutor robot. Quasi-experimental studies have been used to verify the effectiveness of educational actions to improve the hand hygiene process[3,16].

The study was conducted in compliance with the Resolution of the National Health Council (*Conselho Nacional de Saúde* – CNS), no. 466/2012 and the Operational Norm

no. 001/2013 of the CNS, approved by the Research Ethics Council, under opinion number 3,250,667 and CAAE 09095319,1,0000,5413, on April 8, 2019.

The city of Álvares Machado, in the interior of the State of São Paulo was selected for this study, with a population of 24,915 inhabitants, according to the 2019 Census of the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística* – IBGE)[17]. The city's municipal education system has twelve institutions, eight Municipal Schools for Early Childhood and Elementary Education – EMEIF (2,428 students) and four Municipal Schools for Infant Education – EMEI (316 students). The study was conducted in the only two EMEIF in the city with students from the urban and rural areas from the region. The choice to work with Elementary School I was made due to the playful nature of the activity, with the potential to spark the interest of students.

All students regularly enrolled in the 3rd, 4th and 5th grades of Elementary School were invited to participate in the study, initially verbally and, after confirmation of interest, with the consent of the students and their parents by signing the Informed Consent Form. Students of both genders were included in the study, with no restrictions regarding age, ethnicity, family income, school performance and mild hearing and visual impairments. Exclusion criteria were the use of plaster casts or immobilizing splints on one or both regions of the upper limb or the existence of dermatological issues on the hands, such as dermatitis and mycosis.

The minimum sample size was estimated to be 246 sample elements to analyze the interaction between group (3 groups) and time (2 moments) by the mixed ANOVA of repeated measures. The sample calculation was performed using the G*Power software, version 3.1.9.2 (Franz Faul, Universität Kiel, Germany), considering a type I (α) margin of error of 5%, a study power of 80% and a small effect size (0.10).

The total number of students enrolled in the two schools participating in this study was 262 students, being 169 (64.5%) from School 1 and 93 (35.5%) from School 2. There was a sample loss of 59 (22.52%) students, 35 (13.36%) for reasons of transfer, 22 (8.4%) for lack of parental consent, 1 (0.38%) for refusal to participate in the study and 1 (0.38%) %) due to absence due to sick leave (0.38%). Students who were absent during the week in which the collection was conducted were not recalled. Thus, the sample consisted of 203 students, who participated both before and after the educational activity with the tutor-robot. Considering that the sample calculation presented a minimum of 246 participants, it was possible to reach 77.5% of this estimate.

Initially, the tutor robot was built for the playful educational activity regarding hand hygiene. It is a tutor robot with an automated system, structured in the Arduino programming language using the Arduino IDE (Integrated Development Environment) software. The tutor robot was programmed to guide, by voice command and dashboard instructions, the reproduction of the hand hygiene technique through 6 steps, according to the recommendations of the World Health Organization[18]. The tutor robot provided guidance on the simple hand hygiene technique, through text instruction on its dashboard and voice command. It also controlled the timing for each of the steps in the hand hygiene process. The three conditions allowed the student to read and listen to the text messages while simultaneously paying attention to the predetermined timing for the following steps: wetting their hands, applying the alcohol solution to their palms, rubbing their hands with the alcohol solution, rinsing, and drying their hands with paper towels.

Next, a dark chamber was built, with black light inside, enabling the visualization of fluorescent images captured through photographic devices. The images were obtained with a Motorola® cell phone, model Moto Z Play,16 MB camera, placed in the transparent opening on the upper side of the box.

In the first moment of the study, photographic records were taken in the prone and supine positions of the right and left hands inside the dark chamber, under black light (Record 1). This procedure was made to verify possible fluorescence residues resulting from casual contact with chemical substances.

Then, an average of 2.5 mL of alcoholic solution, marked with 25% fluorescein, was applied to one of the sides of the hand and the student was asked to spread the alcoholic solution according to the knowledge and habits he/she had on hand hygiene. After applying the alcoholic solution and drying the hands, the same procedure for obtaining images was repeated (Record 2). Then, the participant was asked to go to the bathroom, wash their hands with soap and water and return to the classroom.

The second stage of data collection, with the tutor robot was conducted after 30 days, with the same students that participated in the first stage. The student placed his/her right and left hands inside the dark chamber, alternating prone and supine positions, and photographic records were taken to verify the presence of residual fluorescence from the last activity or other fluorescent contaminants (Record 3). Then, the student was directed to the tutor robot, which was positioned next to the dark chamber, and the instructions for interacting with the automated system were verbally provided so that he could proceed with hand hygiene according to WHO criteria.

Right after the educational intervention regarding the hand hygiene process using the tutor robot, an average of 2.5 mL of alcoholic solution marked with 25% fluorescein was applied to one of the faces of the student's hands and they were asked to spread the alcoholic solution according to the guidelines acquired regarding this hand hygiene process by the tutor robot.

After applying the alcoholic solution and drying the hands, they were positioned in the dark chamber for photographic recording in the prone and supine positions (Record 4).

The images obtained during stages 1 (Records 1 and 2) and 2 (Records 3 and 4) were initially processed in Adobe Photoshop CS6 Extended software, allowing to set the analysis area. The area was delimited in the wrist, thus maintaining only the image of both hands and fingers.

Afterwards, a second analysis started to evaluate the distribution of fluorescein in the images of the students' hands. It was used the OLYMPUS CellSens Dimension 1.16 Version 510_UMA_cellSens116-Quesnel_en_00 software.

To analyze the distribution of fluorescein, it was necessary, initially, to verify the number of pixels in the field of view of the photographs, a term known as FOV (Field of View). To calibrate the area of analysis, a photographic image of a caliper was recorded, obtained with the same standards used for acquiring hand images of in Records 1 to 4. This included using the same device, maintaining the same distance for taking the photo, and ensuring approximately similar lighting conditions.

Then, for each image, the participants' hand area was determined, using to the following formula:

$$\text{Hand area (pixels)} = \text{FOV (15,925,237 pixels)} - \text{extra area} - \text{hand (pixels)}$$

The calculation of the distribution of the fluorescein preparation in the students' hands, before and after the activity with the tutor robot, is described below, taking the right hand in the prone position as an example:

$$\text{FPR}_{\text{BR}} = \left(\frac{\text{Record 2 (Pixels)} - \text{Record 1 (Pixels)}}{\text{Total area of right hand (Pixels)}}\right) \text{x } 100$$

$$\text{FPD}_{\text{AR}} = \left(\frac{\text{Record 4 (Pixels)} - \text{Record 3 (Pixels)}}{\text{Total area of right hand (Pixels)}}\right) \text{x } 100$$

FPR_{BR}= Fluorescence of the right hand in the prone position before the activity with the tutor robot.

FPR_{AR} = Fluorescence of the right hand in the prone position after the activity with the tutor robot.

The calculation of the effectiveness of students' hand hygiene after the activity with the tutor robot is described below, taking the right hand in the prone position (HPR) as an example:

$$\text{HPR} = \text{FPR}_{\text{AR}}(\%) - \text{FPR}_{\text{BR}}(\%)$$

The independent variables evaluated were area (urban and rural), grade (3rd, 4th and 5th year), gender (male and female), hand position (prone and supine) and hand laterality (right and left). Studying the laterality and hands position is important, as the results may indicate the need to conduct educational actions aimed at taking greater care with these variables.

Qualitative variables were described by relative and absolute frequency distribution. Quantitative variables were described by mean and standard deviation (SD). The hypothesis of normal distribution was verified by the Kolmogorov-Smirnov test with Lillifors correction, and the hypothesis of sphericity verified by the Mauchly test, both were confirmed. The mixed ANOVA test of repeated measures was applied to test the effect of time, group and interaction (group versus time). Pairwise comparisons were performed using Sidak Post-Hoc test. For all analyses, the SPSS software version 19.0 for Windows was used, with a significance level of 5% adopted.

RESULTS

The students' age was 9.6 ± 1.1 years (mean ± standard deviation), with a minimum age of 8 and a maximum of 15 years.

It was possible to observe that there was a homogeneous distribution of participants regarding residing in urban and rural areas, the grades in which they are enrolled and also regarding gender. However, there was a predominance of students enrolled in one of the schools participating in this study. In addition, most of the sample referred to the right hand as being the dominant one (Table 1).

Regarding the use of the tutor robot, it was observed that in all the conditions presented there was an improvement in the hand hygiene process (Table 2). Thus, all results obtained in the "after the robot" (AR) conditions were statistically significant ($p<0.05$), when compared to the "before the robot" (BR) situations.

With the data shown in Table 2, it was also possible to verify the effect of laterality on hand hygiene. Thus, the results found with the control of the variables related to hand position (prone and supine) and the conditions "with robot" and "without robot" show that the students cleaned their right and left hands with the same effectiveness. Taking as an example the distribution of fluorescein in the right prone position, it is observed that, before the robot, this substance reached 55.2% and 60% in the left prone position; there were, however, no significant differences between these results. Similarly, the other comparisons involving laterality did not show significant differences, that is, the students cleaned both their right and left hands with the same effectiveness.

Table 3 shows the results of hand hygiene with fluorescein solution, according to the grade of Elementary School I in which the student is. The results indicate that, in most of the situations, there was an improvement in hygiene after the support of the tutor robot ($p<0.05$). The only exception was observed among 5th grade students, during hand hygiene procedure on the right hand in the supine position.

The 4th grade students performed better than the other grades in the prone position of the left hand and in the supine position, both right and left, always after completion of the playful activity with the tutor robot ($p<0.05$). In all other situations, grade did not represent a determining factor for students' performance in hand hygiene.

Table 1 – Characterization of the study sample regarding school, area of origin, grade, gender and dominant hand (n=203). Álvares Machado, São Paulo, Brazil,2019

Variables		N	%	"p" value
School	1	129	63.5	<0.001*
	2	74	36.5	
Area	Urban	101	49.8	0.944
	Rural	102	50.2	
Grade	3rd	73	36.0	0.688
	4th	67	33.0	
	5th	63	31.0	
Gender	Male	103	50.7	0.833
	Female	100	49.3	
Dominance	Right-handed	185	91.1	<0.001*
	Left-handed	18	8.9	

Source: Prepared by the authors.
*Significant difference of proportion distribution by Chi-square test for p-value ≤ 0.05.

Table 2 – Comparison of the mean and standard deviation of the percentage distribution of the fluorescein-marked alcohol solution in the right and left hands, in the prone and supine positions, before and after the activity with the tutor robot. Álvares Machado, São Paulo, Brazil,2019

Factor	Mean	Standard Deviation	p-value
Prone Right/Before Robot	55.2[a]	27.2	
Prone Right/After Robot	76.4	18.1	
Prone Left/Before Robot	60.0[a]	25.7	
Prone Left/After Robot	82.0	13.1	
Supine Right/Before Robot	87.5[b]	12.9	<0.001*
Supine Right/After Robot	93.4[c]	9.1	
Supine Left/Before Robot	87.7[b]	12.5	
Supine Left/After Robot	93.9[c]	6.9	

Source: Prepared by the authors.
*Indicates significant difference by ANOVA test of repeated measures
Pairwise comparisons were performed using the Holm-Sidak Post-Hoc test
Equal letters indicate absence of significant difference by the Holm-Sidak Post-Hoc test
Different letters, or absence of letters, indicate a significant difference by the Holm-Sidak Post-Hoc test

Table 3 – Comparison of the mean and standard deviation of the percentage distribution of the alcohol solution with fluorescein in the hands of students in the 3rd (n=73), 4th (n=67), and 5th (n=63) grades of Elementary School I, in prone right, prone left, supine right and supine left. Álvares Machado, São Paulo, Brazil,2019

Grade/Position	Without robot	With robot	Anova (p-value)		
	Mean (SD)	Mean (SD)	Grade	Robot	Interaction
3rd Grade Prone Right	52.4 (27.6)	75.5 (18.7)†			
4th Grade Prone Right	55.0 (27.7)	81.1 (16.1)†	0.391	<0.001*	0.036***
5th Grade Prone Right	59.0 (26.3)	72.2 (18.6)†			
3rd Grade Prone Left	60.5 (25.2)	80.2 (14.4)†a			
4th Grade Prone Left	55.9 (26.9)	85.2 (12.4)†b	0.712	<0.001*	0.023***
5th Grade Prone Left	64.0 (24.8)	80.7 (11.9)†			
3rd Grade Supine Right	89.9 (8.1)	93.6 (8.1)†			
4th Grade Supine Right	85.3 (18.7)	96.0 (5.3)†a	0.111	<0.001*	0.003***
5th Grade Supine Right	87.1 (9.0)	90.3 (12.0)b			
3rd Grade Supine Left	89.6 (7.2)	92.7 (7.7)†a			
4th Grade Supine Left	87.4 (16.1)	96.3(4.9)†b	0.169	<0.001*	0.031***
5th Grade Supine Left	86.0 (13.1)	92.7 (7.3)†a			

Source: Prepared by the authors.
***Indicates significant interaction between the conditions with and without the robot and the grade by the Anova test of repeated measures for p-value ≤0.05
**Indicates significant difference between the grades regardless of the conditions with and without the robot by the Anova test of repeated measures for p-value ≤0.05
*Indicates significant difference between the conditions with and without the robot regardless of the grade by the Anova test of repeated measures for p-value ≤0.05
†Indicates significant difference in relation to the condition without robot by the Holm-Sidak Post-Hoc test for p-value ≤0.05
Different letters indicate a significant difference between series within each condition by the Holm-Sidak Post-hoc test for p-value ≤0.05

Overall, it is observed that both in urban and rural areas, students improved the hand hygiene process after participating in the playful activity with the tutor robot (Table 4). These results can be observed in the comparisons made in the respective students' areas of origin (urban or rural) with the same hand position conditions (prone or supine) and also laterality (right and left). Therefore, it is observed that, in the urban area, the distribution of fluorescein in the students' hands, in the prone position and on the right side, which before the activity was 61.1%, reached 76.8% with the intervention ($p<0.05$). Under these same conditions, in the rural area, there was an even greater increase in fluorescence, which initially was 49.5% and then reached 75.9% ($p<0.05$). These effects were reproduced in conditions like those presented, both in urban and rural areas.

Table 4 also indicates the effectiveness of hand hygiene according to position (prone and supine). The results show that, regardless of the students' area of origin, both before and after the activity with the tutor robot, there was a better performance in the hygiene of the right and left hands in the supine position.

Direct comparison of the performance of students from urban and rural areas showed some significant differences. In the conditions PR/BR (61.1% vs. 49.5%), PL/AR (84% vs. 80.1%), SR/AR (94.9% vs. 91.9%) and SL/AR (96 .1% vs. 91.7%) it was possible to observe that students from the urban area had a more satisfactory performance on hand hygiene.

When verifying the results obtained regarding performance of male and female students in the hand hygiene process, it was possible to observe that in males, the playful activity with the tutor robot improved the performance of students in this process (Table 5) . In females, this was also observed, however, only in the prone position of both hands. Plus, it was also observed that both male and female students performed better in hand hygiene in the supine position, either right or left, either before or after the activity with the tutor robot.

In the direct comparison of the effect of the student's gender on hand hygiene performance, it was observed that the male population achieved more satisfactory results in the PR/AR and SL/AR conditions, while the female population presented better performance in PR/BR and PL/BR.

Table 4 – Comparison of the mean and standard deviation of the percentage distribution of fluorescein-marked alcohol solution on the hands of students from urban areas (n=101) and rural areas (n=102).Álvares Machado, São Paulo, Brazil,2019

	Urban	Rural	Anova (p-value)		
	MeanSD	MeanSD	Zone	Factor	Interaction
Prone Right/Before Robot	61.1(26.1)[a]	49.5 (27.3)[†]			
Prone Right/After Robot	76.8(19.1)	75.9(17.2)[a]			
Prone Left/Before Robot	63.5(27.0)[a]	56.7(24.1)			
Prone Left/After Robot	84.0(12.8)[b]	80.1(13.2)[a†]	0.001*	0.001[‡]	0.001[Φ]
Supine Right/Before Robot	88.6(16.1)[b]	86.4(8.6)[b]			
Supine Right/After Robot	94.9(10.6)[c]	91.9(7.0)[c†]			
Supine Left/Before Robot	89.3(15.9)[b]	86.1(7.7)[b]			
Supine Left/After Robot	96.1(6.7)[c]	91.7(6.4)[c†]			

Source: Prepared by the authors.
*Indicates significant difference between zones by Anova test of repeated measures
[‡]Indicates significant difference between the factors by the Anova test of repeated measures
[Φ]Indicates significant interaction between zone and factor by the Anova test of repeated measures
Pairwise comparisons were performed using the Holm-Sidak Post-Hoc test
Equal letters indicate absence of significant difference by the Holm-Sidak Post-Hoc test
Different letters, or absence of letters, indicate a significant difference by the Holm-Sidak Post-Hoc test
[†]Indicates significant difference regarding urban area by the Holm-Sidak Post-Hoc test

Table 5 – Comparison of the mean and standard deviation of the percentage distribution of fluorescein-marked alcohol solution in the hands of male (n=103) and female (n=100) students. (Mean ± standard deviation). Álvares Machado, São Paulo, Brazil,2019

Factor	Male	Female	Anova (p-value)		
	Mean SD	Mean SD	Gender	Factor	Interaction
Prone Right/Before Robot	49.3(28.3)[a]	61.3(24.8)[a†]			
Prone Right/After Robot	79.8(15.4)[b]	72.7(20.0)[b†]			
Left Prone/Before Robot	52.5(28.7)[a]	67.8(19.5)[ab†]			
Left Prone/After Robot	82.7(13.5)[b]	81.3(12.8)	0.06	<0.001[‡]	<0.001[*]
Supine Right/Before Robot	85.9(13.8)[b]	89.1(11.7)[c]			
Supine Right/After Robot	94.5(6.3)[c]	92.2(11.1)[c]			
Supine Left/Before Robot	86.6(13.6)[b]	88.9(11.3)[c]			
Supine Left/After Robot	94.9(6.1)[c]	92.9(7.6)[c†]			

Source: Prepared by the authors.
[‡]Indicates significant difference between the factors by the Anova test of repeated measures
[*]Indicates significant interaction between gender and factor by the Anova test for repeated measures
Pairwise comparisons were performed using the Holm-Sidak Post-Hoc test
Equal letters indicate absence of significant difference by the Holm-Sidak Post-Hoc test
Different letters, or absence of letters, indicate a significant difference by the Holm-Sidak Post-Hoc test
[†] Indicates significant difference regarding gender 1 by the Holm-Sidak Post-Hoc test

DISCUSSION

Considering that in all groups hand hygiene, in the condition before the activity with the tutor robot, presented less satisfactory results of hand hygiene, it is possible to infer that the students' previous technical knowledge about the correct way of hand hygiene, or their habits, would not allow satisfactory hand hygiene that could minimize the risks of diseases transmitted by hands.

It is worth noting that hand hygiene is an important resource to prevent the transmission of various viruses and bacteria that cause colds, flu, pneumonia and other respiratory and intestinal diseases[7,19,20].

In a study conducted with children aged 7 to 12 years old, enrolled in a school in Turkey, evaluated the effectiveness of two proposed educational activities regarding the hand hygiene process. The first educational proposal was to show the students the locations marked with fluorescence and make a comparison with the presence of microorganisms, explaining the need to remove them during hand washing. The second intervention, conducted with another group of students, repeated this procedure, and also provided instructions, using images on the importance of hand washing and addressed the technique according to the steps recommended by the WHO. In the control group, the children did not visualize the distribution of fluorescein and washed hands according to their own knowledge and habits. The effectiveness of hand hygiene in this study was verified by independent evaluators with images and then assigned scores. The study indicated that only the group that participated in the activity that addressed the hand washing technique according to the WHO presented significant results in the hygiene of all parts of the hand[6].

Although there are several methodological differences between the work conducted with children in Turkey and the present study, the educational activity focusing on the technical aspects of hand hygiene proved to be effective in both situations.

A cross-sectional study, with the application of questionnaires to a sample of over 200,000 adolescents aged between 12 and 15 years, from countries with different socioeconomic conditions, indicated that the habit of hand

hygiene in essential situations, such as before meals and after using the toilet is still precarious. The results indicate that in low-income countries, these habits are less practiced by these adolescents. The authors did not specifically verify the hand hygiene technique, as in the present study, however, they did identify that the frequency of using soap during this procedure is rare[2].

An important aspect observed in the present study is that the hands in the supine positions, both right and left, when compared with the prone positions of both hands, in the conditions with robot and without robot, showed better distribution of fluorescein ($p<0.05$). As an example, it is observed in Table 2 that the PR/BR condition, that is, the right hand in the prone position before the activity with the tutor robot, presented a fluorescein distribution of 55.2%, whereas in SR/BR, supine position of the right hand, also before the robot, fluorescence reached 87.5% of the hand surface. Results in this same logic were obtained in AR conditions, after the playful activity with the robot and in both hands. Thus, the effectiveness of hand hygiene was greater in the supine position and, even with the playful activity, this region of the hand was still better affected by the fluorescent solution.

The results found in this study were obtained with Elementary School students, but they are in line with those observed in a study conducted with professionals from two courses in the health area, whose hand hygiene, also evaluated through the distribution of a fluorescent substance, showed that the palm of the hands (supine position) was technically better cleaned in 96.5% of the situations, while the back (prone) was properly cleaned in only 72.7% of the analyzed situations. In this study, the evaluation of fluorescence in different positions and parts of the hands was performed using a "Likert" scale, thus differing from the present analysis, which verified the distribution of fluorescein in equipment that counts the number of pixels in the image. However, regardless of the evaluation method, the results highlight the need for educational investments to improve hand hygiene in the prone position, as the trend seems to be better hygiene in the area where soap or other antiseptic product is applied[21,22].

In a study conducted with medical students in Spain, using a fluorescent marker, it was observed that the right hand was better cleaned with a hydroalcoholic solution than the left, except for the thumb region. According to the authors, considering that the majority of the human population is right-handed, it was expected that hygiene would be less adequately observed in the dominant hand[21]. On the other hand, opposite results were found in work conducted with medical students from Eastern European countries, which showed better hygiene of the non-dominant hand, which can be explained by the fact that the dominant hand rubs the opposite side better, i.e., the non-dominant hand[23].

The methodological differences between these different studies may explain the discrepancies in the results found, especially considering the different ways of evaluating the effectiveness of hand hygiene, with quantitative and qualitative tools. Another possible inference to establish is that, although laterality is an important aspect for motor actions that involve the need for finer control, the act of hand hygiene does not have this characteristic and, therefore, regardless of being right-handed or left-handed, there are no major difficulties in cleaning the contralateral hand. On the other hand, activities such as writing, handling cutlery, require better control and the use of the dominant hand is important in these circumstances.

In the present study, the variable "grade" did not represent an essential aspect for improving performance in the hand hygiene process, although 4th grade students were more successful than the others in the prone position of the left hand, and in supine position both right and left, after the playful activity with the robot. The school year in which the students were was not an essential factor to improve the hand hygiene process in a study conducted in Turkey, with no significant differences in the performance of participants enrolled in the 2nd, 3rd and 4th grades[6].

Although the Turkish study and this one used fluorescent markers to investigate the effectiveness of students' hand hygiene, the method of analyzing the distribution of fluorescein was different. In the study conducted in Turkey, the images were visually analyzed by observers who did not directly participate in the research, whereas in the present study, the software analyzed the images and verified the number of pixels.

Geographical origin is a factor that can influence the habits and lifestyle of a population. In the rural context, it is evident that access barriers are imposed by the lack of human resources in preventive work and structural transport resources, financial shortages and technologies that bring teams closer to rural territories. Thus, residents of rural areas deserve greater attention from public entities, with the purpose of developing policies that ensure better accessibility for this population, especially to health and education services[24].

Considering these premises, one of the associations investigated in the present study refers to the influence of students' living environment, in urban or rural areas, on their performance regarding hand hygiene process. The results found show the need to conduct health care education actions that are more directed towards students from rural areas. In this regard, schools play a crucial role, given their

potential to provide access not only to students but also to their families, thus contributing to reducing the vulnerability of this population.

In the field of dentistry, the literature documents the existence of more precarious oral health conditions in the rural population, with a higher prevalence of dental caries compared to inhabitants of urban areas. Among the factors related to this greater precariousness, not only unfavorable indicators of income, infrastructure and basic sanitation stand out, but also limited access to healthcare and education services, resulting in less consistent levels of information compared to urban areas[25,26].

As previously presented, in some situations, in the present study, the male population obtained more satisfactory results than the female population, but the opposite situation also occurred.

An epidemiological study conducted using a questionnaire that assessed the habits of adults regarding the hand hygiene process, showed that the variable "female gender" represents a positive aspect in terms of knowledge and habits about this process. It was found that females are more likely to use paper towels to turn off the faucets after hand hygiene. However, even in this population, there was a need for educational efforts, particularly in the hand drying step, which is considered important for reducing microorganisms during hand hygiene[27].

The present study showed that, through a playful activity, it is possible to conduct health actions to enhance the mastery of the hand hygiene technique, according to WHO recommendations[18]. Knowledge of the technique is the first step for the simple act of hand hygiene to represent an important tool for disease prevention. However, another important aspect, which was not the scope of this study, is the systematization of the hand hygiene process, which, although it was mentioned during the dynamics with the students, did not represent an object of measurement in this research. Activities of a playful nature, such as the one in this study, can help in conducting scientific and extension studies in the area of nursing. In this regard, nurses can develop work focused on Health Education that can benefit students, healthcare professionals, workers who handle food, and the communities within the areas of healthcare units.

The limitations of the present study include the non-randomization of the sample, the failure to reach the minimum sample size and the fact that the study being conducted in only one municipality. Therefore, it is important to conduct further studies with a randomized clinical trial design, allowing better control of the variables.

CONCLUSION

The playful activity with the tutor robot was effective in improving the students' performance in the hand hygiene process, since, in all situations studied, the results were better after using this resource.

Both male and female students showed better results during the act of hand hygiene after participating in the activity with the tutor robot.

Students from urban and rural areas achieved better results in the hand hygiene process after using the tutor robot. The grade level of the student did not represent a determining factor for their performance in the hand hygiene process and gender was not considered an important variable to determine better performance in the act of hand hygiene.

The laterality of the hands did not represent an important aspect in the effectiveness of hygiene, that is, the dominant hand was as effective as the non-dominant hand in the hand hygiene process. Hand hygiene in the supine position was more effective than in the prone position, that is, the palm of the hands, which represents the location where soap is applied, was better cleansed.

REFERENCES

1. Tartari E, Kilpatrick C, Allegranzi B, Pitted D. "Unite for safety – clean your hands": the 5 May 2022 World Health Organization SAVE LIVES – Clean Your Hands campaign. Antimicrob Resist Infect Control. 2022;11(1):63. doi: https://doi.org/10.1186/s13756-022-01105-y.
2. Smith L, Butler L, Tully MA, Jacob L, Barnett Y, López-Sánchez GF, et al. Handwashing practices among adolescents aged 12-15 years from 80 countries. Int J Environ Res Public Health. 2020;18(1):138. doi: http://doi.org/10.3390/ijerph18010138
3. Malik FR, Reman A, Niazi A, Kifayat F, Afridi N, Khan S, et al. A quasi experimental study on hand hygiene practices among secondary school children in Khyber Pakhtun Khwa. J Pak Med Assoc. 2022;72(4):664-8. doi: https://doi.org/10.47391/JPMA.2051
4. Goel S, Chandrashekar BR. Evaluating the efficacy of handwashing demonstration on hand hygiene among school students – an interventional study. J Educ Health Promot. 2020;9:226. doi: https://doi.org/10.4103/jehp.jehp_94_20
5. Pasewaldt SE, Baller SL, Blackstone SR, Bryan Malenke L. Impact of a hand hygiene curriculum and group handwashing station at two primary schools in East Africa. Int Q Community Health Educ. 2019;39(3):175-87. doi: https://doi.org/10.1177/0272684X18819968
6. Öncü E, Vayisoglu SK, Lafci D, Yurtsever D, Bulut ER, Peker E. Comparison of interactive education versus fluorescent concretization on hand hygiene compliance among primary school students: a randomized controlled trial. J Sch Nurs. 2019;35(5):337-47. doi: https://doi.org/10.1177/1059840518785447

7. Wasihun AG, Teferi M, Negash L, Marugán J, Yemane D, McGuigan KG, et al. Intestinal parasitosis, anaemia and risk factors among pre-school children in Tigray region, northern Ethiopia. BMC Infect Dis. 2020;20(1):379. doi: https://doi.org/10.1186/s12879-020-05101-8.
8. Enkhbat M, Togoobaatar G, Erdenee O. Handwashing practice among elementary schoolchildren in urban setting, Mongolia: a school-based cross-sectional survey. J Environ Public Health. 2022;2022:3103241. doi: https://doi.org/10.1155/2022/3103241
9. Lee SY, Sasaki S, Kurokawa H, Ohtake F. The school education, ritual customs, and reciprocity associated with self-regulating hand hygiene practices during COVID-19 in Japan. BMC Public Health. 2022;22(1):1663. doi: https://doi.org/10.1186/s12889-022-14012-z
10. World Health Organization. Recommendations to member states to improve hand hygiene practices to help prevent the transmission of the COVID-19 virus [Internet]. Geneva: WHO; 2020 [cited 2022 Nov 10]. Available from: https://www.who.int/publications/i/item/recommendations-to-member-states-to-improve-hand-hygiene-practices-to-help-prevent-the-transmission-of-the-covid-19-virus
11. Oliveira AC, Lucas TC, Iquiapaza RA. What has the covid-19 pandemic taught us about adopting preventive measures? Texto Contexto Enferm. 2020;29:e20200106. doi: https://doi.org/10.1590/1980-265X-TCE-2020-0106
12. Talic S, Shah S, Wild H, Gasevic D, Maharaj A, Ademi Z, et al. Effectiveness of public health measures in reducing the incidence of covid-19, SARS-CoV-2 transmission, and covid-19 mortality: systematic review and meta-analysis. BMJ. 2021;375:e068302. doi https://doi.org/10.1136/bmj-2021-068302
13. Oliveira FF, Horonato AK. Play and educational activity for hand hygienization in pandemic times: experience report. Nursing. 2021;24(275):5496-505. doi: https://doi.org/10.36489/nursing.2021v24i275p5496-5505
14. Mouta AAN, Silva NS, Souza SKM, Silva ACB, Costa TRM, Silva DA, et al. Saúde na escola: utilização do lúdico na educação básica para conscientização sobre a higienização pessoal e a prática da lavagem das mãos. Rev Eletr Acervo Saúde. 2020(50):e3222. doi: https://doi.org/10.25248/reas.e3222.2020
15. Ofori SK, Hung YW, Schwind JS, Muniz-Rodriguez K, Kakou RJ, Alade SE, et al. The use of digital technology to improve and monitor handwashing among children 12 years or younger in educational settings: a scoping review. Int J Environ Health Res. 2022;32(3):547-64. doi: https://doi.org/10.1080/09603123.2020.1784398
16. Wu S, Wang RS, Huang YN, Wan TT, Tung TH, Wang BL. Effect of hand hygiene intervention in community kindergartens: a quasi-experimental study. Int J Environ Res Public Health. 2022;19(22):14639. doi: https://doi.org/10.3390/ijerph192214639
17. Instituto Brasileiro de Geografia e Estatística. Censos demográficos: população residente estimada 2019 [Internet]. Rio de Janeiro: IBGE; 2020 [cited 2022 Nov10]. Available from: https://sidra.ibge.gov.br/tabela/6579#resultado
18. World Health Organization. WHO guidelines on hand hygiene in health care [Internet]. Geneva: WHO; 2009 [cited 2022 Nov 10]. Available from: https://www.who.int/publications/i/item/9789241597906
19. Ariza-Heredia EJ, Chemaly RF. Update on infection control practices in cancer hospitals. CA Cancer J Clin. 2018;68(5):340-55. doi: https://doi.org/10.3322/caac.21462
20. Mumma J, Simiyu S, Aseyo E, Anderson J, Czerniewska A, Allen E, et al. The safe start trial to assess the effect of an infant hygiene intervention on enteric infections and diarrhoea in low-income informal neighbourhoods of Kisumu, Kenya: a study protocol for a cluster randomized controlled trial. BMC Infect Dis. 2019;19(1):1066. doi: https://doi.org/10.1186/s12879-019-4657-0
21. Skodová M, Gimeno-Benítez A, Martínez-Redondo E, Morán-Cortés JF, Jiménez-Romano R, Gimeno-Ortiz A. Hand hygiene technique quality evaluation in nursing and medicine students of two academic courses. Rev Latino Am Enferm. 2015;23(4):708-17. doi: https://doi.org/10.1590/0104-1169.0459.2607
22. Wong JSW, Lee JKF. The common missed handwashing instances and areas after 15 years of hand-hygiene education. J Environ Public Health. 2019;2019:5928924. doi: https://doi.org/10.1155/2019/5928924
23. Lehotsky Á, Szilágyi L, Demeter-Iclănzan A, Haidegger T, Wéber G. Education of hand rubbing technique to prospective medical staff, employing UV-based digital imaging technology. Acta Microbiol Immunol Hung. 2016;63(2):217-28. doi: https://doi.org/10.1556/030.63.2016.2.6
24. Santos EO, Pinho LB, Silva AB, Eslabão AD. Analysis of access to the psychosocial care network for users of alcohol and other drugs in rural areas. Rev Gaúcha Enferm. 2022;43:e20210229. doi: https://doi.org/10.1590/1983-1447.2022.20210229.en
25. Borges TS, Cardoso MZ, Fortuna MJ, Reuter CP, Imperatore S, Franke SIR, et al. Oral hygiene, dietaryhabitsandprevalenceof dental caries in adolescentsfrom rural andurbanareas in Rio Grande do Sul, Brazil. Rev Gaúcha Odontol. 2017;65:139-47. doi: https://doi.org/10.1590/1981-86372017000200073255
26. Shimizu HE, Trindade JS, Mesquita MS, Ramos MC. Avaliação do Índice de Responsividade da Estratégia Saúde da Família da zona rural. Rev Esc Enferm USP. 2018;52:e03316. doi: https://doi.org/10.1590/S1980-220X2017020203316
27. Suen LKP, So ZYY, Yeung SKW, Lo KYK, Lam SC. Epidemiological investigation on hand hygiene knowledge and behaviour: a cross-sectional study on gender disparity. BMC Public Health. 2019;19(1):401. doi: https://doi.org/10.1186/s12889-019-6705-5

Acknowledgments:
This work was conducted with the support of the Coordination for the Improvement of Higher Education Personnel (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil* – CAPES) – Funding Code 001.

Authorship contribution:
Project administration: Michael Gabarron Costa, Paulo Roberto Rocha Júnior, Osni Lázaro Pinheiro.
Formal analysis: Michael Gabarron Costa, Paulo Roberto Rocha Júnior, Maria Angélica Spadella, Eduardo Federighi Baisi Chagas, Melissa Vitória Xavier Pinho, Osni Lázaro Pinheiro.
Conceptualization: Michael Gabarron Costa, Paulo Roberto Rocha Júnior, Osni Lázaro Pinheiro.
Data curation: Michael Gabarron Costa, Paulo Roberto Rocha Júnior, Osni Lázaro Pinheiro.
Writing – original draft: Michael Gabarron Costa, Paulo Roberto Rocha Júnior, Osni Lázaro Pinheiro.
Writing – review & editing: Michael Gabarron Costa, Paulo Roberto Rocha Júnior, Osni Lázaro Pinheiro.
Investigation: Michael Gabarron Costa, Melissa Vitória Xavier Pinho.
Methodology: Paulo Roberto Rocha Júnior, Maria Angélica Spadella, Eduardo Federighi Baisi Chagas, Osni Lázaro Pinheiro.
Resources: Michael Gabarron Costa, Paulo Roberto Rocha Júnior, Osni Lázaro Pinheiro.
Software: Maria Angélica Spadella, Eduardo Federighi Baisi Chagas.
Supervision: Paulo Roberto Rocha Júnior, Osni Lázaro Pinheiro.
Validation: Paulo Roberto Rocha Júnior, Maria Angélica Spadella, Eduardo Federighi Baisi Chagas, Osni Lázaro Pinheiro.
Visualization: Paulo Roberto Rocha Júnior, Eduardo Federighi Baisi Chagas, Osni Lázaro Pinheiro.

The authors declare that there is no conflict of interest.

Corresponding author:
Michael Gabarron Costa
E-mail: radgabarron@gmail.com

Associate editor:
Helena Becker Issi

Received: 12.22.2022
Approved: 06.16.2023

Editor-in-chief:
João Lucas Campos de Oliveira