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Comparison between Personal Protective Equipment Wearing Protocols to Shorten Time to Treatment in Pre-Hospital Settings

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Abstract: Background. Arrival times at the scene and provision of initial emergency treatment have importance in pre-hospital care settings. Donning proper protective equipment by medical personnel, as was needed during the COVID-19 pandemic, prolongs the time between the arrival of medical personnel to a patient and provision of primary medical care. **Objective.** We examined the effect of a suggested personal protective equipment (PPE) wearing protocol (gown protocol) on shortening pre-hospital treatment times compared to the current coverall protocol. **Method.** In this prospective simulation-based study, participants were instructed to inject a practice epinephrine syringe into a simulation mannequin after donning either a gown or a coverall PPE kit in the shortest possible time. Participants performed the two protocols in a randomized order. Donning time, physiological measures, and participants' perceptions were measured after completion of each of the protocols. **Results.** Donning times and heart rates were significantly lower in the gown protocol compared to the standard coverall protocol. In addition, participants reported that the gown protocol was more comfortable and allowed provision of better medical care. **Conclusions.** Advantages of using the new protocol included shortening the time until primary medical care can be provided, perceptions of greater comfort, less difficulty in administering medical care, and lower heart rate values.

Keywords: COVID-19; pre-hospital setting; personal protective equipment; PPE donning protocol; shortening time to treatment

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1. Introduction

1.1. Pre-Hospital Setting

Pre-hospital care is a unique setting in which medical personnel arrive with their medical equipment to the scene of an incident where a person needs urgent medical care [1,2]. In these emergency contexts, arrival times at the scene of the incident and provision of initial emergency treatment may be important in some specific scenarios [3,4]. The emergency medicine system in the pre-hospital setting is based largely on short working intervals that enable treatment to be quickly administered to a patient who needs it [5,6].

Magen-David-Adom, Israel's national emergency medical services, operates advance life support teams that include a paramedic team leader and a driver who may be a medic or senior medic. All staff members are qualified to provide life-saving treatment, such as injecting an automatic epinephrine syringe (also known as an EpiPen®) as first aid to patients experiencing a severe allergic reaction. For these patients, quick EpiPen® injection is highly important and can be lifesaving [5,6].

1.2. Personal Protective Equipment

The work of medical personnel sometimes requires the use of personal protective equipment (PPE). These protective measures are taken to avoid exposure to infections or infectious diseases. However, the use of this equipment has far-reaching effects on the caregiver in terms of complicating communication, inducing headaches, experiencing discomfort during use, and more [7–9].

In December 2019, the coronavirus (COVID-19) pandemic outbreak became global. The pathogen was spread through the air and had a very high infection rate. The COVID-19 pandemic brought with it many challenges to the healthcare system, among which were the need for medical personnel to wear protective equipment. In the first months after onset of the pandemic, the personal protective equipment (PPE) kit in the pre-hospital setting in Israel included non-sterile gloves, an FFP3/N95 standard face mask, a surgical face mask, a protective visor, and protective coveralls [10]. Donning the coveralls on the way to the scene was impossible; hence, this had to be done after parking the emergency vehicle. The consequence of this procedure was a potential delay in medical care provision, as it prolonged the time until care could be given to a patient.

1.3. A New Protective Protocol for EMS Personnel

Donning PPE properly was a significant factor in prolonging the time between the arrival of medical personnel at the scene of an incident and provision of primary medical care to the patient. The study presented in this paper examined a new PPE wearing protocol (called the "gown protocol" in the study) whose purpose was to shorten the time it took to provide *initial* treatment to patients without significantly impairing the level of protection. The protective measures used as part of the gown protocol are approved for use by medical teams around the world [9]. There are several advantages to the suggested protocol over the existing one, including the ability to wear the protective items while sitting in the ambulance on the way to the scene of an incident, thus potentially reducing the delay in providing primary care. The suggested protocol is based on the knowledge that exposure of less than 15 min to the COVID-19 virus does not endanger medical personnel (this fact relates to some COVID-19 types) [11]. According to this protocol, the team leader wears the protective gown on the way to the scene and provides *initial* treatment to the patient during the first 15 min. Meanwhile, the rest of the team don the full PPE kit (including coveralls, gloves, N95 mask, surgical mask, and visor) at the incident scene and replace the team leader at the end of a set period. The medical personnel leader then dons the full PPE kit and returns to continue the medical treatment.

1.4. Objectives

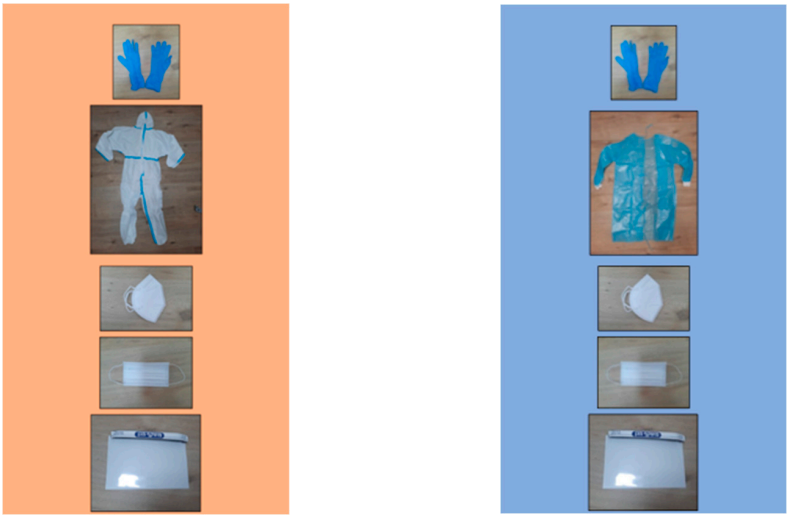
The main objective of the study was to examine the effect of PPE wearing protocol on pre-hospital treatment times. The secondary objectives of the study were: (a) to compare primary medical treatment duration between the two protocols (gown protocol and coverall protocol), and (b) to compare participants' perceptions of the two protocols (gown protocol and coverall protocol).

2. Materials and Methods

2.1. Settings and Intervention

This was a prospective simulation study. Participants were students studying at the Faculty of Health Sciences at Ben-Gurion University who had taken a basic first-aid course. After filling out a questionnaire with demographic information and watching an explanatory video, participants arrived at the simulation room where they performed an individual PPE donning exercise, practicing EpiPen® injection in each of the two protocols (see Figure 1). Participants were then instructed to don the PPE kit in the shortest possible time and inject a practice EpiPen® syringe into a mannequin in a simulation room. We measured the length of time it took participants to perform these activities in each of the protocols. In addition, participants' physiological measures, oxygen saturation, and heart

rate were measured before the onset of exercise and at the end of each simulation (after injection of a practice epinephrine syringe). The order of execution of the simulations was determined randomly and, between the two simulations, the participants had a 15 min break. The break ensured that any physical exertion during the first simulation would not affect the second simulation and that the physiological measures of the participant had returned to normal. At the end of the second simulation, participants were asked to complete a perception questionnaire that dealt with their comfort perceptions, difficulties in providing medical treatment, and safety perceptions when using each protocol (coverall and gown), rating these factors on a seven-point Likert scale.



(**a**) (**b**)

Figure 1. (**a**) Coverall kit; (**b**) gown kit.

2.2. Sample Size

The sample size was calculated using PS: Power Sample Size Calculation, version 3.1.6 (October 2018), created by William D. Dupont and Walton D. Plummer, Jr., from the Vanderbilt Biostatistics–DalePlummer website (https://biostat.app.vumc.org/wiki/Main/PowerSampleSize (accessed on 2 August 2022)). The calculation utilized a significance level of 0.05 and an intensity of 0.8. Thus, a sample of 50 participants made it possible to detect a time difference between the groups equal in size to 0.4 standard deviations or more at the requested significance level and intensity.

2.3. Statistical Analysis

The statistical analysis was performed using SPSS software, version 23. First, a statistical analysis compared the difference between the first and second measurements to examine whether the order of the executed protocol affected the performance. Second, differences between participants' time measurements and heart rate values for each of the protocols were examined using a paired *t*-test. Then, we examined the differences between participants' answers in the perception questionnaire for each protocol using a Wilcoxon test.

To examine the differences between the two protocols, quantitative variables were constructed based on the data collected in the study. The time variable expressed the difference in the time it took to perform the protocols for each participant. Three additional quantitative variables (comfort perception, safety perception, and difficulty in providing medical treatment) expressed the differences between each participant's answers to the two questions in the perception questionnaire relating to the coverall protocol and the gown protocol for each factor (comfort, safety, and difficulty in providing medical treatment). The distribution of the variables constructed from the perception questionnaire was examined by measuring the difference between the continuous quantitative variables and the time and

background variables, such as age and academic year. Various statistical tests were used, such as the Mann–Whitney test, Spearman test, Pearson test, and paired *t*-test, depending on the distribution of the variables.

3. Results

Sixty-four students participated in the study. Their demographic characteristics are presented in Table 1.

Table 1. Demographic characteristics of the study participants.

Variable	Type	Main Indices
Age	Quantitative continuous	Mean = 25.08 +/− 2.797 Median = 25 years (range 18, 31)
Gender	Qualitative dichotomous	Female = 51.6% Male = 48.4%
Academic program	Qualitative nominal	School of Emergency Medicine = 73.4%, School of Nursing = 6.3%, School of Medicine = 14.1%, graduate program = 6.3%
Academic year	Quantitative discrete	Median = 2nd year (IQR 25% = 2, 50% = 2, 75% = 3; range 1, 6) first year = 14.1%, second year = 46.9%, third year = 28.1%, fourth year = 6.3%, fifth year = 1.6%, sixth year = 3.1%
Had the participant taken a first-aid course in the past?	Qualitative dichotomous	Yes = 100%
Had the participant used PPE in the past?	Qualitative dichotomous	Yes = 92.2% No = 7.8%
Had the participant used an EpiPen injector in the past?	Qualitative dichotomous	Yes = 64.1% No = 35.9%

3.1. Comparison of Time Measurements between the Two Protocols: Coverall Protocol and Gown Protocol

The time that it took each participant to don the PPE and provide an EpiPen® injection in each of the protocols was measured. The difference between the measurements of the first and second simulation was not significant (Wilcoxon, $p = 0.706$), implying that the order of the executed protocol did not affect the performance. Gown protocol time measurements were found to be significantly shorter (mean 80.16 +/− 14.60 s) compared to coverall protocol time measurements (mean 93.89 +/− 21.42 s) ($p < 0.001$). These results are presented in Figures 2 and 3.

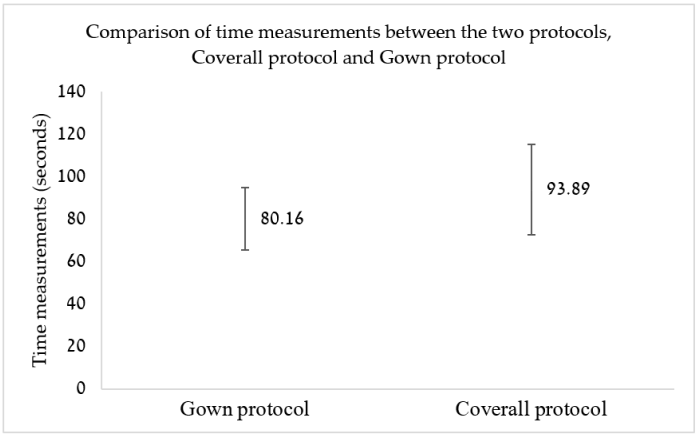


Figure 2. Comparison of center and dispersion indices (mean and standard deviation) between the two protocols examined in the study: coverall protocol and gown protocol.

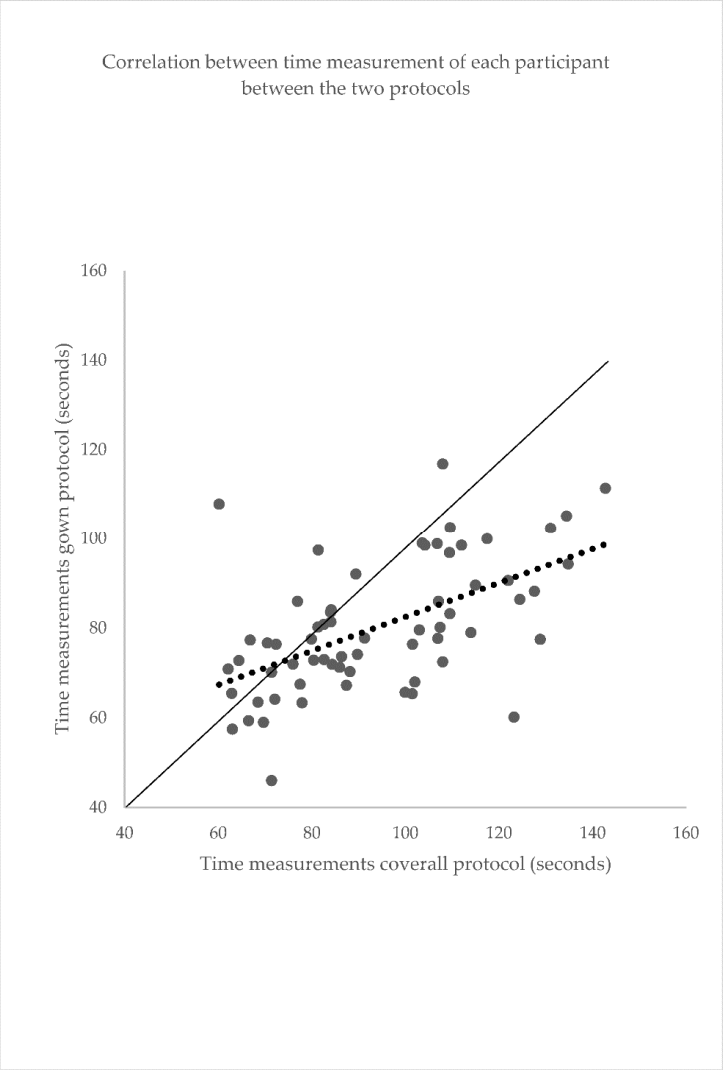


Figure 3. Comparison of time measurements of each participant between the two protocols examined in the study: coverall protocol and gown protocol. The solid line represents the equality line, and the dotted line is the trendline of the measurements.

3.2. Heart Rate Measurements

The heart rate of each participant was measured after providing an EpiPen® injection while using each protocol: the gown protocol and coverall protocol. Comparison of heart rate measurements between the two protocols showed a statistically significant difference in the heart rate of the participants ($p < 0.001$). After using the coverall protocol, higher heart rate values were found (mean 99 +/− 19.0 bpm) compared to using the gown protocol (mean 93 +/− 18.27 bpm). These results are presented in Figure 4.

3.3. Comfort Perception

A statistically significant difference was found in the comfort perception rating using the two protocols ($p < 0.001$). The median value of the full coverall protocol rating was 3, while the median value of the gown protocol was 6. These results are presented in Figure 5. It was found for most participants that the higher their sense of comfort in the gown protocol, the lower it was in the coverall protocol, and vice versa. When examining a single-variable relationship between the comfort variable and the background and time variables (difference in time measurements between the two protocols) in the study, three statistically significant relationships were found. The first was between the comfort perception variable and the time difference variable ($p = 0.04$), the second was between the comfort perception

variable and the difficulty of providing care variable ($p < 0.001$), and the third was between the comfort perception variable and the safety perception variable ($p = 0.019$).

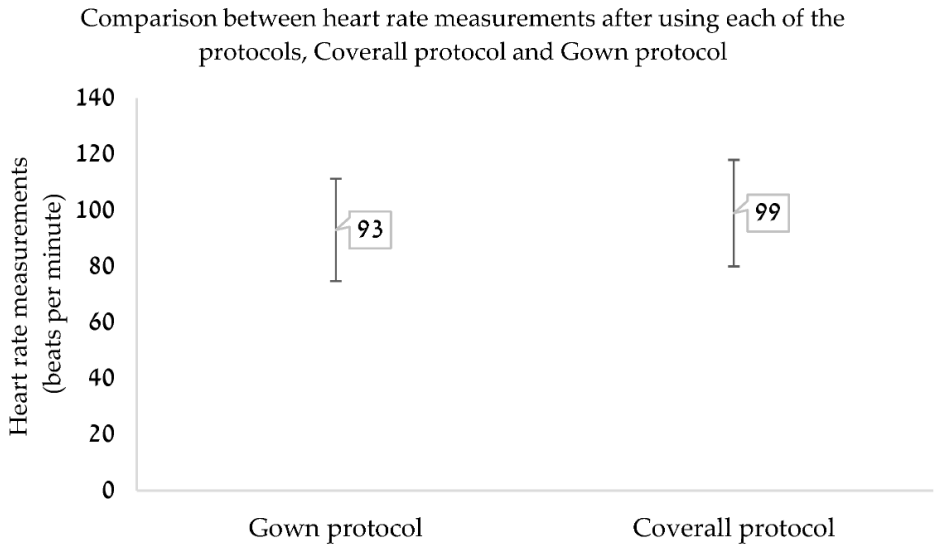


Figure 4. Comparison of heart rate measurements and dispersion indices (mean and standard deviation) after using each of the protocols.

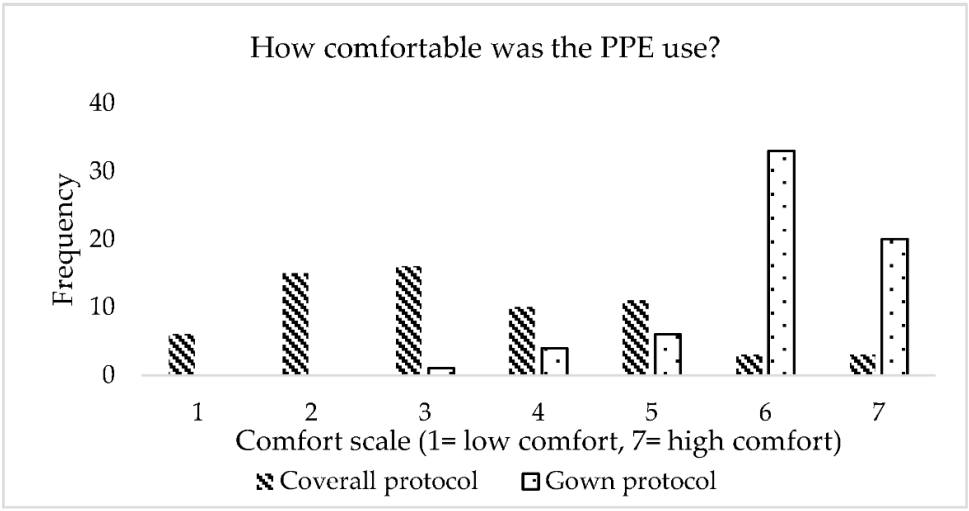


Figure 5. Comfort rating from the perception questionnaire after using the two protocols.

3.4. Difficulty in Providing Medical Care

The results of the study showed that there was indeed a statistically significant difference in the rating of the difficulty in providing medical care between the two protocols ($p < 0.001$). The median value of the difficulty rating for providing care using the coverall protocol was 2, while the median value of the difficulty rating using the gown was 1. These results are presented in Figure 6. It was found that, for most participants, the higher the sense of difficulty was for the epinephrine injection in the coverall protocol, the lower it was in the gown protocol, and vice versa. When examining a one-variable relationship between the variables of difficulty in providing care and the background and time variables (difference in time measurements between the two protocols) in the study, two statistically significant relationships were found. The first relationship was between the variables of difficulty in providing care and comfort perception (r = 00.432, $p < 0.001$). The second statistically significant relationship was between the variables of difficulty in providing care and safety perception (r = −0.344, $p = 0.005$).

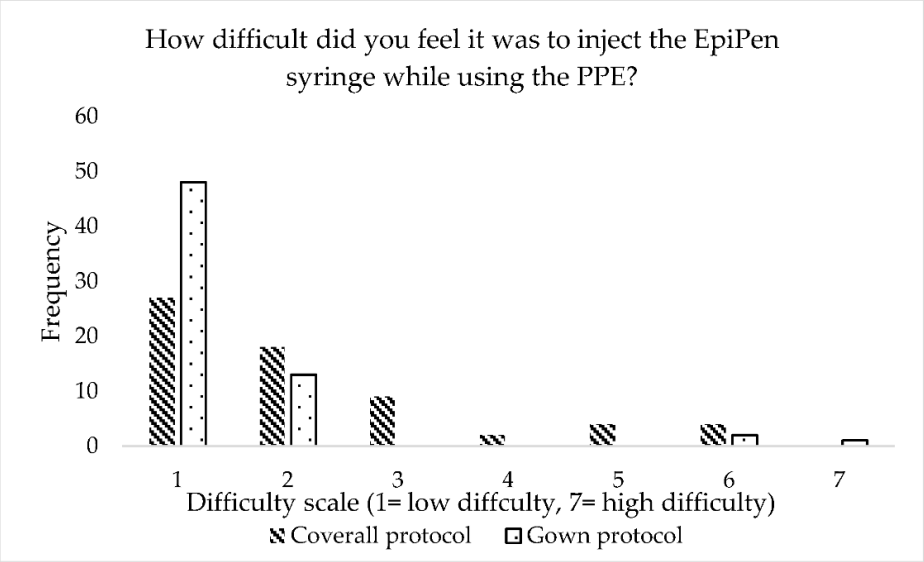


Figure 6. Difficulty in providing a medical care rating from the perception questionnaire after using the two protocols: coverall protocol and gown protocol.

3.5. Safety Perception

No statistically significant difference was found in safety perception between the two protocols (p = 0.35). The median value of the safety perception index used in the coverall protocol was 6, while that of the safety perception index used in the gown protocol was 5. These results are presented in Figure 7. When examining a single-variable relationship between safety perception and the background and time variables (time measurement difference between the two protocols) in the study, two statistically significant relationships were found. The first relationship was between the variables of safety perception and comfort perception (r = 0.293, p = 0.019). The second relationship found to be statistically significant was between the variables of safety perception and difficulty in providing treatment (r= −0.344, p = 0.005).

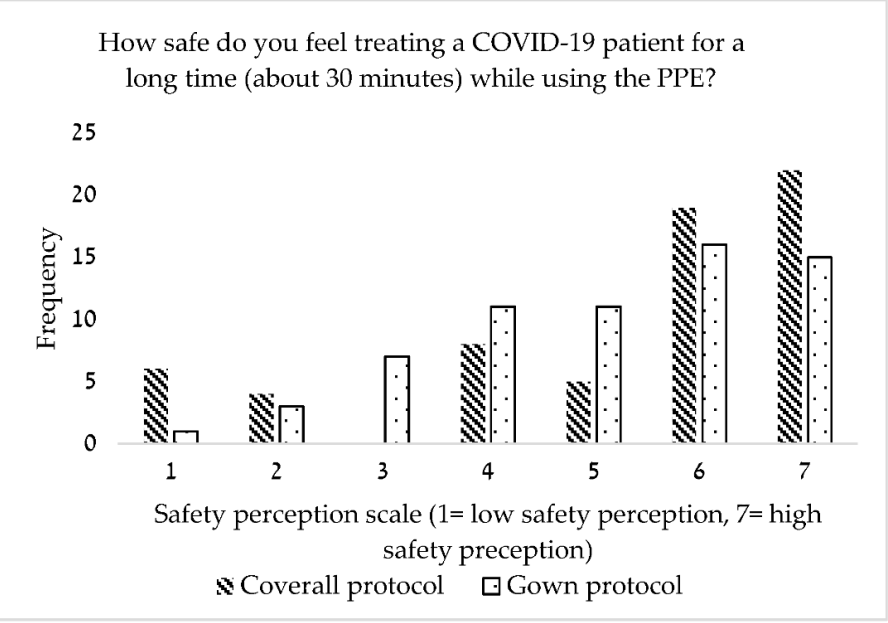


Figure 7. Safety perception rating from the perception questionnaire after using the two protocols: coverall protocol and gown protocol.

4. Discussion

4.1. Duration of PPE Donning and Provision of Primary Medical Treatment: Coverall Protocol and Gown Protocol

In addition to shorter donning time using the gown protocol, it is possible to wear the gown while the emergency vehicle is en-route, thus avoiding a delay in providing primary care to the patient when arriving at the incident scene. The coverall protocol, which is currently practiced among emergency crews in the pre-hospital setting, requires donning the PPE only after parking the emergency vehicle upon arrival at the scene.

The time range measured using the coverall protocol was 60.19–142.65 s (1–2.24 min); using the gown protocol, it was 45.94–116.75 s (0.76–1.94 min). Even though both time frames were relatively short, this is a clear difference. However, it is important to remember that the study was conducted under simulated conditions; thus, it could not fully replicate the actual working conditions of emergency crews. That is, the protocol simulations took place in a closed and air-conditioned simulation room at a constant temperature, whereas, in the real world, temperature conditions vary according to the season of the year. For example, during the hot summer months in Israel, wearing the existing protective equipment—the coverall protocol—often involves removal of the top layer of the work uniform to avoid excessive sweating, which would require a change of uniform during the shift. There is also a mental difficulty in wearing non-ventilated protective equipment. These aspects consume extra time in the technical action of wearing such equipment. Further, participants were not required to move equipment from place to place, as is generally required by emergency crews in an actual pre-hospital setting (carrying a resuscitation bag, oxygen bag, monitor, and medication bag) [6], and they were only required to inject the syringe prepared for them near the protective equipment. Transporting equipment in a pre-hospital setting prolongs the time it takes to reach a patient. These aspects extend the time before the patient can receive primary medical care and, for this reason, the quality of care may be impaired. Thus, the time it takes to put on the PPE upon arrival at a patient's address should be shortened, recognizing the advantages inherent in using the gown protocol: that it took less time to don the PPE in the simulation and that this was possible to achieve even on the way to the scene of an incident.

4.2. Heart Rate Comparison between the Gown and Coverall Protocols

In addition to measuring the duration of donning the PPE, the heart rate values of each participant were measured three times: upon arrival to the simulation room and near the end of each of the two protocol simulations. Studies show that the use of protective equipment has an effect on the physiological and cognitive indicators of medical personnel [12,13]. Impacting these metrics may affect the medical care provided by the medics [13] and even impair their decision making [14–16]. It can be expected that differences in physiological metrics between the coverall and gown protocols would affect a medic's cognitive performance.

After using the coverall protocol, higher heart rate values were found compared to using the gown protocol. The results support existing knowledge about the effects of using PPE on medical workers' physiological indicators [13] and performance [12].

4.3. Subjective Indicators: Comfort Perceptions, Difficulty in Providing Medical Care, Safety Perceptions

4.3.1. Comfort Perceptions

For most participants, the higher the sense of comfort in the gown protocol, the lower it was in the coverall protocol. Studies show that the use of the coverall protocol makes it difficult for medical personnel to communicate with each other. Two major reasons for this are visual limitations caused by condensation that accumulates on the face shield and hearing impairment because the coverall covers up the ears [8,9,17,18]. Other studies have shown that wearing the coverall may result in excessive sweating and fluid loss during use [8,9]. In addition, other studies have shown that, even though the use of protective equipment that covers more body parts does offer optimal protection, there is also more

discomfort during use and even difficulty in removing the equipment [19]. In addition, because the gown protocol does not cover the back of the head, it was hypothesized that this protocol would be rated as more comfortable to use compared to the coverall protocol.

We found that, for longer time differences between the two protocols, the comfort perception difference value was smaller. Only six participants (about 9%) rated the coverall protocol as more comfortable compared to the gown protocol, and the rating difference for these participants was very low (0–2). The literature regarding the comfort of using the coverall protocol compared to the gown protocol is also consistent with the results of the current study, according to which use of the coverall protocol requires a longer duration compared to the gown protocol.

Greater comfort perception in the gown protocol was correlated with more difficulty in providing medical care using the coverall protocol. This result is consistent with the existing knowledge in the literature that a higher comfort perception reduces difficulty in providing medical treatment [20].

However, it is difficult to draw conclusions based on the relationship found between the variables of comfort perception and safety perception since the correlation coefficient (r) was very low (r = 0.293). This indicates a relationship that is indeed significant but, in practice, is very weak.

4.3.2. Difficulty in Providing Medical Treatment

The quality of medical treatment can be measured using many parameters, including assessing the difficulty in providing it. In this study, we measured participants' perceptions of the difficulty of injecting an epinephrine syringe to rate the quality of medical treatment while using both protocols. The results show that there was a statistically significant difference in rating the difficulty in providing medical treatment between the two protocols. For most participants, a higher difficulty perception while injecting the EpiPen using the coverall protocol resulted in a lower difficulty perception when using the gown protocol, and vice versa. There is agreement between this finding and the existing knowledge in the literature. A study published in 2020 assessed how the performance of surgeons from 30 countries was affected by the protective equipment (N95, FFP3 face masks, face shields, gloves, and gowns) they were using. It found that many surgeons felt their performance was negatively impacted. Various explanations for the decrease in performance quality in the operating room have been proposed, including greater difficulty in communicating with other staff members and visual impairment [17].

We found a relationship between the difficulty in providing medical treatment and safety perceptions. However, it is difficult to draw a conclusion based on this relationship since the correlation coefficient was very low. Again, this indicates a relationship that was found to be significant but, in practice, is very weak between the variables.

4.3.3. Safety Perceptions

Studies show that the safety perceptions of medical personnel affect the quality of medical treatment [17,20]. Low safety perceptions affect caregivers' mental well-being metrics [21], and, subsequently, can affect the quality of care provided to patients [18]. As the protective items of the coverall protocol cover a wider surface area of the caregiver's body compared to the gown protocol, we hypothesized that safety perceptions would be higher when medical personnel felt less exposed during treatment. However, this hypothesis was not confirmed, as, for both protocols, the safety perception rating was high, with no statistically significant difference. These results do not match the existing knowledge in the literature—that feelings of safety are higher when using protective equipment that covers a larger body area [22].

Even though we found a relationship between safety and comfort perceptions, it is difficult to draw any conclusion because the correlation coefficient was very low, which indicates a very weak relationship between the variables. Another relationship was found between safety perceptions and the difficulty in providing medical treatment. Here, a weak

positive relationship was also found; therefore, it is also difficult to draw a conclusion in this case as well.

This study was designed in the first year of the COVID-19 pandemic when knowledge about the form of the virus spread and the methods of infection were fundamentally different compared to the knowledge that exists today. At the outbreak of the COVID-19 pandemic, it was thought that the virus was transmitted by micro-droplet transmission (aerosol) [23] and by encountering a contaminated surface due to the virus' ability to survive on surfaces for several days [24]. Based on these beliefs, protection and work protocols were adapted for medical personnel working in hospital and pre-hospital settings. It is now known that the virus is transmitted mainly by droplet transmission, meaning it cannot survive for a long period of time on surfaces and contaminate them [24]. This knowledge changes the need for various protection methods and work protocols. However, in the pre-hospital setting in Israel and in the framework of Magen-David-Adom, the current accepted PPE wearing protocol is still the coverall protocol.

Although no statistically significant difference was found in safety perceptions using the two protocols examined in the study, and relationships with weak correlation coefficients were found for background variables, the existing knowledge in the literature supports that safety perceptions affect many aspects of the quality of patient care. It is likely that the safety perceptions using PPE when treating patients positive for COVID-19 have changed since the time this study was conducted due to changes in our existing knowledge about possible paths of infection. For these reasons, further research on the subject is needed.

As this study was conducted only under simulated conditions, we recommend conducting a follow-up study to examine the effectiveness of using the gown protocol in field conditions and as part of the work of medical personnel. This would shed light on additional conditions that might affect the medical response given to patients in pre-hospital settings.

4.3.4. Limitations

As mentioned before, this study was conducted under simulated conditions. This has some meaningful limitations. Firstly, the environmental condition, such as temperature, did not necessarily resemble the extreme conditions that can occur in the hot summers in Israel. Secondly, the simulated conditions did not allow us to emulate the need for EMS crews to carry heavy equipment after donning the PPE, which can prolong the time until provision of initial medical care to the patient. Another limitation was the changing knowledge about the COVID-19 virus. Our study was conducted during the middle of the first year of COVID-19 pandemic in Israel, when the COVID-19 virus was thought to be transmitted by touching infected surfaces. Today, we know that this is not true. For this reason, we assume that the safety perceptions of the participants about the two protocols may have changed, and it would be interesting to research it in future research.

5. Conclusions

Shortening the time until provision of primary medical care, higher comfort levels, less difficulty in providing medical care, and lower heart rate values are advantages in using the gown protocol over the coverall protocol. The shortened duration of time before provision of primary medical treatment in the pre-hospital setting, together with the other factors measured, demonstrate the effectiveness of using the gown protocol compared to the coverall protocol. While the study was conducted during the COVID-19 pandemic, its results can and should be considered for application in outbreaks of future pandemics.

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Institutional Review Board Statement: The Ethics Committee of the Faculty of Health Sciences' Human Subjects Research of Ben-Gurion University of the Negev approved the study (request number 11-2021).

Informed Consent Statement: Informed consent was obtained from all participants.

Data Availability Statement: Data available upon request.

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Conflicts of Interest: The authors declare no conflict of interest.

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