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Impact of personal protective equipment on clinical output and perceived exertion

Shelly Lynn Maynard, R Kao, DG Craig

ABSTRACT

Background and aim Safe clinical care within Ebola Virus Disease Treatment Units (EVDUs) mandate the use of personal protective equipment (PPE), comprising a fluid impermeable hooded suit, visor, gloves and rubber boots. The aim of this study was to assess the impact of this PPE on clinical personnel’s performance in the EVDU, Kerry Town, Sierra Leone.

Methods An anonymous questionnaire was administered to healthcare professionals (HCPs) entering the EVDU ward area (Red Zone (RZ)), during a 2-week period to assess perceived exertion using the Borg Rating of Perceived Exertion Scale.

Results A total of 62 clinical episodes undertaken by 20 HCPs were analysed. There were no episodes of heat illness during the study. HCPs spent a median of 74 (IQR 55–95) minutes within the RZ. Median durations of RZ activity were similar throughout the 24 h period (p=0.22), but Borg scores were significantly higher per minute spent within the RZ were significantly greater between 11:00 and 14:59 compared with RZ entry between 15:00 and 10:59, respectively (12 (6–15), n=13; 8 (6–9), n=48; p=0.022). Rates of weight loss per minute spent within the RZ were significantly greater between 11:00 and 14:59 compared with 15:00–10:59, respectively (0.014 (0.009–0.023) kg/min, n=6; 0.007 (0.004–0.013) kg/min, n=37; p=0.037).

Conclusions Despite acclimatisation and proactive clinical tasking, HCPs in the EVDU experienced significantly greater rates of weight loss, and perceived exertion scores during the hottest times of the day. These findings should be considered by those planning healthcare facilities for future humanitarian missions where HCPs will provide clinical care in full PPE.

INTRODUCTION

West Africa has been in the grip of the largest outbreak of Ebola virus disease (EVD) in history. By September 2015, this outbreak of EVD has infected 13 683 individuals with 3953 confirmed deaths in Sierra Leone alone.1 The UK government’s response to the EVD crisis is focused on Sierra Leone, led by the Department for International Development (DFID) in partnership with various non-governmental organisations, Public Health England and the Ministry of Defence. The UK has funded the construction of seven EVD treatment centres across the country, the first of which, the Ebola Virus Disease Treatment Unit (EVDTU) Kerry Town, opened on 5 November 2014. This site comprised of an 80-bed facility operated by Save the Children International with a functionally separate, but colocated DFID-funded 20-bed healthcare worker treatment facility previously operated by the British and Canadian Military Medical Services. The facility provides limited air-conditioning in patient treatment areas.

EVD typically presents with the onset of a non-specific febrile illness, followed approximately 5 days later by a gastrointestinal phase, characterised by copious diarrhoea and vomiting. These body fluids are highly infectious, posing a significant risk to all individuals coming into contact with patients who are infected with EVD, and have resulted in higher rates of infection among healthcare professionals (HCPs) during this outbreak.2 In order to mitigate the risk of cross-infection while caring for patients who are infected with EVD, HCPs must wear robust personal protective equipment (PPE) and undertake a number of protective drills, such as a full glove and apron change must be performed at each care episode in the facility. The PPE used at the military EVDTU comprised of a liquid impermeable protective hooded suit (Microgard 2000TS, Microgard, Hull, UK), rubber wellington boots, two pairs of long gloves, FFP2 face mask, surgical cap and a full-face visor as previously described.3 This PPE impairs evaporative cooling, and increases the risk of heat illness. The multiple steps involved in safely
removing the PPE can take up to 30 min for newly trained staff. In addition to routine clinical care, there are a number of non-clinical physically demanding procedures undertaken in the EVDTU, which are also performed while wearing PPE, such as chloride management and tent intufflation. This study aimed to examine the physical impact of caring for patients in an IV in a tropical climate while wearing PPE, examine durations of clinical care and individual clinical output within the EVDTU, in particular, during the hottest times of the day and to examine rates of weight loss, and perceived physical exertion during the hottest times of the day (11:00–15:00) when temperatures were at their peak, compared with other times of the day.

METHODS

A questionnaire was used to prospectively capture data on HCPs entering the suspected and confirmed wards (Red Zone (RZ)) at the EVDTU Kerry Town during a 2-week period from 26 January 2015 to 9 February 2015. The questionnaire was distributed to all HCPs of one nursing shift within the study period. A continuous rolling shift working pattern was undertaken during the study period as follows: morning shift (day 1, 07:00–14:00); afternoon shift (day 2, 13:30–22:00), night shift (day 3, 21:30–07:30), morning shift (day 4) and so on. Since, these shift periods overlapped during the anticipated hottest times of the day (11:00–15:00), it was prospectively decided to examine this timeframe separately. HCPs completed the questionnaire upon exiting from the RZ following the doffing procedure of their PPE. The questionnaire, prospectively captured the following data: demographics (age and sex); profession (physician, nurse, medic); time of RZ entry; length of stay within the facility; weight before and after entering the facility; tasks assigned prior to entry; tasks performed while in the facility; time taken to perform each task within the RZ; barriers to completing tasks and perceived exertion scale using the 15-point Borg Rating of Perceived Exertion Scale (Table 1). Body weight was measured using a set of standard mechanical bathroom scales, which were zeroed prior to each measurement. The same set of scales was used throughout the study. No specialist body mass measuring equipment was available in theatre.

In order to provide a semiquantitative assessment of clinical outputs for each entry into the RZ, a scoring system was prospectively developed by consensus to allocate a score to each RZ task (both direct patient contact and non-clinical tasks) undertaken while wearing PPE (see online supplementary Table S1). This scoring system reflected both the anticipated duration and physical exertion required to complete each task. For each RZ entry, the total clinical output for each HCP was summated and recorded in a dedicated database.

Statistical analysis

Statistical analysis was performed using Graphpad Prism (GraphPad Software, La Jolla, CA, USA). Data values were presented as mean±SD, median±IQR or percentages unless otherwise stated. Normality testing for continuous variables was assessed using the D’Agostino–Pearson method. Continuous data were compared using Student’s t test, analysis of variance (for >2 groups) or the Kruskal–Wallis test for non-normally distributed variables. Categorical data were analysed using χ² tests.

Study approval

The study was prospectively approved by the deployed local research committee, and by the chain of command.

RESULTS

A total of 62 clinical RZ episodes were analysed during the 2-week study period undertaken by a total of 20 HCPs (four physicians, six nurses and 10 medics). These individuals had an estimated mean relative humidity of 80% (SD±7%, maximum 86%; minimum 74%). The mean dry bulb temperature at 12:00 was 30.2°C (SD±1.2°C, maximum 32.4°C; minimum 27.8°C). The mean dry bulb temperature at 12:00 was 30.2°C (SD±1.2°C, maximum 32.4°C; minimum 28.3°C), with an estimated mean relative humidity of 80% (SD±7%, maximum 93%; minimum 65%). There were no episodes of heat illness among the HCPs during the period of study. During the 62 care episodes, a total of 789 procedures were performed. The procedures were divided into clinical (324, 41.1%) and non-clinical RZ tasks (465, 58.9%); of the clinical taskings, 159/324 (49.1%) were prospectively tasking prior to RZ entry, compared with 165 (50.9%) tasks performed reactively in response to patient needs while in the RZ.

Time spent in the RZ

The HCPs spent a median of 74 (IQR 55–95, range 30–210) minutes wearing PPE within the RZ. There was no correlation between the age of the HCP and the duration of RZ care (Spearman’s r=0.15, 95% CI −0.12 to 0.39, p=0.26). Male and female HCPs spent similar lengths of time within the RZ (male, 73 (60–98) minutes, n=41; female, 75 (55–93) minutes, n=21, p=0.76). Duration of care within the RZ was then assessed against time of RZ entry according to the four time periods—mornings (07:00–10:59), midday (11:00–14:59), evenings (15:00–21:59) and night (22:00–06:59). Median durations of RZ activity were similar for these four time periods (mornings, 83 (66–137) minutes, n=18; midday, 70 (58–93) minutes, n=13; evenings, 60 (55–80), n=23; nights, 84 (60–87) minutes, n=8; p=0.22).

Table 1 The 15-point Borg scale for ratings of perceived exertion

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<tr>
<td>7</td>
<td>Very light</td>
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<tr>
<td>8</td>
<td>Fairly light</td>
</tr>
<tr>
<td>9</td>
<td>Somewhat hard</td>
</tr>
<tr>
<td>10</td>
<td>Hard</td>
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Borg score and time spent in RZ

There was no significant correlation between overall duration of clinical care in the RZ and the Borg score (Spearman’s r=0.20, p=0.13). However, Borg scores during the midday period were significantly higher, when compared with RZ entry at other times (11:00–14:59, 12 (6–15), n=13; 15:00–10:59, 8 (6–9), n=48; p=0.022 (Figure 1.).
Clinical output and time spent in the RZ
As expected, clinical output as assessed by total clinical output score, significantly correlated with overall duration of RZ activity (Spearman’s r=0.33, p=0.008). However, there were no significant differences in the median, and overall clinical output during the different time periods assessed (mornings, 20 (9–27), n=18; midday, 25 (9–31), n=13; evenings, 17 (8–23), n=23; nights, 24 (6–46), n=8; p=0.84).

Weight loss and time spent in the RZ
There was a weak correlation between weight loss and overall time spent within the RZ (Spearman’s r=0.29, p=0.052). There was a trend towards a greater degree of weight loss during the hottest times of the day compared with other times of RZ entry, respectively (11:00–14:59, 0.75 (0.68–1.63) kg, n=6; 15:00–10:59, 0.60 (0.40–1.00) kg, n=37; p=0.10). However, the rate of weight loss per minute spent in the RZ was significantly greater during the hottest parts of the day compared with other time periods, respectively (11:00–14:59, 0.014 (0.009–0.023) kg/min, n=6; 15:00–10:59, 0.007 (0.004–0.013) kg/min, n=37; p=0.037) (Figure 2).

DISCUSSION
This study describes the impact of PPE use coupled with environmental stress on clinical care in a military EVDtu, Kerry Town, Sierra Leone. There was a significantly increased rate of weight loss among HCPs providing clinical care to patients with EVD at the hottest times of the day, which correlated with significantly increased perceived exertion at these times as assessed by the Borg score. Despite the increased physiological burden, HCPs spent similar lengths of time in the RZ, and achieved similar clinical outputs during the hottest parts of the day compared with other times of RZ entry. This study demonstrates, the additional physiological impact of PPE use on HCPs while working in a tropical environment. It emphasises, the importance of appropriate acclimatisation prior to deploying to a tropical environment. Commanders of future contingency operations in tropical environments should actively seek to minimise non-essential clinical work, during the hottest times of the day in order to mitigate the risk of heat illness.

A primary goal in this area of research is to ensure the safety of clinical personnel while attempting to maintain HCP productivity and a high level of patient care. This requires a balance between the type of PPE worn by clinical staff, and the physiological burden imposed by the PPE itself. This study is the first of its kind to report upon individually reported perceived exertion scores while providing clinical care in PPE. EVD has had a catastrophic impact upon healthcare in West Africa, and this study was a real-time evaluation of clinical work carried out by HCPs wearing PPE in a tropical environment. We reported both physical (weight loss) and psychological (Borg score) markers for potential heat stress in HCPs providing care in PPE. The study used simple equipment including a set of bathroom weighing scales, and the data were prospectively collected by a single investigator. The questionnaires were anonymised in order to reduce the risk of bias.

Due to the decreasing incidence of EVD in Sierra Leone during the period of this study, only 62 care episodes were reported in the questionnaires during a 2-week period. The data were collected prospectively, however, we did not directly correlate the collected data with local temperature and humidity readings at the time of RZ entry for each individual. Selection bias is possible, since only one of the four clinical shifts in the EVDtu on a 24 h rotation was questioned, and this shift was the principal researchers’ own team. However, the four EVDtu nursing shifts were prospectively assigned with similar proportions of junior and senior clinical staff, and we believe that these results are generalisable across the rest of the personnel. We recognise that weight loss data were only available for a proportion of all RZ entries, and that weight loss was recorded for only 6/13 separate RZ clinical episodes during the hottest times of the day. This reflects the operational tempo and the conflicting clinical demands placed upon individuals, particularly following RZ exit when debriefing of shift leaders occurs. The locally developed clinical scoring system was developed by local consensus and has not been externally validated.

The tropical climate of Sierra Leone routinely provides typical daytime ambient temperatures of 30°C and humidity in excess of 70%. The provision of clinical care while in PPE imposes an additional degree of heat stress, with a risk of subsequent heat illness, due to the reduced ability to lose body heat through sweat evaporation. Wearing a semipermeable outer barrier suit significantly reduces continuous work times before reaching a core temperature limit at 38.5°C compared with permeable, but relatively tight clothing. It is clear that further laboratory and environmental studies examining the physiological impact of filovirus PPE, and the risk of heat stress would be extremely useful.

Current guidance for commanders in mitigating heat illness is provided by Joint Service Publication (JSP) 539. This provides threshold values for continuous maximum permitted continuous work intensity (expressed as 1 h exposure with aminimum of
30 min rest after the activity), for military personnel at a given environmental temperature (WBGT). The threshold values vary for acclimatised and unacclimatised personnel. JSP 539 states that the maximum work rate for acclimatised personnel at 30°C should be ‘medium’, equivalent to marching at 3.6 km/h (2.3 miles/h) with a 30 kg load for 1 h with 30 min rest after the activity. JSP 539 further states that ‘If CBRN clothing is worn, it is not safe to perform activities at a high or above work rate or to run at any environmental temperature without specific medical advice.’ As a result, clinical staff typically enter the RZ for periods ranging from 30 min to a maximum of 2 h during cooler times of the day. This results in frequent staff turnover, uses significant resources in terms of both manpower and equipment consumption including PPE, disrupts continuity of care, and potentially increases the risk of infection due to frequent suit changes and physical degradation.

It is clear from the data presented that the potential for heat illness is greatest between the hours of 11:00 and 14:59. In order to mitigate the risk of heat illness, thorough acclimatisation of personnel is essential, and clinical care and time spent in the RZ should be closely monitored, and minimised during these times. This should include rotational shift patterns and routines, using air-conditioned facilities where possible, and ensuring adequate rest periods. In addition, clinical care should be proactively assigned in an attempt to minimise HCP entry into the RZ during the hottest times of the day. Although, fully air-conditioned facilities are not always feasible in developing countries, efforts should be made to provide shaded and cooled areas for clinical care, since these measures are usually low cost and reliable.

CONCLUSION

This study describes the impact of caring for patients with EVD while wearing PPE, and demonstrated significant increases in both rates of weight loss and perceived exertion scores during the hottest times of the day. Because of the increased risk of heat illness to HCP while caring for patients with EVD, HCP safety should be of utmost concern, and these findings should be considered by those developing and planning care facilities for future humanitarian missions where HCPs will provide care in full PPE.

REFERENCES