UTILITY OF MECHANICAL AIDS TO REDUCE THE PHYSICAL DEMANDS OF SHIPBOARD EMERGENCY DAMAGE-CONTROL TASKS

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INTRODUCTION

With the advent of women being assigned to U.S. Navy combat vessels, gender differences in emergency task performance have become an operational readiness aiid national security issue. Inability of crew members to perform emergency damage-control tasks mag be potentially life threatening. Tragedies, such as the USS Stark (FFG-31) incident, offer vivid testimony to the enormous physical demands placed on ship's personnel during sustained fire-fighting operations.

In order to optimize shipboard operatioiial readiness, safety, and worker productivity the objectives of tlie present investigation were to: 1) identify emergency shipboard damage-control taslts that may benefit from ergonomic intervention, 2) develop ergonomic aids to reduce tlie physical demands of the selected tasks, 3) assess physiological. psychophysical aiid damage-control task performance of U.S. Navy men aiid women. and 4) compare damage-control task performance of subjects before and after ergonomic intenmition.

MATERIALS and METHODS

Based on information from various training site and shipboard visits. and interview data collected from damage-control personnel. tlie following two tasks were identified for analysis. Task I: Estricate injured/unconscious personnel (Mannequin drag) and. Task 2: C02 bottle extinguisher carry.

The above tasks were chosen for evaluation because 1) task procedures were amenable to ergonomic intervention, 2) task adininistratioii coulc be conducted onboard ship with minimal impact on tlie ship's crew aiid 3) tasks could be easily aiid realistically simulated aiid performance measured accurately.

Testing was conducted aboard the USS Emory S. Land, (AS-39) ported at the Naval Station. Norfolk. Va. Twenty four females and 23 males from the ship's company volunteered as subjects. Group mean±SD age, height aiid body mass €or tlie men and women were 24.3±4.6 yrs, 175.6±5.1 cm, 79.5±10.8 kg (men) and 25.7±5.8 yrs, 163.2±7.7 cm. 70.9±13.8 kg (women), respectively.

On separate days each subject performed Tasks 1 aiid 2 under both standard and experimental conditions. The order of presentation of tlie two tasks aiid of tlie standard and experimental conditions were counterbalanced across the subjects.

Task 1: Mannequin drag: Subjects were instrumented with a Uniq Heart Watch (Model 8799. Computer Instruments Corp. Hempstead. ***NY)*** for telemetric

measurement of heart rate, and then dressed in a Fire Fighting Ensemble (FFE) including boots. coveralls, gloves, and Oxygen Breathing Apparatus (OBA) (without the oxygen producing canister or the face mask). Fire helmets were not worn. The "unconscious firefighter" was a **74.8** kg mannequin fully suited in a 15.9 kg FFE (total body mass 90.7 kg). Upon command, tlie subjects had 30 s to move the mannequin as far as possible along a worn "non skid" weather deck.
Immediately upon completing the task, each subject was required to give an overall Rating of Perceived Exertion (RPE) as well as provide separate WE scores for different body regions (2). The 10-point category-ratio scale described by Borg (1) was used for assessing RPE.
Each subject performed Task 1 under two conditions: Standard - a simple "lift and drag" where the subject crouched. lifted tlie mannequin by grabbing underneath tlie arms, and moved the mannequin by walking backwards and, Experimental - a "tether drag" where the subject looped a tether under the arms of the mannequin, placed another loop over his/her shoulder and moved tlie mannequin by either walking forward or backward.

Task 2: CO_2 bottle extinguisher carry: Subjects reported to the test area dressed in working coveralls and steel toed footwear. They were instrumented for telemetric heart rate measures as described above. On command, tlie subjects lifted a standard shipboard C02 fire extinguisher **(23 kg)** from the deck, and carried it as quickly as possible through a 40 m course. The round trip course involved traversing up and down two inclined ladders ***(55*** from tlie horizontal with a combined vertical height of 5.3 m) between the ships decks. Subjects were not allowed to miss steps in ascending or descending tlie inclined ladders. nor were they allowed to run when crossing the decks. They were encouraged to walk as rapidly as possible on the decks.

Subjects performed Task *2* under two conditions: Standard - a simple "lift and carry" where they crouched. lifted the extinguisher. and carried it unaided through tlie prescribed route and. Experimental - a "strap-assisted carry" where they crouched. affixed the strap to the estinguislier with a carabiner clip, placed the strap over their head (diagonal across tlie torso), and then stood to begin the prescribed route. **An** investigator demonstrated the two task conditions and each subject was walked through the test course before commencing the task.
Task perforniance was measured as the overall time to complete the route. Immediately upon completion of each task condition (i.e., within 10 s), right and left grip strength were measured (one trial on each hand). Subjects were then debriefed and asked to give an overall RPE and an RPE for tlie different parts of the upper bod!.

RESULTS

Mannequin dray! task: Table 1 shows tlie distance (m) tlie mannequin was dragged in 30 s by tlie men aiid women using the shoulder aiid tether drag techniques. Significant gender differences in performance were observed for both techniques ($p<0.0001$). Although there was no significant difference in performance between the two drag techniques ($p>0.05$), a significant interaction between gender and drag technique was found ($p<0.05$). There was a slight tendency €or tlie tether drag technique to improve female drag distance, but decrease male performance relative to the shoulder drag technique. However, post hoc analysis using Tukey's HSD test revealed that these tendencies were not statistically significant.

The highest RPE for the shoulder drag were reported at the hands (7.2), and lower back (6.0) regions. The RPE for these body locations as well as for the lower arms were reduced significantly (between 47% and 67%; $p<0.0001$) using the tether drag technique. RPE for the other body parts were similar for tlie shoulder drag and tether drag techniques ($p>0.05$).

Use of the tether significantly reduced tlie overall RPE (shoulder drag technique = 6.5 vs 4.75 for tether drag: $p<0.0001$). Despite tlie lower RPE with the tether drag, peak HRs were similar with the two techniques (shoulder drag technique = 91% of age predicted maximum heart rate (HR_{max}) vs 88% €or tether drag; $p=0.06$). The women tended to display lower peak HRs than tlie men (86% vs 93% of HR_{max}; $p<0.05$). as well as lower overall RPE scores (4.9 vs 6.3: $p<0.05$).

CO_2 bottle carry task: Table 1 shows tlie times required for tlie men aiid women to complete the CO_2 bottle carry task using tlie standard and strap-assisted carry. **A**

TABLE 1
Mannequin drag and CO_2 bottle carry task performance. All values are means±SD.

	MALES	FEMALES
Mannequin Drag Distance (m)*		
Shoulder Drag	26.7 ± 8.3	7.8± 4.7
Tethered Drag	23.7 ± 8.1	8.3 ± 5.1
C02 Bottle Carry Time (s)*		
Standard Carry	39.9 ± 8.5	65.7 ± 24.5
Strap-assisted Carry	43.0 ± 7.5	65.8 ± 21.6

* Significant gender difference **in** performance ($p<0.0001$).
Significant interaction between gender and drag technique ($p<0.05$).

significant gender difference in performance on this task was observed. Tlie average time taken by females was 59% longer than that taken by males ($p<0.0001$). Using the strap did not alter significantly the time to complete the task ($p>0.05$).

For the standard carry the riglit arm and right hand received the highest W E (range 3 to 3.6). Tlie RPE for these body locations were reduced significantly (between 38% and 43%; $p<0.0001$) using tlie strap. However. use of tlie strap significantly increased RPE for the neck region from 1.1 (very slight) to 2.6 (slight to moderate) ($p<0.0001$).

Use of the strap did not affect overall RPE (standard carry = 4.5 vs 3.9 for strap-assisted carry: $p=0.052$). or peak HR (standard carry = 88% vs 90% HR_{max} for strap-assisted carry $p>0.05$). However, there was a significant 9% decrease in riglit handed grip strength immediately following completion of the standard carry task ($p<0.001$). Grip strength following completion of the strap-assisted carry was not significantly different from the pre-task measurements.

CONCLUSIONS

1. On average. the task performance of women was 32% (mannequin drag) and 63% (CO_2 bottle extinguisher carry) that of men (includes both standard and experimental conditions).
2. The ergonomic interventions failed to improve task performaiice of either men or women, although significant reductions in RPE for several body parts were observed.
3. The time required to utilize the mechanical aids appeared to have couiiteracted any potential performance benefits that may have been realized by lowering the physical demands of the tasks.
4. Reductions in RPE may support a benefit to performance when damage-control tasks arc of' a sustained nature, as often experienced during combat scenarios.

REFERENCES

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Supported by the Defense Women's Health Research Program (Tasking No. N642235CRCMA01-1464). The opinions and assertions contained herein are the private ones of the authors and are not to be construed as official or reflecting the views of the Navy Department or tlie naval service at large. This work was done by U.S. Government employees as part of their official duties and therefore cannot be copyrighled.