ENERGY EXPENDITURE, PHYSIOLOGICAL WORKLOAD AND POSTURAL CONTROL DURING WALKING ON A MOVING PLATFORM

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INTRODUCTION

At sea, ship movements, such as pitch, roll and/or vertical movements, *can* be quite strong. Working aboard such a moving ship is likely to be more demanding than when the same job is performed ashore, because of extra attentional and muscular efforts required to maintain one's balance. Therefore, tasks which require motor activity or perceptual-motor skills may become very fatiguing, especially when they must be performed while standing or walking. Although some attention (Colwell, *1989)* has been given to these problems, no attempts have been made to quantify these motion induced task strains or to correlate them to ship motion parameters.

Data from a pilot study showed that it was possible to measure the energy consumption of subjects walking on a treadmill during separate roll, pitch and vertical movements of a ship motion simulator (SMS). A follow up experiment was performed in which subjects were required to walk on a treadmill in the SMS cabin to test the assumption that real ship motions may contribute to a higher workload than comparable work ashore.

METHODS

Eleven SMS movement conditions were investigated, two of which consisted of pure two dimensional sinus movements (roll and vertical), two of simulated ship movements and seven of various combinations of large and/or small vertical, pitch and/or roll movements derived from the simulated ship motion profiles. The presentation of the conditions was randomized within and between subjects.

During all different motions of the SMS, ventilatory parameters (Oxycon Σ, Mijnhardt, the Netherlands) and heart rate (Sport Tester, Polar Electro, Finland) of twelve walking subjects (men and women) on a treadmill with a speed of 3.6 $km \cdot h^{-1}$ were measured. Every condition of the actual experiment lasted for approximately *15* minutes. Data were collected only during the last *10* minutes, assuming that steady state levels were reached.

Movement induced interruptions (MII's) are disturbances in the postural control of the subjects caused by the movements of the SMS. The MII's were scored by an observer, watching a video image, and by the subject in the SMS.

All results were compared with a stationary condition of the SMS. Metabolic rate for all conditions was calculated from oxygen uptake and respiratory equivalent (ISO 8996).

All physiological parameters were subjected to an analysis of variance with conditions, gender, body Ienght and body mass as independent variables. Differences between conditions were also analyzed for significance with a Tukey post hoc test. MII's had to be tested with a multitude of paired comparison t-tests, because non-homogeneity of their variance prevented the use of analysis of variance.

RESULTS

The results showed that in conditions which included large pitch movements energy expenditure was largest, followed by conditions which include large roll movements (Fig. 1).

Physiological workload of walking for the most demanding conditions (hPr, P, hpR and pR) was on average 29.9% of total work capacity of the subjects. On average, walking on the treadmill during the most demanding conditions required 22% more energy than when the SMS remained stationary.

No significant differences in heart rate were found between the conditions except for the conditions which showed highest (hPr) and lowest heart rate (hp).

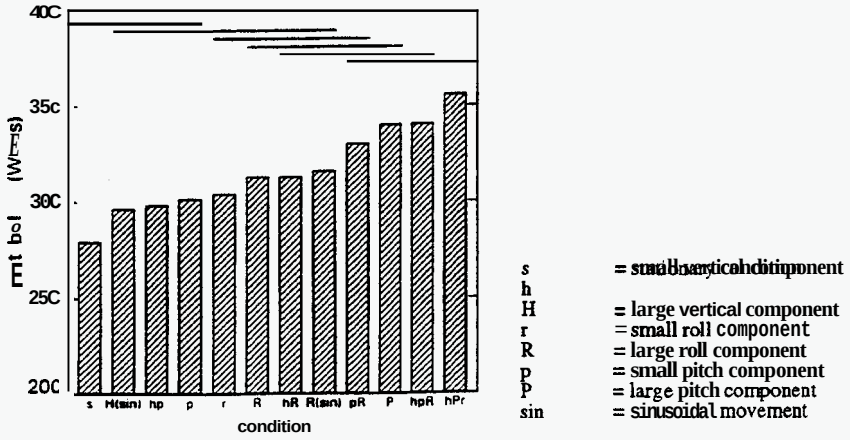

Fig. 1 Group mean values of metabolism during different SMS movement conditions. Conditions connected with a horizontal line in the upper part of the figure do not differ significantly from each other.

The correlation between MII-ratings of the observer and the subject in the SMS was very high (r=.92), which indicates that the reliability of the scoring procedure was very good. It appeared that most MII's happened during the conditions in which the SMS made movements with large roll components (Table I). Statistical analysis showed that conditions with large roll components differed significantly from the other conditions, with the exception of the predictable sinus roll movement that did not differ from the other conditions.

Table I Mean movement induced interruptions of all subjects during a 10 minutes period for the different moving platform conditions

	CONDITION											
	s	H(sin)	hp	p	r	hPr	P	R(sin)	R	hR	pR	hpR
MII's	.00	.00	.04	.12	.48	.51	.71	1.56	2.28	2.36	2.48	3.14

CONCLUSIONS

The results of this study showed that even a simple task as walking requires substantially more energy of the subjects when performed on a moving platform than when performed in a stationary environment. Walking on a moving platform gives highest energy expenditure when platform motion includes at least a large pitch component, or a combination of pitch and roll components.

If platform motion includes a significant roll component, a significant increase in problems with postural control is likely to happen, but this does not necessarily cause as much of an increase in energy expenditure.

REFERENCES

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