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Age and BMI interact to determine work ability in seafarers

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Background Seafaring is known to be a demanding occupation but the implications of ageing in seafarers are poorly understood.

Aims To investigate task demands and work ability in merchant seamen at sea and to identify factors predicting work ability.

Methods This was a cross-sectional study carried out on a single vessel during a summer deployment. Instantaneous heart rate (HR) was recorded at 5-s intervals during representative 8-h shifts in 41 merchant seamen. Participants completed the work ability index and also rated their daily task demands using the National Aeronautics and Space Administration Task Load Index (NASA-TLX). Body mass index (BMI), waist circumference and demographic details were recorded.

Results Work demands were found to be moderate according to both HR data and TLX scores. The mean BMI was 27.5 kg/m^2 (standard deviation 3.3) and the mean age was 47 years. The majority of participants rated their work ability as 'good' to 'excellent'. The best predictor of work ability was the interaction between BMI and age, whereas there was a statistically significant negative correlation between HR and age.

Conclusions Work ability in this group of seafarers was found to be high and the work was shown to be moderately demanding, on average. Although work ability declined with age and with BMI independently, the best predictor of work ability was the interaction between BMI and age, with increased BMI having a deleterious effect on work ability in older employees doing moderately demanding work.

Key words Ageing; BMI; seafarers; WAI.

Introduction

Two secular changes in developed countries are taking place: populations are ageing and becoming increasingly overweight. Much is known about the medical implications of these trends, but less is known about the employment implications.

Research into the ageing workforce goes back >60 years. Welford [1] concluded that, although age-related decrements in capacity can be measured, a single process changes at different rates in different people and different processes change at different rates within individuals. Thus, groups of older workers are more heterogenous than groups of younger workers and research findings can be contradictory at times. However, after 50 years of age, performance decrements become apparent [2,3]. In the UK, the Health and Safety Laboratory, in its review of research on employability, used the term 'older workers' to refer to people >50 years of age [4]. A few generalizations can be made: with advancing age, decrements can be expected in aerobic capacity, general health, grip strength, lifting strength, balance, eyesight, hearing, reaction time, limb motility, tissue and joint motility and elasticity, tolerance for paced work, ability to recover from slips and trips, knee function, longer recovery time from physical work, short-term memory, tolerance for heat and cold and joint function (pain/arthritis) [4–6].

The Work Ability Index (WAI) [7] is a tool that greatly simplifies the study of ageing in workforces because it requires employees to rate their current work ability in relation to their lifetime best, taking into account other factors, such as medical conditions and the deleterious effects of any of the decrements above. The WAI has been shown to predict occupational disability.

Seafarers are of particular interest because life at sea imposes additional demands compared with life ashore

and the changes listed above would be expected to diminish their work ability. Ship motion increases task demands and time to complete tasks [8,9] and causes losses of balance, sea sickness, sleep disturbance, slips, trips and falls and general tiredness. Seafarers use ladders and hatches daily, sometimes in extremes of temperature, and spend long periods aboard ship, isolated from family and with limited opportunity to disengage from work. This lack of control may be stressful [10].

Little is known about the capabilities of seafarers in relation to their occupational demands and, with the exception of fatigue, which is well-documented [11], little is known about the physical demands of life at sea. The aim of the current investigation was to quantify the physical demands placed on seafarers during their normal daily working activities in relation to their self-assessed work ability. A second aim was to identify factors predictive of work ability.

Methods

The study, which was approved by the Ministry of Defence Ethics Committee, was a cross-sectional one, using a convenience sample of volunteers from the crew of a single ship on a deployment to the Mediterranean in June 2010. All personnel were informed of the purpose and invited to participate. The decision to sample from a single ship on one deployment ensured that all subjects encountered similar work demands (that vary according to ship design) and were exposed to similar motions, without exposure to extremes of heat or cold. Sea states were low throughout the deployment and the experimenter was onboard at all times.

Volunteers were drawn from all specializations and included both ratings and officers. All participants gave their informed consent. No exclusion criteria were applied since all crew members were in possession of a valid ENG-1 (Seafarer Medical Certificate) (confirming fitness to serve at sea) and therefore deemed fit to participate [12].

Heart rate (HR) measurements were collected using a Polar™ S180i (Polar Electro, USA) HR monitor consisting of a conductive strap (worn around the chest) and a wristwatch. This apparatus is lightweight and worn under work clothes and so does not impede work. In the case of galley staff, the wristwatch was carried in a pocket within transmission distance because of hygiene restrictions. The sampling rate was set at every 5 s. The study procedure was as follows: volunteers reported to the experimenter and the purpose of the study was explained. A day was chosen for the collection of the HR data for each volunteer for a single 8-h shift that was representative of a normal day's work at sea. In the majority of cases, the monitors were distributed, donned and synchronized prior to the start of a daily shift at ~08:00 h. The monitors were returned post-shift and data downloaded.

Both absolute HR and age-corrected HR [age-predicted maximal HR ($APHR_{max}$) = HR/220 − age] were recorded [16], the latter to approximate task demands relative to theoretical physiological capacity.

At the conclusion of the shift, participants returned to a briefing room where they completed two questionnaires: the WAI [13] and the National Aeronautics and Space Administration Task Load Index (NASA-TLX) [14].

Anthropometric measurements were made in the ship's sickbay when the sea state allowed for accurate measurement, using the following equipment and procedures according to standardized guidelines [15]:

(i) Stature: volunteers removed their shoes before standing on a stadiometer (Invicta, Leicester, UK) with the feet together. Heels, buttocks and scapulae were in contact with the stadiometer and participants were instructed to look straight ahead, inhale steadily and the measurement taken to the nearest 0.1 cm.
(ii) Mass: volunteers were barefoot, in general working clothes, with all items removed from the pockets. Weight was measured to the nearest 0.1 kg (Seca, Hamburg, Germany).
(iii) Waist circumference (WC) measures to the nearest 0.1 cm were taken at the narrowest point of the torso using a Lufkin metal tape (Rabone Chesterman, UK).

Summary statistics for daily (8-h) HR were calculated (mean, median, maximum, minimum, etc.) and descriptive statistics for participant demographics, WAI and TLX scores were calculated. Next, a correlation matrix was generated using Pearson product-moment correlation coefficients. Finally, a stepwise linear regression analysis was conducted. WAI score was treated as the dependent variable and the HR data, TLX scores and demographic data were treated as predictors.

Results

Forty-one merchant seaman (54% of the crew) volunteered for the study. Of these, 38 were male. Table 1 summarizes participant demographics. The mean age of the sample (all males) was 45 years [standard deviation (SD) = 11 years], mean body mass index (BMI) 28 kg/m^2 (overweight) and mean WC 96 cm.

Table 1. Demographic and anthropometric characteristics (N = 41)

	Mean	SD	Range
Stature (cm)	178	10	1.68–1.97
Mass (kg)	87	12.4	63–119
BMI (kg/m^2)	27.5	3.3	20.1–34.2
WC (cm)	96	10.1	74–112
Age (years)	45	11.0	20–60

As can be seen from Figure 1, the age distribution was skewed, with a large proportion of participants aged >50 years.

The percentage of the participants at a healthy weight (using a BMI of ≤25) was <25%, which is in accord with the secular trend in obesity in the UK. Approximately 20% were obese (BMI ≥ 30) (Figure 2).

Table 2 below shows the mean responses for HR for the sample. The significant inter-subject variability is obvious, with large SD and range scores. This reflects the wide variety of job profiles and individual characteristics within the sample group. On average, over a typical work shift, the HRs are indicative of 'moderate work' [16]. Each individual's $APHR_{max}$ was calculated, and their mean and maximal working HRs then compared with this. Averaged results are shown in Table 3 below. Mean $APHR_{max}$ was 175/min, with a SD of 11. On average, the sample was working at 51% of their $APHR_{max}$ over the 8-h shift, with a range of 36–71%.

The NASA-TLX mean ratings of the demands fell towards the midpoint of the scales, indicative of moderate demands as a percentage of maximum: mental demands 65%, SD 21%; physical demands 55%, SD 25%; time pressure 65%, SD 22%; effort 65%, SD 21%; frustration 55%, SD 30% and satisfaction with daily performance 70%, SD 18%.

The mean WAI score of 43 (SD = 4, range of 28–49) is classified as 'good' [13]. The range was small and positively skewed, with the majority rating their work ability as 'good' or 'excellent'.

Few of the Pearson product–moment correlation coefficients were statistically significant. Age correlated negatively with WAI [$r = -0.33$, degrees of freedom (df) = 40, $P < 0.05$] but not with BMI, WC or any of the NASA-TLX scores. Older participants rated their work ability lower than younger ones. BMI correlated positively with WC, as might be expected ($r = 0.75$, df = 40, $P < 0.001$) and negatively with smoking ($r = -0.41$, df = 40, $P < 0.001$) but not with the HR data. Thus, participants with higher BMI tended to be non-smokers but did not demonstrate higher HRs at work.

The WAI classifies work as 'mental', 'physical' or 'physical and mental' and subjects fell into each of the three groups. One-way analyses of variance revealed there were no statistically significant differences between these three groups in age, BMI, BMI × age, participation in sport or mean/max HR.

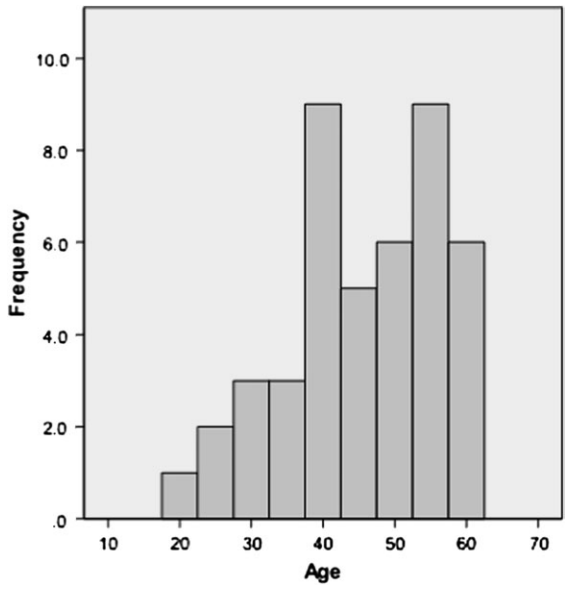

Figure 1. Age distribution of the participants.

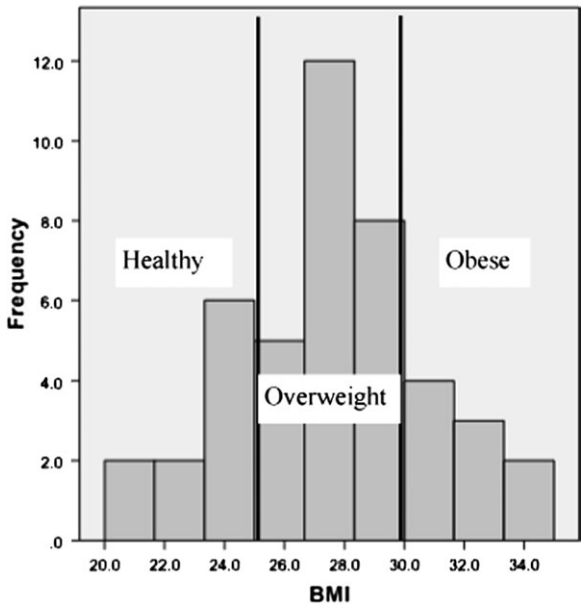

Figure 2. Distribution of BMI.

Table 2. Mean HR (beats/min) parameters over an 8-h shift ($N = 41$)

	Mean	SD	Range
Average	91	11	59–117
Median	84	12	55–118
Minimum	63	7	46–86
Maximum	143	20	85–200

Table 3. Mean HR (% max) normalized for age predicted maximum ($APHR_{max}$)

	Mean	SD	Range
Percentage of $APHR_{max}$ during sustained work (%)	51	6	36–71
Percentage of $APHR_{max}$ during maximal work (%)	82	11	52–124

A multiple linear regression was performed on the WAI data. A statistically significant model emerged ($F_{11,41} = 10.21, P < 0.05$), adjusted $R^2 = 0.19$ and $\beta = -0.46$. The interaction between BMI and age accounted for 19% of the variance in WAI. The only predictor of WAI was the interaction between BMI and age: older participants with higher BMI reported lower work ability.

Discussion

In our study of work ability in seafarers, we found that both BMI and age were inversely associated with work ability but the effect of high BMI on work ability was greater in older subjects. Work ability was rated as high and work demands were found to be moderate. Despite the heterogeneity of the sample, task demands (as measured by TLX scores and WAI classification) were distributed evenly across the age and BMI ranges. Therefore, these findings are not the result of older workers with high BMIs performing more physically demanding tasks and reporting lower ability as a consequence of their workload.

Continuous measurements of HR over a shift have been used to determine cardiovascular strain at work and thus to infer work severity [16,17]. Work demands were moderate overall, but with high peaks at different times of the day. Mean HRs ranged from 'light work' (59/min) through to 'heavy work' (117/min)

An individual tolerance level for maximum HR can be calculated (16 as $APHR_{max}$–20 beats/min). The tolerance level was found to be 155 beats/min (SD = 11 beats/min) on average and most participants performed below this level (mean = 143 beats/min, SD = 20 beats/min). However, 22% performed maximal exertions above this level. All of these individuals were members of either Engineering or Logistics and Supply and were therefore most likely to do physically demanding work in the heat of engine rooms or galleys, where they are exposed to radiant heat from generators and ovens.

One of the main limitations of this study is the relatively small sample size. No statistical power calculations were conducted prior to the study because of the limited number of potential subjects on board, but the effect sizes were known to be large—based on an expected decline in aerobic capacity of 20% from age 25 to 60 [13]. If accompanied by correspondingly higher HRs in older subjects, 40 subjects should have been sufficient to detect real differences. In a previous study of 322 seafarers working on the same kinds of ships [18], the mean age was 42 years (the average age of the seafaring workforce in the organization), slightly younger than the participants in the present study, but again, indicative of an ageing workforce. The TLX data indicate a moderately high level of satisfaction with work performance and all other scores were generally clustered around the mid-points of the rating scales. This is comparable to the earlier study [18], where work demands were rated similarly. Despite the small number, the 41 seafarers appeared representative of the workforce as a whole in terms of age and perceived work demands. One strength of the study is that HR data were recorded for 8 h during a normal work day at sea, giving an objective measure of work demands. Because all subjects were serving on a ship at sea for the duration of the experiment, the study environment was far more controlled than it would have been on land (subjects' dietary intakes and consumption of caffeine and alcohol were more constrained).

Most respondents rated their work ability as 'good' to 'excellent', despite the high proportion 'at risk' of health problems according to the guidelines of the National Institute of Clinical Excellence [19]. There are several possible reasons for this. Previous studies have shown a low prevalence of psychological strain [20] and a general absence of dissatisfaction with the psychosocial work environment in this group, which may reflect a benign work environment or stoicism in response (unwillingness to admit to problems or difficulties). Some have argued that work in isolated environments such as ships can have 'salutogenic' effects because employees are isolated from many of the stresses and strains of everyday life [21]. Seafarers in this organization go to sea for periods of 4 months, followed by 3 months' leave, allowing plenty of time for recovery. A survivor effect may also be in operation. Analysis of medical retirement data indicates that seafarers in this organization are four times more likely to be retired on medical grounds than Royal Navy personnel [22] and that medical retirement rate rises rapidly after age 40 (the mean age of Naval personnel is 32 years compared with 42 years in this population of seafarers). Thus, those whose work ability had declined most were more likely to have been medically retired and participants >45 in the present study are 'survivors'. Furthermore, all subjects possessed ENG-1 certificates as a requirement of work. It can be argued that this creates a 'healthy worker effect' since only those fit enough to pass the medical examination involved were permitted to work on the ship. Thus, the present findings may only be applicable to professions where this kind of occupational screening system is in place.

The fact that WAI scores were not influenced by task demands or HR is likely to be because much of the work was self-paced. The opportunity for self-pacing also explains why neither mean nor maximum HR correlated with BMI or WC. Figure 3 shows an example of a HR tracing taken over an 8-h shift. The individual is a 45-year-old male and the shift runs from 08:00 h (at time point 0 min) to 17:00 h (at time point 540 min). Figure 3 shows the high variability of HR responses over the shift (a range of >100 beats/min) as well as the tendency for HR peaks (during physical activity) to be interspersed with recovery periods. In this example, the

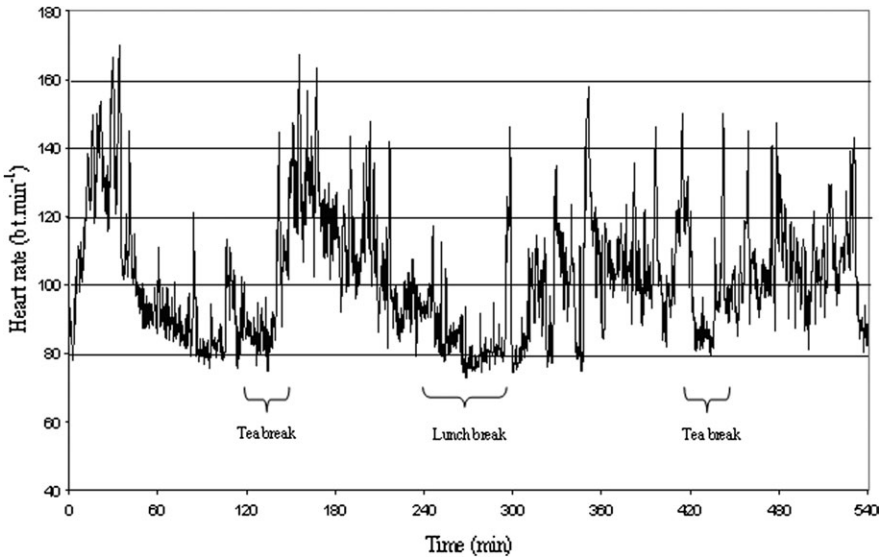

Figure 3. HR record from an individual over an 8-h shift (08:00–17:00 h).

subject's HR quickly returns to baseline at the end of a shift, indicating that a deficit has not accumulated. Thus, the seafarers in the present study were able to maintain their work ability by pacing themselves such that, for example, those with lower work ability did not necessarily have higher mean HRs.

Weight gain in adult men is normal up to the age of 50 years due to the presence of a small, positive energy balance. It tails-off at about the age of 50 years [23]. At the age of 45 years, the average body mass of men and women is ~20% higher than it was 20 years before. In the present study, there was no correlation between BMI and age, which is probably explained by this phenomenon; i.e. individuals >47 years (the mean age of the participants) had ceased to gain weight, while many of those under 47 years had already become overweight or obese. This is likely to be the case in other groups of workers where the mean age is ~45 years. The best predictor of WAI score was the interaction between BMI and age, in the expected direction. Older personnel with high BMI reported lower work ability. The validity of the regression model is limited by the small sample size. However, the model suggests that the effect of BMI on work ability is large and illustrative predictions can be made. Taking a WAI cut-off score of 43 to separate excellent work ability and good work ability, the model predicts that work ability will decline at 47 years of age in people with BMIs of ≥30 (the average age of the participants in this study). For those with BMIs of ≤25, the predicted age of the same decline in work ability is >56, a difference of 9 years. It is not however possible to propose an upper BMI/age limit for seafarers from these data; measurements on a larger sample under a wider range of environmental conditions would be needed. However, the present findings suggest that the two secular trends mentioned in the introduction should be considered together, rather than separately. The prevention of obesity in the younger adult population will lessen the future impact of ageing on work ability.

Key points

- The work demands of the merchant seafarers in this study were moderate overall, and most rated their work ability as 'good' or 'excellent'.
- None of the work demand measured objectively or estimated by self-report predicted work ability.
- The best predictor of work ability was the interaction between body mass index and age in the expected direction: the adverse effect of high body mass index was greater in older seafarers.

Conflicts of interest

None declared.

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