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Body size and ability to pass through a restricted space: Observations from 3D scanning of 210 male UK offshore workers

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A B S T R A C T

Offshore workers are subjected to a unique physical and cultural environment which has the ability to affect their size and shape. Because they are heavier than the UK adult population we hypothesized they would have larger torso dimensions which would adversely affect their ability to pass one another in a restricted space. A sample of 210 male offshore workers was selected across the full weight range, and measured using 3D body scanning for shape. Bideltoid breadth and maximum chest depth were extracted from the scans and compared with reference population data. In addition a size algorithm previously calculated on 44 individuals was applied to adjust for wearing a survival suit and re-breather device. Mean bideltoid breadth and chest depth was 51.4 cm and 27.9 cm in the offshore workers, compared with 49.7 cm and 25.4 cm respectively in the UK population as a whole. Considering the probability of two randomly selected people passing within a restricted space of 100 cm and 80 cm, offshore workers are 28% and 34% less likely to pass face to face and face to side respectively, as compared with UK adults, an effect which is exacerbated when wearing personal protective equipment.

1. Introduction

Body size is an important determinant of physical work capability and of space requirements for a range of working environments. Greater space provision may be desirable in order for optimal approaches to physical tasks, and also to provide a sense of ambient space, which may make employees safer and feel more comfortable as they work. A founding design principle of ergonomics is the capacity to accommodate human variability in body size. In order to achieve this aim, the designer will commonly consider the dimensional range in a particular anthropometric measurement (e.g. stature) in the sample in question, and make the design compatible with most individuals. However, if an alternative dimension is selected (e.g. sitting height), some of those previously accommodated may find themselves disaccommodated depending what the spatial constraints are. This is because different body dimensions are only moderately correlated with one another within a sample, a well recognised academic finding as the lack of 'geometric similarity' for different sized individuals (Nevill et al., 2004). Unsurprisingly, larger individuals in any occupational setting require more space than smaller people in order to move and work, and common practice is to design to the 95th centile of male size. However, global variability in size is considerable – with mean height of different adult groups has estimated to be as much as 40 cm (Pheasant, 1986). In addition, individuals from different ethnicities may have different limb proportions as well as absolute size (Holliday and Ruff, 2001), and these factors in addition to the poor correlation between some dimensional measurements can make it difficult to estimate exact size and space requirements. For example shoulder breadth based on the male 95th %ile bideltoid breadth, which is frequently used as a design standard for space allocation is reported to vary between 40.0 cm in Sri Lankans and 56.9 cm in Americans (Peebles and Norris, 1998). In addition to

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nationality, different professions recruit individuals suited to the tasks which favour individuals of different size. While most noticeable amongst elite sports athletes such as basketball players and racing jockeys, increased size, relative to a general population, has been reported in firefighters (Hsaio et al., 2014) and truck drivers (Guan and Hsaio, 2012).

The situation is made more complex when a change in absolute body size is likely within the lifespan of a designed space. This phenomenon is readily apparent when considering historic buildings, ships or furniture, which appear too small when viewed today. In such cases where secular trend in body size, the principle of *design for sustainability* becomes paramount (Nadadur and Parkinson, 2013) in order to mitigate the risks of the ill-effects for workers, which need to consider dynamic as well as static spatial needs. Urban planning uses evaluative tools described in Willis et al. (2004) in designed spaces which relate person-flow to a range of factors, including effective corridor width, group size, crowd density etc. They also noted previous work on ‘buffer zones’ between people and buildings, street furniture and other individuals. In theory, individuals would change their movement behaviour to avoid infringing this zone, preserving a clearance distance which would differ according to the type of object. However the researchers described the difficulty in substantiating and standardising observed variable clearance distances due to differences in experimental design.

In an offshore installation, designs may be more functional than aesthetic. Such environments may have narrow corridors, steep stairwells, exposed walkways and a range of trip and snag hazards more similar to a maritime than an urban environment. The offshore worker necessarily confronts a range of hazards, which are mitigated by strictly enforced procedures – which relate to personal protective equipment, movement around the platform and the response in an emergency. Offshore installations have been in the North Sea since the early 1970s and undergo cycles of inspection and refurbishment, and decisions to provide space beyond the minimum requirements set out by governing legislation need to be balanced against the extra cost incurred. However, to date, consideration of space requirements has not had the benefit of detailed knowledge of shape of actual workers themselves, but rather established databases or design standards which may not represent the workforce accurately.

Offshore workers are subjected to a range of influences which affect their size, with the result that they differ from the host populations from which are recruited. In some circumstances, occupational work itself can provide a training stimulus – especially for the upper body – and differences in physique could be attributed to the training effect of the physical work done. Increasing mechanisation in the latter half of the 20th century, has undeniably diminished the ‘training influence’ of manual work across the population as a whole, however, a range of strenuous roles persist today within the offshore workforce. Strenuous physical work is likely to add muscle, particularly in the upper body and arms, which has the capacity to enlarge the physique considerably. Even amongst workers whose occupational work is not sufficiently strenuous to constitute a significant training stimulus, there may be a culture of strength training in a recreational setting, which may have an equivalent or even greater effect.

In addition to occupational exercise, the global pandemic of obesity has profoundly altered the physiques of working populations. While the secular trend for increasing stature has slowed since the 1980s to near zero levels, the trend for obesity prevalence and incidence is accelerating rapidly. Defined as an accumulation of excessive body fat, obesity can enlarge all parts of the body, affecting all body dimensions, perhaps with exception of stature itself. Morbid obesity particularly affects the upper body, adding to the volume, breadth and depth of the torso.

In the 1980s, UK offshore workers were observed to be heavier than age-equivalent by between UK reference males by between 1.5 and 4.6% and had higher estimated body fat than an equivalent aged onshore sample (Light and Gibson, 1986). The average UK offshore worker body weight between 1985 and 2009 rose by 19% to 90.9 kg, approximately 9% heavier than the UK male adult average. These findings are consistent with the phenomenon of self-selection of larger individuals, but scrutiny across age groups and years of service would be required to confirm how strong such an effect might be. In addition, there may be a cultural effect whereby food intake and, for some individuals, regular strength training may assume heightened significance. Previous work defined the space footprint via key dimensions (Ledingham and Stewart, 2013), and irrespective of which underlying cause may be more probable, we hypothesised that the UK offshore workforce would have greater bideltoid breadth and chest depth than the UK average, and that for individuals with an enlarged space footprint, egress capability where lateral space is restricted would be correspondingly reduced. As a result, this study aimed to quantify the pertinent anatomical dimensions in offshore workers relative to the general population, and to assess the probability that two randomly-selected individuals are able to pass one another in a restricted space.

2. Methods

This study was part of a larger study of the size and shape of UK offshore workers involving 44 university students and staff together with 667 offshore workers. The larger study was in two phases. Phase One involved the university sample and a total of 26 scans for protocol optimisation and scanner calibration, together with the construction of a size-adjustment for moving between the form-fitting and survival suit clothing assemblages. Phase two involved quota sampling across seven weight categories of the male offshore workforce designed to match the weight profile from 2009 data supplied by “Vantage POB” (the personnel and certification tracking system for oil and gas operators). The present study utilises summary data from phase one, and data from 210 offshore workers from phase two, equally representative of all weight categories. Participants were ‘core crew’ whose job entailed 50% or more time being spent offshore, and were recruited via posters and leaflets circulated via Oil & Gas UK and key stakeholders. Measurements were made at various locations likely to ensure a throughput of volunteers, including one offshore installation, heliports, safety training providers, occupational health providers' and office premises, primarily in Aberdeen, but also in Norfolk which services the Southern North Sea sector. For this each volunteer underwent 3D body scanning using an Artec L scanner (Artec Group, Luxembourg) in a standing position wearing form fitting shorts, and again with a full survival suit and lifejacket over their regular indoor clothing as depicted in Fig. 1.

Scans were processed using Artec studio 9 software (Artec Group, Luxembourg). This involved global registration, fusion and hole-filling processes, which rendered the scans into 3D objects suitable for measurement extraction. Scans were oriented using a positioning tool which standardised the presentation in 3D xyz space, with the x axis anterior-posterior, y axis lateral and z axis vertical, which enabled co-ordinates to be calculated for all placed landmarks.

Measurements were extracted manually after placing landmarks on the most lateral aspect of convex surface of the deltoid to create a section, and in addition the most anterior point on the thorax when viewed in the sagittal plane. Bideltoid breadth was