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Variability in body size and shape of UK offshore workers: A cluster analysis approach

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ABSTRACT

Male UK offshore workers have enlarged dimensions compared with UK norms and knowledge of specific sizes and shapes typifying their physiques will assist a range of functions related to health and ergonomics. A representative sample of the UK offshore workforce (n = 588) underwent 3D photonic scanning, from which 19 extracted dimensional measures were used in k-means cluster analysis to characterise physique groups. Of the 11 resulting clusters four somatotype groups were expressed: one cluster was muscular and lean, four had greater muscularity than adiposity, three had equal adiposity and muscularity and three had greater adiposity than muscularity. Some clusters appeared constitutionally similar to others, differing only in absolute size. These cluster centroids represent an evidence-base for future designs in apparel and other applications where body size and proportions affect functional performance. They also constitute phenotypic evidence providing insight into the 'offshore culture' which may underpin the enlarged dimensions of offshore workers.

1. Introduction

1.1. Body size and occupational groups

Variability in absolute and relative body size characterises all human populations. Amongst workers in specific industries such as firefighters and police, it is well recognised that individuals may differ from those of a host population, for instance by being taller and heavier (Hsiao et al., 2002). Such a difference has consequences for a range of factors including space provision, visibility of signage and optimising functionality and cost of equipment. Some body size differences between professional groups and the host population may exist as a consequence of recruitment, for example resulting from a height stipulation. Others may become increasingly prevalent with years of service, as a result of the nature and culture of the work environment, and its scope for developing specific muscle mass, or affecting energy balance. Over time, especially with legislative change within professions, the demographics of the occupational group itself may alter. All these factors coexist to determine the observable body size in a professional group at any one time, and have the potential to change it markedly over time. As a result, representative surveys of body dimensions within professional groups for vocationally-relevant sizing for clothing (Laing et al., 1999) and personal protective equipment (Hsiao et al., 2015) are appropriate, but may require regular updating in order to remain valid.

1.2. Physique classification using somatotype

Genetic and environmental influences have the potential to render bodily physique almost infinitely variable. Much of this variation is usefully described using the somatotype approach originally proposed by Sheldon et al. (1940), and used subsequently either by the rating of photographs (Carter and Heath, 1990), or by anthropometric measurements (Heath and Carter, 1967). These yields a size-independent tri-axial physique rating which focuses on body proportions in terms of adiposity (endomorphy), musculoskeletal development (mesomorphy) and linearity or relative weight (ectomorphy). In addition to phenotypes which exemplify these singular traits, more typically, a person's physique will reflect a combination of two or all three. While somatotyping might attract criticism for oversimplifying the complexity of body shape, any assessment of physique must balance accuracy with time taken to acquire measurements. While taking much longer than stature and mass assessments for body mass index (BMI) calculation,

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somatotype describes shape in a tissue specific manner which overcomes most of the inadequacies of BMI in failing to describe changes associated with ageing (Wells et al., 2008a), or inter-country or inter ethnic differences where centralisation of abdominal fat is pertinent (Wells et al., 2008b). Somatotyping is most commonly applied to child growth or athletes from different sports as a tool for tracking change or sporting talent identification. The technique has been also used in body image studies to identify desirable physiques (Stewart et al., 2014) but to date no somatotype studies of professional groups has been performed. 3D body scanning has augmented traditional anthropometry for describing physique by enabling cross sectional areas and segmental volumes to be extracted. This approach was successfully applied by Olds et al. (2013) using 29 measurements in a purposive sample of 305 individuals as part of a cluster analysis of military recruits. The result was that for both male and female groups, three physique clusters were selected, differing in the three primary physique classifications within somatotyping. However, as useful as somatotyping is, there are limitations to its size-independent schema in representing global physique variation, because larger individuals are not simply scaled up versions of smaller ones. In a sample of 478 athletes and non-exercising controls, taller individuals had greater relative leg length than their shorter counterparts, heavier individuals had disproportionately greater girths whereas differences in muscle mass and distribution related to the type (power, endurance, strength etc.) of sporting activity undertaken (Nevill et al., 2004). This suggest that cognisance needs to be taken of absolute as well as relative measures.

1.3. Survival suit design

Designers of tools, clothing and transportation systems require information of absolute as well as relative size of populations in order to ensure their products are fit-for-purpose. Their challenge frequently includes balancing the available size/space with the cost of a range of sizing options. Although bespoke design may be an unnecessary luxury for most types of work and protective clothing, the design of survival suits might be an exception. Helicopter aviators worldwide face a small but significant risk of unintentional immersion in water which can result in irreversible cooling and lethal hypothermia (Tikuisis, 1999). In the UK continental shelf, 62,000 offshore workers are transported to installations by helicopter, wearing survival suits of a specified type, and clothing assemblages commensurate with the season. Each of the 11 commonly-worn survival suit sizes which aims to maximize the survival of the individual in the event of cold water immersion, but also optimise the dry ‘wearability’ and comfort for standing, walking and sitting. The wide variability of body shape pertaining to each size inevitably challenges designers. While the main fabric may stretch, a range of other features including zips, vents, pockets, reflective panels etc. are all required for the specification, and all impose constraints on the design. Personal fit preference is likely to vary between individuals, especially for those whose measurements are atypical for their overall body size. A tight-fitting suit will be better for cold water survival, while a looser fitting suit with larger air gaps may be more comfortable while worn dry, but more prone to water ingress which is likely to impair its performance by its extent and location (Tipton, 1997), and have higher buoyancy which is noted to hamper egress underwater (Brooks et al., 2001). While helicopter pilots may have made-to-measure survival suits, the vast majority of the UK offshore workforce will wear one of the established sizes of suit, broadly categorised by the person’s stature and chest girth.

Whether for survival suits, or other work wear or personal protective equipment, until recently, designers had no accurate data on the size of UK offshore workers to work from, relying either on historic data, assumptions and iteration from usage data. With clear evidence that the workforce is not typical of UK males, and is now anatomically larger than before (Stewart et al., 2015), the design process now has an unprecedented potential to ‘fit the design to the human’, rather than ‘fit the human to the design’, because of the much larger range of size and dimensional parameters now known in this vocational group. The aim of this study was therefore to characterise shape variability amongst UK offshore workers, both according to weight category, and also in terms of a key number of clusters based on natural size groupings within the workforce.

2. Methods

2.1. Sample

Participants in this study are from the Size and Shape of Offshore Workers (SASOW) study (Ledingham et al., 2015) and recruited as a representative sample of the male UK offshore workforce aged 40.6 ± 10.7 y (mean ± SD). They were selected by quota sampling across seven weight categories ($n = 588$; 84 in each), which matched the most recently available data on body weight of the entire workforce. These categories were as follows in kg: <76.4; 76.5–82.4; 82.5–87.4; 87.5–91.4; 91.5–97.4; 97.5–104.4; >104.5. The sample size was selected in order to be equivalent or larger than the previous study of Light and Dingwall (1985) and to constrain the 95% confidence interval for the true workforce weight to 1.1 kg – a value which can be expected with the diurnal weight fluctuation. The sample selected individuals across these weight categories, matched almost perfectly to the most reliable reference weight for the offshore workforce, collected in 2009 [Chi-square value = 11.7; 11 df, $P = 0.613$].

2.2. Measurements

Participants were professionals ‘core crew’ (who worked at least 50% time offshore) for whom all required data were available, recruited via a range of media from Oil & Gas UK and key stakeholders. Stature, mass and scan measurements took about 20 min and were acquired mostly at Aberdeen heliports but also in Norfolk which services the Southern North Sea sector. 3D body scans using an Artec L scanner (Artec Group, Luxembourg) wearing form-fitting shorts, and also with a full survival suit and lifejacket over their regular indoor clothing, standing erect, and also with arms and legs abducted, and also sitting, as described previously (Stewart et al., 2015). This involved arms being supported by orthopaedic walking poles, which were subsequently erased from the scanned images. Appropriate suit sizing was allocated according to manufacturer’s recommendations. Body mass index was calculated as a crude index to identify morphological similarities and differences between suit size groups.

Scans were processed and positioned using Artec studio 9 software (Artec Group, Luxembourg), prior to extracting 26 dimensional measurements which relied on visually identifiable landmark locations placed digitally on the scan surface, such as the axilla, nipple, naval and anterior knee, together with the most anterior, posterior or lateral aspects of convex surfaces. The measurements included linear distances, girths and segmental volumes, which are fully described in Ledingham et al. (2015) with reproducibility established using blinded re-analysis of 28 individuals. Of the measurements, 19 raw or derived measures were selected for analysis in the present study.