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**Shape change and obesity prevalence among male UK offshore workers after 30 years: new insight from a 3D scanning study**

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## **Abstract**

**OBJECTIVES:** In 1984, male UK offshore workers had greater overweight and obesity prevalence, and fat content than the general population. Since then, body mass has increased by 19%, but without accompanying anthropometric measures, their size increase, current obesity and fatness prevalence remain unknown. This study therefore aimed to acquire contemporary anthropometric data, profile changes since the original survey, and assess current obesity prevalence in the male offshore workforce.

**METHODS:** 588 men, recruited via quota sampling to match the workforce weight profile, underwent stature, mass and 3D photonic scanning measurements from which anatomical girths were extracted, enabling computation of body mass index (BMI), total fat and visceral adipose tissue (VAT).

**RESULTS:** On average, UK male offshore workers are now 8.1 y older, 3.1 cm taller, 13.9 kg heavier, and have greater girths than in 1984, which are >97% attributable to increased weight, and <3% to age difference. Mean BMI increased significantly from 24.9 to 28.1 kg.m<sup>-2</sup> and of the contemporary sample, 18% have healthy weight, 52% are overweight and 30% obese, representing an increase in overweight and obesity prevalence by 6% and 24% respectively. Waist cut-offs identify 39% of the contemporary sample as healthy, 27% at increased health risk, and 34% at high risk.

**CONCLUSIONS:** UK offshore workers today have higher BMI than Scottish men, although some muscular individuals may be misclassified by BMI. Girth data, particularly at the waist, where dimensional increase was greatest, together with predictions of total and visceral fatness, suggest less favorable health status in others.

## **Introduction**

Exploration and production has required offshore workers to service the installations in the UK continental shelf for over four decades. Over this period, the size and demographic of the workers have undergone considerable expansion and change. In 2014, over 64000 personnel travelled offshore, and of these, 84% were British, 45% were 'core crew' (working at least 100 days offshore) and 3.6% were female (Oil & Gas UK 2015). The era leading to this present profile also witnessed the global pandemic of obesity progressively afflicting the western world, whereby individuals respond normally to the abnormal and obesogenic environment they inhabit (Swinburn et al 2011). With its severe consequences in terms of disease risk, quality of life, and the healthcare burden, the offshore workforce has not escaped its effect. Evidence from an anthropometric survey which randomly sampled 419 male offshore workers during 1984 suggested offshore workers were already heavier and fatter than their onshore counterparts (Light and Gibson 1986), at a time when the prevalence of obesity was about a third of that today. Since then, weight of offshore workers has increased by an average of 19%, with increased body size affecting passing ability in restricted space (Stewart et al. 2015) and helicopter window egress (Stewart et al. 2016). A recent study of the workforce identified a 'super-centralization' of body shape in anatomical regions associated with fat accumulation shape (Stewart et al. in press) are suggestive of adverse health risk.

Recent data from the Scottish Health Survey revealed that while the rate of incidence of obesity was slowing, Scotland's obesity figures remain amongst the worst of any of the Organisation for Economic Co-operation and Development nations (The Scottish Government 2015). In men 16 – 64 years, 69% are either overweight or obese, while only 31% had normal weight or were underweight. Equivalent English data are little better, indicating 67% for male adults to be overweight or obese (National Obesity Observatory, Public Health England 2014). Comparison of offshore workers with equivalent Scottish data may be justified because more of them reside in

Scottish hubs than elsewhere in the UK, even though the marginally poorer health in Scotland than England may make the result of the comparison somewhat conservative.

Stature, mass and calculated body mass index determined by occupational health providers at offshore medicals of all individuals travelling offshore is bound by confidentiality agreements to employers and employees, and not currently in the public domain. Routine weights of the passengers at heliports are unaccompanied by stature measurements, precluding any inference regarding relative weight of the offshore population using body mass index. Thus despite prior evidence of increased body weight and fat levels among offshore workers, relative to the general population (Light and Gibson 1986), the prevalence of overweight and obesity amongst the current offshore population remains unknown.

The recent size and shape of offshore workers (SASOW) survey (Ledingham et al. 2015) recruited a representative weight sample of the entire workforce, and extracted a range of anthropometric measurements in common with the 1984 survey, including neck, chest, waist hip and wrist girths. Therefore, the purpose of this study was to use this new data 1) to profile dimensional difference in girths since the original anthropometric survey; 2) to assess the current prevalence of overweight and obesity within the workforce; and 3) to make comparison with available national data to assess whether a weight or size discrepancy persists in this occupational group which might have implications for health risk.

## **Methods**

### *Participants*

A sample of 588 males aged  $40.6 \pm 10.7$  y (mean  $\pm$  SD) was selected via weight category quota sampling to represent the latest available industry surveillance data on UK offshore workforce

weight (Aker Solutions, 2010). This was achieved via identifying in advance weight category ranges which required to be sampled to ensure the weight profile of the entire workforce was accurately represented. The weight categories (in kg) were as follows:  $\leq 76.4$ ; 76.5-82.4; 82.5-87.4; 87.5-91.4; 91.5-97.4; 97.5-104.4;  $\geq 104.5$ , and 84 were selected for each, in order to have 95% confidence that the true weight was within 1.1 kg, a value which could be anticipated with diurnal fluctuation in individuals. The study was an observational cross-sectional design, and was conducted according to the guidelines laid down in the Declaration of Helsinki, and all procedures were approved by the Robert Gordon University ethical review panel. All participants were advised of the study via industry communications to member organisations (media and leaflets) and all provided written consent prior to participation.

Participants comprised 'core crew', and mostly measured at Aberdeen heliports, but also in industry offices and offshore, during 2013 and 2014. Stature and mass were acquired using a portable stadiometer (model 213), and digital scale (model 875) respectively (Seca, Hamburg, Germany). In addition participants underwent 3D body scanning using an Artec L scanner (Artec Group, Luxembourg) as part of a larger study described previously (Ledingham et al. 2015) which included a standing scan wearing form-fitting shorts, and with arms and legs abducted. Body mass index (BMI) was calculated by dividing scale mass by stature in meters squared in order to identify normal, overweight and obese groups. After processing the scans, girths were extracted using Artec studio 9 software (Artec Group, Luxembourg). This relied on visually identifiable and verifiable landmark locations placed digitally on the scan surface, representing the minima (neck, waist and wrist) maxima (hip) or recognizable anatomical landmarks (e.g. nipple for chest girth), corresponding with those of the original anthropometric survey (Light and Dingwall 1985). Acquired stature, mass, waist and hip girths, together with age were used to predict total and

visceral fatness using a new geometric model based on body roundness validated against magnetic resonance imaging (Thomas et al. 2013) with supplementary information which includes an on-line calculator, available at <https://www.pbrc.edu/research-and-faculty/calculators/body-roundness/>).

Categories were created for age groups  $\leq 30$ ; 31-40; 41-50 and  $\geq 51$  y, obesity, by calculated BMI (in  $\text{kg.m}^{-2}$ ; normal  $\leq 24.9$ ; overweight 25.0-29.9; obese  $\leq 30.0$ ), and waist (in cm;  $<94$ ; 94-102;  $>102$ ) in line with current recommendations of the Scottish Intercollegiate Guidelines Network for Obesity (2012). Comparative summary data were obtained from the original anthropometric survey reports Light and Gibson 1986; Light and Dingwall 1985) and Scottish Health Survey data (The Scottish Government 2009; 2015).

### *Statistical methods*

Reproducibility of extracted measurements was established using blinded re-analysis of 28 individuals to calculate technical error of measurement. Absolute girth differences between the 1984 and the current data were adjusted using algorithms created via ln mass and age terms from the 2014 offshore workers survey. Chi squared, univariate analysis of variance and Least Significant Difference post hoc tests were used to compare study participant groups with normative data. SPSS Version 21.0 (Armonk, NY: IBM Corp) was used for all statistical tests.

### **Results**

The representativeness of the selected sample of the wider male workforce for weight was confirmed using a Chi squared test (Chi-square value = 11.7; 11 df,  $P=0.613$ ). The physical characteristics of participants are summarized in table 1. In addition the mean age of the sample (40.6 y) closely matched the mean age of the 2014 workforce (40.8 y).

\*\*\* table 1 near here \*\*\*

Technical error of measurement for extracted girths at minimum waist, umbilical waist and hip were 0.60, 0.39 and 0.36% respectively, compared favorably with experienced anthropometrists' manual measurements.

Neck girth, chest girth, waist girth, hip girth and wrist girth were the five extracted measurements which allow for direct comparison between the current study and the original anthropometric survey conducted by Light and Dingwall (1985) and the comparison of mean values is illustrated in figure 1.

\*\*\* Figure 1 near here \*\*\*

The 2014 raw girth data means were greater by an average of 13.5%, varying between 9.9% at the wrist to 16.3% at the waist. However, the differences were not uniform across the percentile range. The average increase across the five girths at the 1<sup>st</sup> percentile was 8.9% greater, while the 99<sup>th</sup> percentile was 18.3% greater. These averaged percentile differences in measurement values are illustrated in figure 2.

\*\*\* Figure 2 near here \*\*\*

Using the algorithm model based on the relationship of ln mass with girths, the observed size difference attributable to the age difference between the 1984 sample and the current sample explained 2.5% of waist and 1.7% of neck girth increases, and was < 1% for the other girths, with the remainder attributable to increased body mass.



Waist girth and BMI were considered in their informant role for describing disease risk (SIGN 2010; WHO 2000) (no offshore workers were underweight according to these definitions). This analysis highlights the interaction of BMI with waist to identify risk status, and provides a visual indication of prevalence in each category. This is illustrated in figure 3 (note that two categories have no occurrences: waist <94 cm and BMI  $\geq 30 \text{ kg.m}^{-2}$ ; waist >102 cm and BMI <25  $\text{kg.m}^{-2}$ ) while a further two categories (waist <94 cm and BMI 25–29.9  $\text{kg.m}^{-2}$ ; waist 94-101.9 cm and BMI <25  $\text{kg.m}^{-2}$ ) are not specified as increased risk, despite the guideline stating “Increased waist circumference can also be a marker for increased risk even in persons of normal weight” (SIGN 2010).

\*\*\* Figure 3 near here \*\*\*

Comparison of UK offshore workers with Scottish Health Survey data for BMI revealed offshore workers to have greater values ( $P=0.021$ ) with no interaction of age and group, as illustrated in figure 4. The prevalence of overweight or obesity is illustrated in figure 5.

\*\*\* Figures 4 and 5 near here \*\*\*

Estimates of the total % fat and % visceral fat of offshore workers in 1984 and 2014 are contained in figure 6.

\*\*\* Figure 6 near here \*\*\*

## Discussion

Offshore workers in 2014 are taller, heavier and have greater girth than in 1984. Greater stature (178.7 v 175.6 cm) explains very little of the weight gain since 1984 (1.6 kg of the 13.9 kg increase). The greater mean age of the contemporary sample explains very little of its size increase, the vast bulk of which can be attributable to weight gain. The mean BMI increase over three decades is broadly reflective of English speaking nations across a similar timespan (NCD Risk Factor Collaboration (2016)). The UK male offshore workforce appears to have greater BMI than the general Scottish population, and displays a higher prevalence of overweight and obesity across until the age 55.

While BMI adjusts for stature in comparing the relative weight of groups, its utility in describing fatness according to standard definitions of overweight and obesity (WHO 2000) is not without its critics. Firstly, it conflates relative weight, with an excess of fat, and this may not be justified. In a large sample of Canadian adults BMI correlated better with anthropometrics for muscle mass and skeletal frame size than adiposity, leading the study's authors to conclude that in this respect BMI was "more misleading than informative" (Ross et al. 1988). Secondly, prevalence and incidence data for overweight and obesity essentially attribute a scale variable to a dichotomous outcome. As a result of a modest increase in relative weight, prevalence can be profoundly affected if it transcends an arbitrary threshold, which, in the view of some, overstates the case for obesity's epidemic status (Friedman 2009). Support for this stance is seen by observing the greater BMI of offshore workers yet the lesser prevalence of overweight / obesity in the 55-66 y age group (figures 4 and 5). The prevalence of overweight or obesity across the 2014 offshore sample is 82% using BMI, while using waist girth, the presence of elevated or high risk is 61%. The difference in these values is worthy of consideration, and begs the question of whether overweight prevalence in the offshore sample might be the result of muscle development, and not excess fat. A total of 125 out of 479 individuals (26%) with excess weight have waist girth within the healthy zone,

suggesting excess development of bodily tissue is not centralized to the abdominal region. This would be consistent with typically muscular physiques which are the product of occupational activity or volitional strength training which is commonplace on offshore installations. While this study did not formally assess this practice, the 3D scans have the capability to depict muscularity with clarity, revealing that many participants were indeed strength-trained, and likely to be heavy, despite being apparently lean.

Evidence from waist girth suggests that while some offshore workers categorized as overweight have a healthy waist size, the majority (74%) of overweight or obese individuals have an enlarged waist, representing a health risk. Most concerning are the 179 individuals (30% of the total sample) whose waist exceeded 102 cm, which has been reported to be close to the 95<sup>th</sup> centile for healthy individuals in the USA (Flegal 2007). Although their study was designed to match a slightly different demographic population, it showed the waist circumference to be normally distributed, indicating a potential for generalization. Furthermore, their protocol for measuring waist 'just above the iliac crest' as compared with our minimum waist values (between the iliac crest and the 10<sup>th</sup> rib) , means that our measurements are conservative (i.e. may underestimate prevalence of enlarged waist) relative to theirs, and that comparatively few UK offshore workers with a minimum waist > 102 cm are likely to be healthy.

The difference in mean waist for offshore workers between 1984 and 2014 equates to 0.46 cm.y<sup>-1</sup> while that reported for Scottish men aged 16 – 64 y between 1995 and 2013 is 0.33 cm.y<sup>-1</sup> (The Scottish Government 2014). If the latter were extrapolated in a linear fashion back to 1984, it would suggest Scottish men's waists were a mean of 2.5 cm larger than those of offshore workers. If this were the case in reality, then two important implications must be considered. First, the estimates of relative fatness of the offshore workforce compared with the population in the 1980s

may not be valid. Greater adiposity would be expected to be associated with a larger waist, because even without increased centralization of fat patterning in fatter individuals, the suprailiac skinfold site, which forms part of the predicted fat calculation is located very close to the anatomical waist. In addition, the use of skinfolds to calculate adiposity requires considerable skill, and despite using a similar prediction formula for skinfold-derived fat (Durnin and Womersley 1974), without equivalent training and standardization of the measuring instrument and skinfold procedure which became adopted early in the 21<sup>st</sup> century (Marfell-Jones et al. 2006), earlier studies which lacked such inter-laboratory quality control could foreseeably have produced different results purely as a result of technique and methodological differences. Furthermore, the four-site method of skinfold acquisition uses peripheral and torso sites summed as a total, and does not give any indication of the relative centralization of the fat distribution. Given that age and level of adiposity both have a centralizing effect on fat patterning (Stewart 2003), the conclusion that in the 1980s offshore workers were *fatter* could conceivably follow from a high peripheral fatness, but a lesser torso fatness which did not appreciably enlarge the waist. Secondly, by contrast, if the offshore workers really were *leaner* than equivalent Scottish men in 1984, then as a subgroup they have adapted to increase adiposity, matching and subsequently exceeding that of the reference population.

While the obesity epidemic has afflicted all industries, quite why its effect appears so pronounced in offshore workers is far from clear. There are several speculative possibilities which might explain part of this effect, relating to energy balance. It is estimated that in the 1960s the 'energy balance flipping point' was attained in the USA, whereby a decreased food energy supply "move less, stay lean" phase was replaced by an "eat more, gain weight" phase (Swinburn et al. 2011). Increasing food access, facilitated by mass food preparation and availability, together with behavioral and cultural aspects of food were among the observed environmental moderators of

this effect. In this respect, the culture of offshore working, with its plentiful energy-dense, palatable food available at all hours of the day, combined with diminishing physical outlay as a result of increasing mechanization and inactive entertainment choices may be relevant.

Behavioral aspects of weight gain were already being attributed to the social function of meal times offshore and their capability for encouraging overeating in the 1980s (Swinburn et al. 2011). It is therefore possible that persistent unrestrained eating behaviors in light of a low or moderate energy requirement could explain the excess body size in offshore workers. Furthermore, the average length of service offshore of the current study sample is more than twice that of the original sample of Light and Dingwall in 1985 ( $P < 0.001$ ), meaning the effect of an adverse energy imbalance would have had longer to accumulate in our sample, with more accentuated results.

Selectivity in recruitment is a further explanation which is difficult to rule out. It is possible that larger workers are attracted to work in the offshore industry. Evidence in support of this reveals US workers in protection services (firefighters, police and guards) were both taller and heavier than an average across a range of professions (Hsaio et al. 2002). However, when compared with the general US population, firefighters were no taller but significantly heavier, and had larger upper body builds. In UK offshore workers, in addition to being heavier, there is evidence that they are taller in all age groups in comparison to Scottish norms (The Scottish Government 2014) ( $P < 0.05$ , two-tailed). Beyond these morphological factors, it has been further suggested that UK offshore workers may be less risk-averse than other professional groups, by nature of the type of work activity, and the transportation to installations by helicopter. Support for this view is for the higher prevalence of smoking in the offshore population than amongst UK men as a whole (32 v 25 %) (Mearns and Hope 2005; Goddard 2006). If true, this might predispose individuals to be less

receptive to health messages relating to their body size or lifestyle choices than their onshore counterparts.

Despite conflicting evidence regarding whether UK male offshore workers were fatter than the comparable male population in the 1980s, today, the relative weight and shape of offshore workers compares unfavorably with those of the Scottish or UK males. Based on morphology and predicted fatness, the majority of offshore workers have elevated health risk, relative to those of normal weight and waist girth, the magnitude of which is considerably greater than in the 1980s. A conspiracy of factors renders the offshore work setting an obesogenic environment, which include diminished occupational activity, highly palatable and abundant food, and immersion in a culture for prolonged periods which may do little to encourage healthy lifestyle choices. Further research is essential to identify susceptible individuals in relation to the interaction of behavioral choice, corporate culture and the efficacy and acceptability of health-enhancing initiatives. It is also likely that in a global industry dominated by multinational operators, these observations will prevail beyond the UK to all parts of the globe where this sector is active. It cannot be ruled out that other professions may experience similar findings, particularly those which may isolate individuals for periods of time in a culture which elevates the importance attached to eating. If so, this should signal a more concerted effort throughout occupational health settings and beyond to champion health initiatives across a range of professions.

#### Conflict of Interest

The authors declare no conflict of interest.

#### Author Contributions

GF and AS obtained the grant funding for the study, RL undertook the scanning of the workforce, and AN and HW provided statistical advice for analyzing the data findings and interpretation. AS led the write up of the manuscript, with contributions from all co-authors.

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Table 1. Physical characteristics of participants

	Mean	SD	min	max
Age (y)	40.6	10.7	22.0	66.0
Stature (cm)	178.7	6.8	161.7	201.1
Mass (kg)	90.5	13.7	50.9	149.0
Waist (cm)	97.9	10.6	68.4	140.5
Body Mass Index (kg.m <sup>-2</sup> )	28.3	4.0	18.6	45.3
Years offshore	10.9	4.3	0.1	40.0

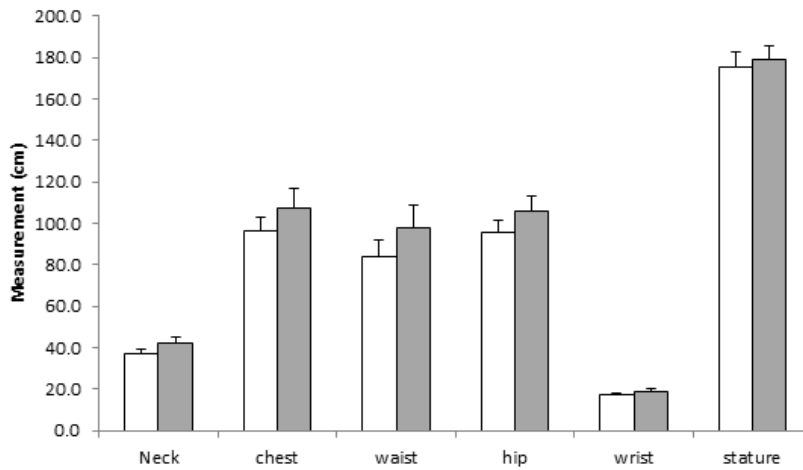


Figure 1 Mean girths and stature in UK offshore workers in 1984 (white) and 2014 (grey) (P<0.0001 for all comparisons)

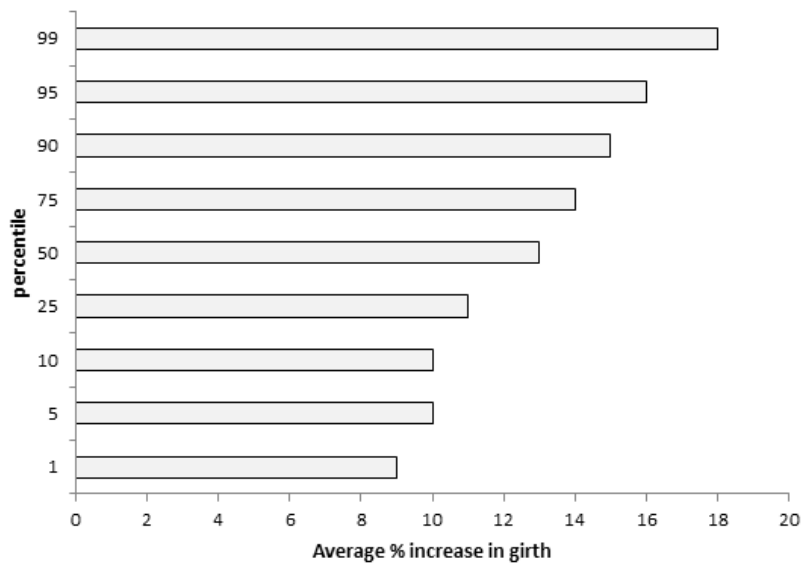


Figure 2 Increase in an average of 5 girth\* measurements since the survey of Light and Gibson (1986) by percentile (\*neck, chest, waist, hip and wrist girths)

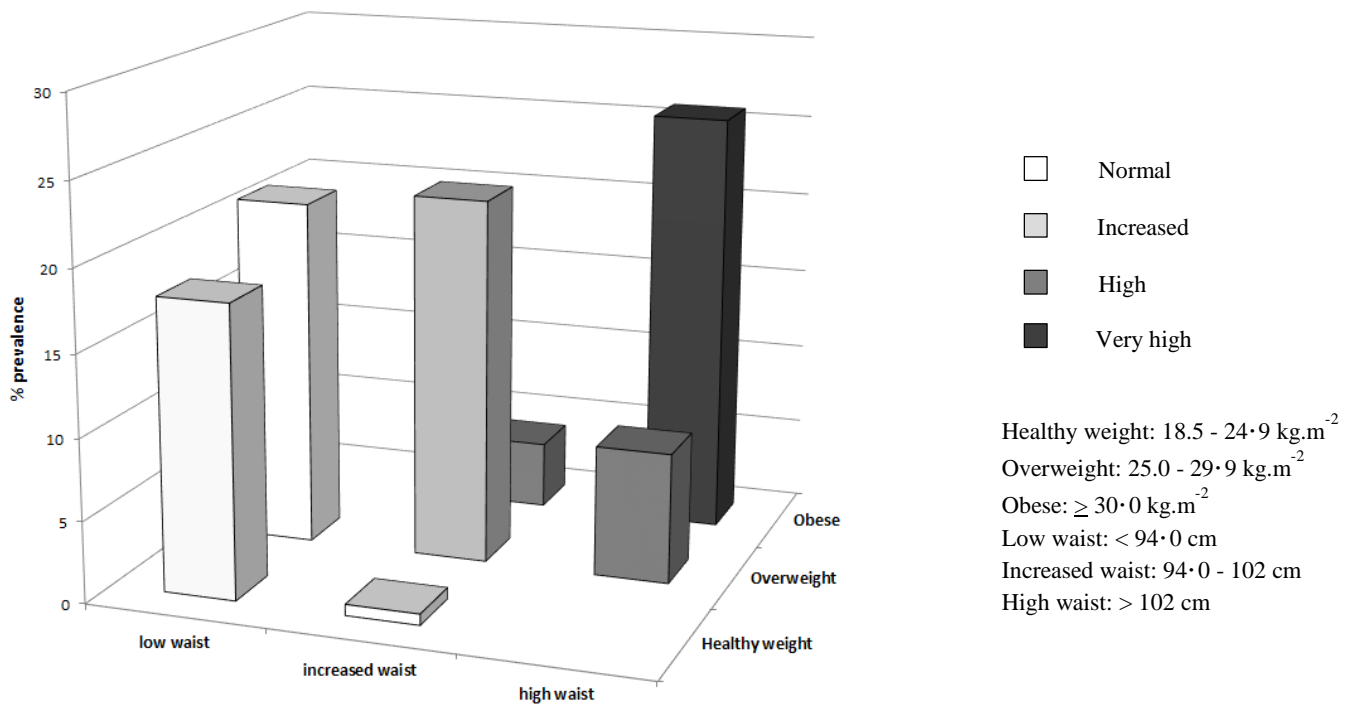


Figure 3 Health risk in offshore workers (n=588) according to obesity category by BMI and waist circumference according to the Scottish Intercollegiate Guidelines Network 2010

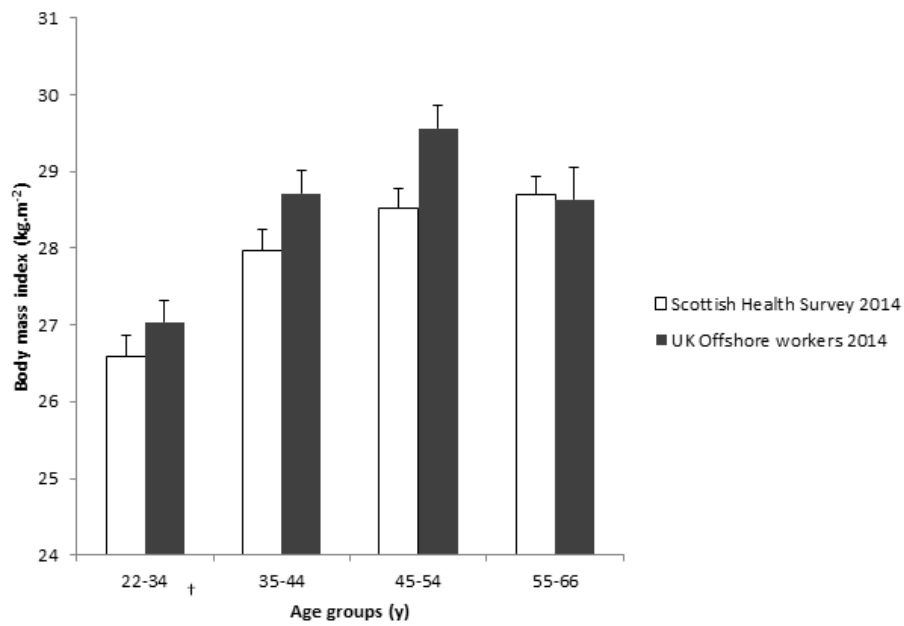


Figure 4 Comparison of Body Mass Index of male UK offshore workers with Scottish Health Survey data. (Main effect  $P=0.021$ ; no interaction of group with age; error bars represent 1SE; † includes one offshore worker aged 21)

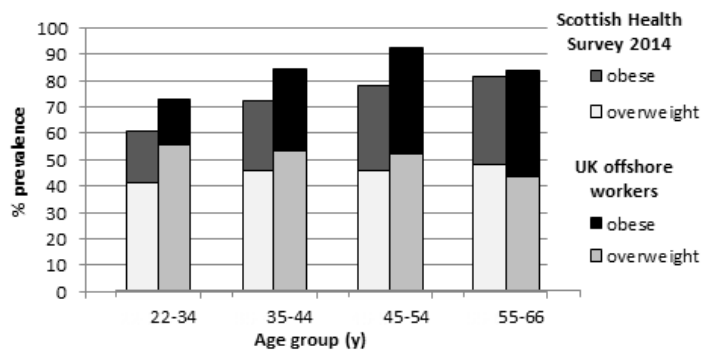


Figure 5 Prevalence of overweight and obesity in male offshores workers ( $n=588$ ) and Scottish Health Survey in 2014 ( $n=1254$ ); † includes one offshore worker aged 21

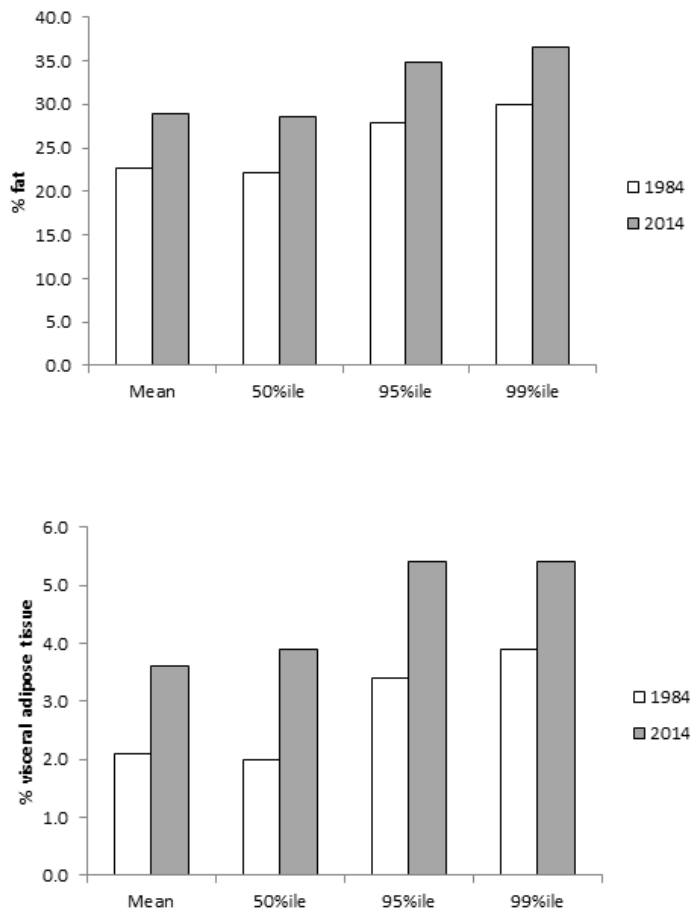


Figure 6 Upper: Total % fat; Lower: % Visceral adipose tissue for mean and selected percentiles in UK offshore workers in 1984 and 2014, both predicted from the body roundness model of Thomas et al. (2013) using the algorithm for Caucasians