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Time changes in the body dimensions of male Australian Army personnel between 1977 and 2012

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ABSTRACT

The aim of this study was to quantify time changes in the body dimensions of male Australian Army personnel. Following a systematic review, two studies were identified and matched for occupation and age ($n = 669$) with time changes in 12 absolute and 11 proportional body dimensions assessed between 1977 and 2010–12. Changes in means were expressed as absolute, percent and standardised changes, with changes in variability assessed visually and as the ratio of coefficients of variation (CVs). Time changes in absolute dimensions were typically positive (increases) and moderate in magnitude (median standardised change ± 95%CI: 0.53 ± 0.23), and while changes in proportional dimensions were typically negligible (median standardised change ± 95%CI: 0.16 ± 0.33), substantial changes (standardised changes ≥0.2 or ≤−0.2) were observed in several dimensions. Variability in body dimensions has also typically increased (median ratio of CVs ± 95%CI: 1.10 ± 0.07) and become more right-skewed. These findings have important implications for the design and acquisition of new military vehicles, body equipment and clothing.

1. Introduction

Time increases in body size have been well documented for people of all ages over the past couple of centuries (Cole, 2000, 2003; Danubio and Sanna, 2008; Hauspie et al., 1997; Roche, 1979). These increases in body size are believed to be due to improvements in environmental conditions, nutrition and access to health care, leading to the reduction of growth-inhibiting factors (Malina, 1979; van Wieringen, 1986). Few studies however have documented time changes in professional military personnel. While time changes in body dimensions have previously been reported for Australian, British, Kenyan and US military personnel over the period 1854–2008, a small number have reported time changes for only professional military personnel (Paquette et al., 2009; Soar, 1999; Tomkinson et al., 2010) with most reporting on recruits, personnel yet to complete basic military training, or a combination thereof plus professional military personnel (e.g. Bartholomew, 1980; Cuff, 1993; Greiner and Gordon, 1992; Knapik et al., 2006; Moradi, 2009; Moroney et al., 1971; Rosenbaum and Crowdy, 1992; Steegmann, 1985). Collectively, studies of professional military personnel have examined time changes in measures of centrality (typically expressed as changes in means) and provide strong evidence for increases in the size of absolute body dimensions over time. However much less is known about time changes in variability (i.e. the spread of measurements about the middle) or time changes in proportional body dimensions (which provide an indication of changes in body shape). Despite limited published data, it has been observed that increases in the body dimensions of Royal Australian Air Force personnel were typically proportional to increases in general body size measures such as stature and mass, indicating that some military populations have increased in size but not shape over time (Tomkinson et al., 2010). This time-related pattern is expected based on geometric scaling, which theoretically suggests that time changes in body dimensions (e.g. lengths, breadths, circumferences and segmental heights) should approximate time changes in stature (Olds et al., 1995), assuming no meaningful time changes in cultural practises (e.g.

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diet and exercise). In addition, while changes in variability have rarely been reported, Tomkinson et al. (2010) showed that increases in weight, Body Mass Index (BMI), hip and waist circumference measures were non-uniform and right-skewed, with the largest time increases observed in those with the largest body size.

A lack of current anthropometric data on professional military personnel can contribute to personal equipment sizing and human machine interface design problems. For example, until recently the Australian Army were relying on old Australian datasets or newer datasets on international military populations (e.g. from the UK) for procurement specifications. This approach is limiting given: (a) a lack of evidence that the body size and shape of military personnel in one country are representative of their peers in another country; and (b) convincing evidence of recent time increases in the body size of professional military personnel from Australia and the US (Paquette et al., 2009; Tomkinson et al., 2010). An understanding of recent time changes in body dimensions has important implications for ensuring correct human-machine (e.g. tanks, airplanes, submarines) and human-equipment (e.g. body armour and helmets) fit. The aim of this study therefore was to quantify time changes (in means and variability) in the body dimensions of male Australian Army personnel.

2. Material and methods

2.1. Systematic review

To examine time changes in the body dimensions of male Australian Army personnel, a systematic review of the scientific literature (in accordance with the PRISMA guidelines, Moher et al., 2009) was conducted to locate studies explicitly reporting descriptive anthropometric data (with a view to obtaining raw data) on all military personnel (not limited to Australia) in order to identify all possible studies that reported on male Australian Army personnel. Candidate studies were searched for in March 2014 using the following bibliographic databases: Academic Search Premier (1984–), Embase (1980–), MEDLINE (1966–), Online Defence Information Network (1950s–), PubMed (1966–), ScienceDirect (1823–), Scopus (1960–), and SPORTDiscus (1949–). The search string used for the electronic search was: ((((((((((height) OR mass) OR weight OR body size) OR girth*) OR circumference*) OR breadth*) OR length*) OR anthropometry) OR body weights and measures) OR body composition) AND ((((((((((military) OR military personnel) OR army) OR soldier*) OR armed force*) OR submariner*) OR sailor*) OR marine*) OR navy) OR air force). All available titles and abstracts were assessed for eligibility, and if there was uncertainty or the abstract was not available, then the full-text report was retrieved. Email contact was made with several Australian anthropometrists (within the Australian Defence Force [ADF] and academic institutions) to ask whether they knew of any appropriate studies. This search strategy identified 13,456 eligible studies and, following a review of all titles and abstracts, 102 studies were retained for further analysis, including several classified ADF technical reports for which appropriate declassification permissions were sought and granted. Eligible studies were excluded if descriptive anthropometric data were reported for:

(a) non-Australian Army personnel or Australian Army personnel not able to be differentiated from other military groups (e.g. Air Force and Navy);
(b) atypical personnel or those not broadly representative of the Australian Army population (e.g. those with known injury or illness);
(c) female-only samples or mixed samples that were unable to be separated by sex;
(d) a sample previously reported in another included report;
(e) body dimensions for which explicit landmarking and measurement procedures were not available; and
(f) Australian Army personnel yet to complete basic recruit training.

Of the 102 eligible studies, 99 were excluded based on the above criteria with three studies retained for further analysis. The reference lists of these articles were examined and cross-referenced although no new studies were identified. Only studies for which raw anthropometric data were available were retained in order to best estimate time changes in measures of centrality and variability. Raw data were available for two ADF anthropometric surveys conducted in 1977 (Hendy, 1977) and 2010–12 (Tomkinson et al., 2012).

Hendy (1977) completed a tri-service (Air Force, Army and Navy) anthropometric survey of ~3000 randomly sampled male permanent ADF personnel aged 17–50 years between January and November 1977. This included 1044 male Army personnel (representing 4.4% of 23,720 permanent male Australian Army personnel) who were physically measured for 31 body dimensions. Measured Army personnel were trained and regular users of military-specific equipment and workplaces and were classified as: (a) weapons users, (b) transportation, (c) clerks and others, (d) aviation, (e) catering, and (f) technical personnel. The repeatability of the 1977 measures was very good, with nearly perfect test-retest correlations (mean Pearson's correlations±95%CI: 0.95 ± 0.01) (Hendy, 1977).

Tomkinson et al. (2012) completed a large anthropometric survey (the Australian Warfighter Anthropometric Survey [AWAS]) of 2138 permanent Australian Army personnel aged 18–40 years who were recruited from five Army bases between July 2010 and April 2012. This included 1861 males (representing 6.9% of 26,994 permanent male Army personnel) and 277 females (representing 9.1% of 3042 permanent female Army personnel) who were physically and digitally measured for 84 body dimensions. Recruited male personnel represented 15 Corps and 70 trades, with 93% (1732 of 1861) born in either Australia or New Zealand and the remainder born in Asia (2%), Europe (2%), the Pacific Islands (1%) or other countries (2%). The repeatability of the 2010-12 measures was very good, with very small systematic errors (median percent changes in means ± 95%CI: 0.02 ± 0.04%), very small random errors (median percent typical errors±95%CI: 0.47 ± 0.07%), and nearly perfect test-retest correlations (median intra-class correlations±95%CI: 0.996 ± 0.001) (Tomkinson et al., 2012).

2.2. Initial data analysis

Prior to calculating time changes, all raw data were checked and cleaned to ensure quality. For consistency between datasets, all female data (13% or 277 of 2138) in the 2010-12 dataset, and all data on males not aged 18–40 years (8% or 85 of 1044) in the 1977 dataset, were excluded. Thirdly, all raw data were checked for anomalies by running range checks with data ±3 standard deviations away from the mean identified as being potentially anomalous. However, following visual examination of scatterplots relating each dimension to Stature (or Sitting Height for seated measurements) and Weight, potentially anomalous data were considered to be acceptable and were retained for further analysis.

A comparison of two surveys revealed that 12 of 31 absolute body dimensions measured in 1977 were identically measured in 2010–12 using the same measurement protocols and equipment, including four heights, three circumferences, three breadths, one length and Weight. All absolute body dimensions (except Stature) were normalised as a fraction of Stature (note, Weight was