Characterizing torso shape variations in Australian Defence Force populations using statistical shape modelling

Tamara M. Grant[1], Nick A.T. Brown [1,2], Alison Fogarty[3], Greg L. Carstairs[3], Celeste E. Coltman[1]
[1]University of Canberra Research Institute for Sport and Exercise, Faculty of Health, University of Canberra, Canberra, Australia
[2]Queensland University of Technology, Faculty of Health, Brisbane, Australia
[3]Defence Science and Technology Group, Melbourne, Australia

Email: tamara.grant@canberra.edu.au

Summary

This study aimed to develop a statistical shape model (SSM) of the torso from an Australian Army population to characterize variability in soldier torso anthropometry. Major shape variations were captured in the first 3 principal components. This SSM provides a basis for describing and classifying torso shape in soldiers that can be used to optimize the ergonomic fit of body armour systems.

Introduction

Clothing and personal protective equipment (PPE) used in the Australian Defence Force (ADF) is often unisex and offered in limited sizing [1]. Body armour systems form a critical component of PPE, combining soft armour materials and hard ballistic plates HBP to protect the vital thoraco-abdominal organs. Larger HBPs provide greater organ coverage, but may impair range of motion, cause discomfort and hinder a soldier's ability to complete operational tasks [2]. Optimizing HBP designs requires balancing protection with ergonomic fit/mobility, which is dependent on soldier anthropometry and anatomy [3, 4].

Traditional anthropometric surveys, commonly conducted in military populations, provide limited information about body shape. Three-dimensional (3D) surface anthropometry capture information about body shape that is not described by traditional methods. Statistical shape models (SSM) are used to characterize geometric variability in large datasets [5] but have not been used to inform HBP design. This study utilized data from a 3D surface anthropometric survey of Australian Army personnel to generate a SSM of the torso to characterize shape variation.

Methods

A sample of 178 point clouds were cropped from whole-body 3D surface scans collected as part of the Australian Warfighter Anthropometry Survey (12% female, 88% male). Point clouds were cropped at the sternal notch, iliac crests and acromion processes to isolate the torso region of interest for each participant.

Analyses were performed using a custom pipeline in Python. Cropped point clouds were down-sampled, registered, a mean point cloud was calculated, and a principal component analysis was performed to characterize shape variance in the training population. The mean point cloud was deformed along ±3 standard deviations of each principal component (PC) to enable data interpretation.

Results and Discussion

Principal component analysis revealed that 60% of shape variation was explained by the first 9 PCs. Major variations were captured by the first 3 PCs (Figure 1). 18.8%, 10.9% and 7.8% of variation were explained by PCs 1, 2 and 3, respectively. PC 1 represented variation at the bust/chest, PC 2 represented variation in chest breadth and height, and PC 3 represents variation in depth at the abdominal region. These sources of variation may be important considerations for fit when designing torso-borne equipment and apparel.

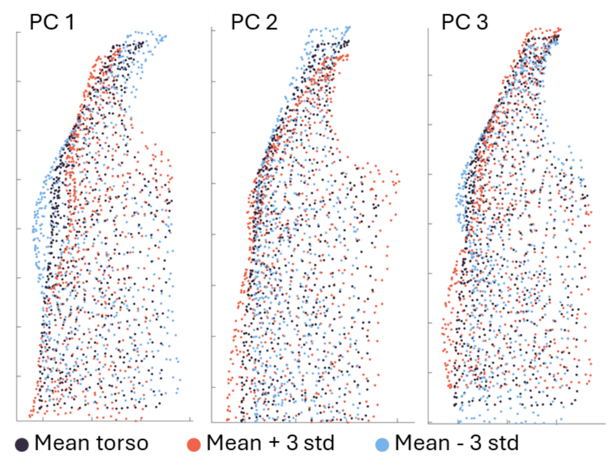

Figure 1: Visualization of mean point cloud deformed by ±3 standard deviations along first 3 principal components (PCs).

Conclusions

The first 9 PCs explained 60% of variance, with the first 3 PCs capturing the major sources of variation. SSMs have not been used to inform torso-borne PPE design previously. SSM outputs suggest that population variation in chest depth/bust size, chest breadth, and depth of the abdominal region should be considered when optimising fit of HBPs.

Acknowledgments

This research was funded by the Department of Defence, Australian (ID 12182).

References

[1] Todd (2007) *Developing Effective Systems for Ready-To-Wear Clothing*; Woodhead Publishing Limited.
[2] Brisbine BR et al. (2022). *PLoS One*, **17**(11): e0278174.
[3] Coltman CE et al. (2022). *Appl Ergon*, **98**: 103602.
[4] Summers SJ et al. (2023). *Appl Ergon*, **106**: 106.
[5] Azouz et al. (2006). *Vis Comput*, **22**(5): 302-314.