Understanding the trade-offs between protection, performance and integrated survivability

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Introduction: Heavy load weights cost in terms of soldier performance. Few studies, however, have specifically examined the contribution of other Clothing and Individual Equipment (CIE) mass properties (e.g., bulk, stiffness). Canada is employing the standardized LEAP combat mobility course to understand the contributions of these CIE mass properties to soldier mobility decrements. Follow-on simulator studies that replicate soldier movement speeds and movement patterns under the same loads have enabled us to gather empirical data of soldier vulnerability to enemy fire under select scenarios. Results will inform the trade-space of protection versus performance and integrated survivability.

Methods: Twenty-four combat arms soldiers completed the LEAP course in three CIE configurations. LEAP completion time, load weight, clothed anthropometry (bulk) and range of motion (stiffness) data were gathered. Multivariate analyses evaluated the quantitative interaction between LEAP performance and mass properties, soldier characteristics and perception. A Principal Component Analysis (PCA) was used to reduce the number of dependent variables used for a subsequent regression analysis. In the follow-on simulator study, 31 soldiers engaged human targets moving across gaps between points of cover at speeds representative of LEAP sprint speeds under various loads. Shooting performance and the relationships with target conditions were examined by collecting hit probabilities, distance and time to hit, radial error, shot location and number.

Results: From the LEAP study analysis, eight factors with an eigenvalue > 1 accounted for 86% of the total variance. Regression analyses showed that LEAP performance could be accounted for by the eight components. Load weight and torso bulk measures were both found to be strongly associated with relative LEAP performance. Stiffness measures were inversely associated with LEAP performance. Decrements in mobility translated to increased vulnerability in the simulator study, with the speed of target movement a significant main effect across all hit probabilities examined. Accuracy results show strong effects of both range and speed, as well as gap width. The effect of a speed-accuracy trade-off showed that faster moving targets are not only less likely to be hit but, when hit, they are hit less accurately.

Conclusions: Objective measures of mass properties (load weight, bulk volume, and stiffness) showed association with LEAP task performance. Knowledge about the interdependence between mass properties, soldier characteristics, combat mobility task performance and soldier susceptibility to enemy fire will influence the design of future modular scalable body armour, as well as decision aids for their effective employment to improve integrated soldier survivability.

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Agile usability product design assessment of warfighter worn robotics

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Introduction: While biomechanical assessments gather extensive objective data regarding the performance and design characteristics of wearable robotics, they can be timely, intensive, and costly. By modeling assessments after agile usability testing, design teams receive extensive system specific feedback in real time at relatively low costs. This methodology has been used for a variety of soft and rigid exoskeletons, load distribution devices, and energy harvesters. Additionally, it has been used for cooling garments, chemical biological ensembles, duty uniforms, and packs.

Methods: Agile assessments can be executed early in the design process, requiring only a single prototype. Typically 3–5 participants are assessed individually, performing a variety of basic mobility and mission tasks. Donning, doffing, adjustability, compatibility, ease of use, impact on mission performance, mobility, acceptability and fit are key metrics. Specific activities are customized to focus on the individual test item. For example, in the case of a knee energy harvester, activities focus on tasks related to knee mobility (high steps, stair climbing, taking a knee, squatting, sitting on the ground, aiming a weapon in the kneeling posture, etc.). The majority of the findings are focused on observations from the test team and discussions with participants. A less rigid assessment structure allows for flexibility in test activities and lines of investigation not previously identified. Findings lead to identifying necessary critical design changes early in the development and acquisition process, without incurring significant costs or resources.

Results: Written summaries of the activities and findings are provided to the product team and provide project and design documentation. However, by integrating the team into the assessment, project officers, designers and engineers are able to see and hear warfighter feedback firsthand, thereby allowing the team to leave at the end of the day with an understanding of issues with the current prototype and ideas for how to fix them. This allows for more agility in the design process, where issues can be identified early and design changes can be quickly implemented. This method allows multiple assessments and design iterations of a test item to be placed on warfighters within a shorter amount of time, reducing the number and severity of potential issues warfighters experience in larger, more costly field evaluations and when eventually fielded.

Conclusions: In summary, this method has proven beneficial in identifying gross form, fit and function issues related to warfighter worn robotics while providing immediate feedback for the team to continue their iterative design process.

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Heavy load weights cost in terms of soldier performance. Few studies, however, have specifically examined the contribution of other Clothing and Individual Equipment (CIE) mass properties (e.g., bulk, stiffness). Canada is employing the standardized LEAP combat mobility course to understand the contributions of these CIE mass properties to soldier mobility decrements. Follow-on simulator studies that replicate soldier movement speeds and movement patterns under the same loads have enabled us to gather empirical data of soldier vulnerability to enemy fire under select scenarios. Results will inform the trade-space of protection versus performance and integrated survivability.