Development of Methods to Assess Self-Reach Capability

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Body armor worn by soldiers adversely affects the performance of some physical tasks. These restrictions may also affect the ability to "self-reach" to locations on their own bodies or on their body borne gear. This paper describes the development of laboratory methods to quantify self-reach capability and the results of pilot testing. Participants rated the perceived difficulty of each self-reach motion on a 10-point scale. With data from a larger study population, logistic regression models could be developed to make predictions of the difficulty rating distribution for target populations. UNCLASSIFIED: Distribution Statement A. Approved for public release.

INTRODUCTION

Several studies have shown that body armor worn by soldiers adversely affects the performance of some physical tasks (Sellinger et al. 2010; Hasselquist et al, 2012). These restrictions may also affect the ability for soldiers to reach to locations on their own bodies or on their body borne gear (self-reach). There is little data in the literature to indicate the extent to which self-reach capability is affected by body armor or task conditions.

The current analysis is part of a larger research effort to quantify the effects of body armor and body-borne equipment on seated reach capability and difficulty. This paper describes the development of laboratory methods to quantify self-reach capability and the results of pilot testing.

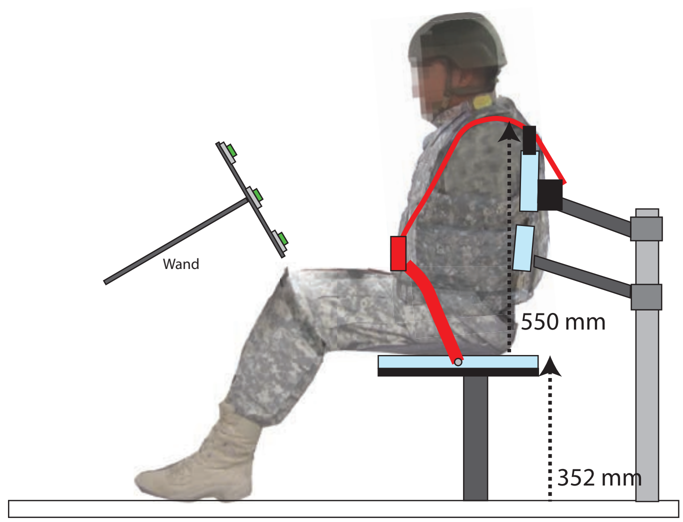

Figure 1. Laboratory configuration for methods to assess self-reach capability.

METHODS

Laboratory Set-up

A mock-up of a squad seat with dimensions typical of a military tactical vehicle was used in this study (Figure 1). The seat was equipped with a 5-point harness. The lower restraints were tightened manually. The upper restraints were equipped with retractors. During testing the upper restraints were fed back into the retractor with the participant sitting back in the seat, then the restraints were locked with a belt lock to prevent feed-out (Figure 2). The seat was mounted at a height (H-point above the floor) of 352 mm with a seat back set at 10-degrees aft vertical and a horizontal seat pan surface (Figure 1). Participants' motions were recorded using a 13-camera VICON passive optical motion capture system. The outcome of motion capture analysis is not included in this report.

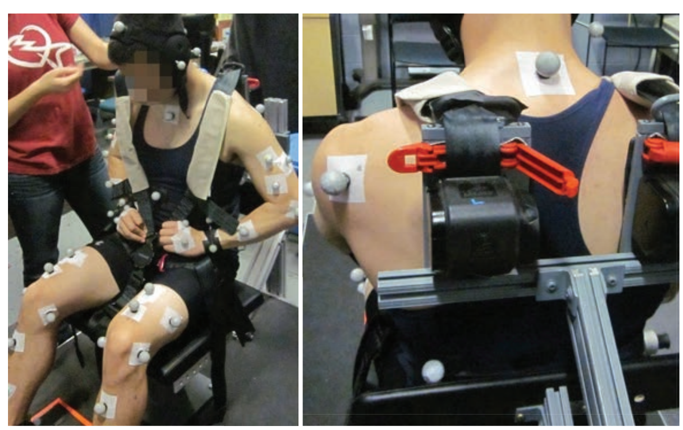

Figure 2. Participant donning 5-point harness in minimally clad garment and 5-point harness with harness locks.

Ensemble and Harness Conditions

Each participant was tested in three ensembles: minimally clad (MCG), wearing body armor, i.e., personal-protective equipment (PPE) alone, and wearing the PPE and body borne gear (BBG) (Figure 3). PPE consisted of a tactical vest that incorporated 4 hard plates. BBG was also composed of additional rigid geometries. All ensemble levels were sized according the participant's body dimensions. Velcro straps and gear were adjusted in an attempt to standardize fit across the participants.

The effect of the harness was also investigated. Test condition order was blocked and randomized by ensemble and harness level. The with-harness and no-harness conditions were nested within each ensemble condition.

Figure 3. A participant in minimally clad (MCG), personal protective equipment (PPE), and body borne gear (BBG) ensemble levels (left to right).

Self-Reach Protocol

Participants performed a series of reaches to various targets on the torso, lower extremities and the opposing upper extremity (Figure 4). These target locations were chosen to sample the boundaries of the self-reach envelope. Prior to data collection, the experimenter marked anatomically referenced reach target locations on the skin (lower extremities) or gear/PPE.

Prior to the start of each trial, participants to assumed a standardized posture with the lower back in contact, parallel legs and thighs (no splay), ankles located directly under the knee, and the left, opposing arm lowered to their side with the palm oriented towards the body. For each trial, the experimenter tapped the wand tip on the desired target to cue the participant (Figure 5). A 2nd experimenter verbally instructed participants to reach to the wand-tip. Participants attempted to reach the wand tip using index finger of their right hand.

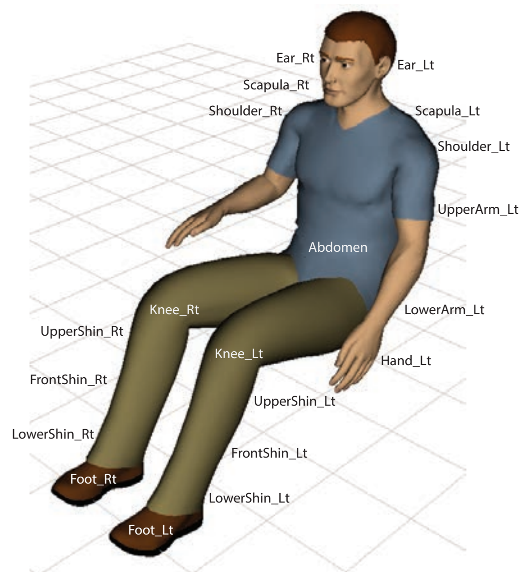

Figure 4. Self-reach targets.

Immediately following each reach, participants provided a subjective rating of the reach difficulty on a 10-point scale from 1 (minimal difficulty) to 10 (maximum difficulty). Targets that were not reachable were assigned a rating of 11.

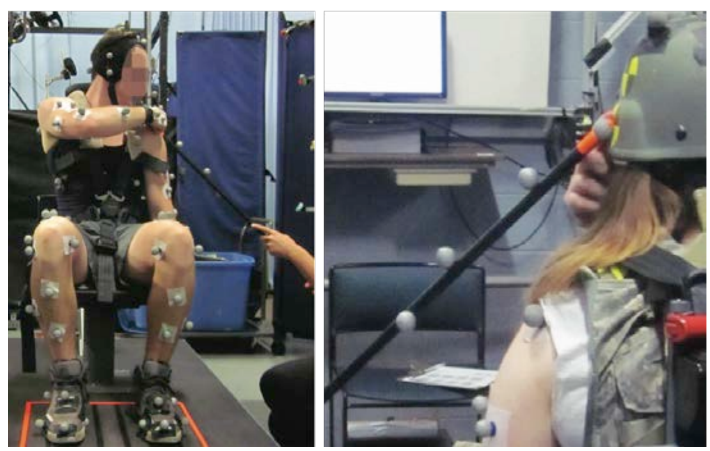

Figure 5. Participants minimally clad (left) and wearing PPE (right), reaching for marker tip of wand that an investigator has placed on a target marked on the participant.

Data Analysis

A repeated measure MANOVA was used to assess the impact of ensemble and harness on self-reach. With the small number of pilot subjects, this analysis is exploratory and should not be interpreted as providing generalizable results. Contingency analysis was also performed on the distribution of the difficulty ratings across the ensemble and harness conditions for each of the self-reach locations. To evaluate these distributions a cut-off criterion was imposed at a difficulty rating of 5. Chi-square tests of independence were conducted. A Bonferroni adjusted alpha level of 0.0025 per test (0.05/20) for multiple comparisons was applied. All statistical analyses were performed using JMP software version 11.0 (SAS Institute, Cary, NC).

Pilot Study Participants

Five women and five men were tested in this pilot study. All participants were right-hand dominant and with no history of musculoskeletal disorders or functional mobility impairments. Anthropometric data were gathered from each participant to characterize overall body size and shape following the procedures in Hotzman et al. (2009). All measurements were obtained minimally clad, except that stature was measured with and without shoes to characterize heel height. The male study population averaged 180.7 (85.1) cm for stature, 85.7 (15.6) kg for weight, and 26.4 (5.4) kg/m^2 for body mass index (BMI). Female participants averaged for stature 165.6 (88.8) cm, 68.9 (10.9) kg for weight, and 25.1 (3.1) kg/m^2 for BMI.

PRELIMINARY RESULTS

Median perceived difficulty ratings by the participants in each ensemble configuration with and without harness are represented on Figure 7. A repeated measures MANOVA test was conducted to test ensemble and harness effects on self-reach assessments across the body. To adjust for a lack of sphericity, Greenhouse-Geisser Epsilon corrections were evaluated. All of the multivariate tests of main effects were significant (p<0.0001), indicating that the self-reach rating scores across the targets, ensemble, and harness levels have at least one mean vector pairing that produced a significant difference. To illustrate specific mean differences, Figure 6 plots the least square mean effect of the ensemble and harness levels across the self-reach targets.

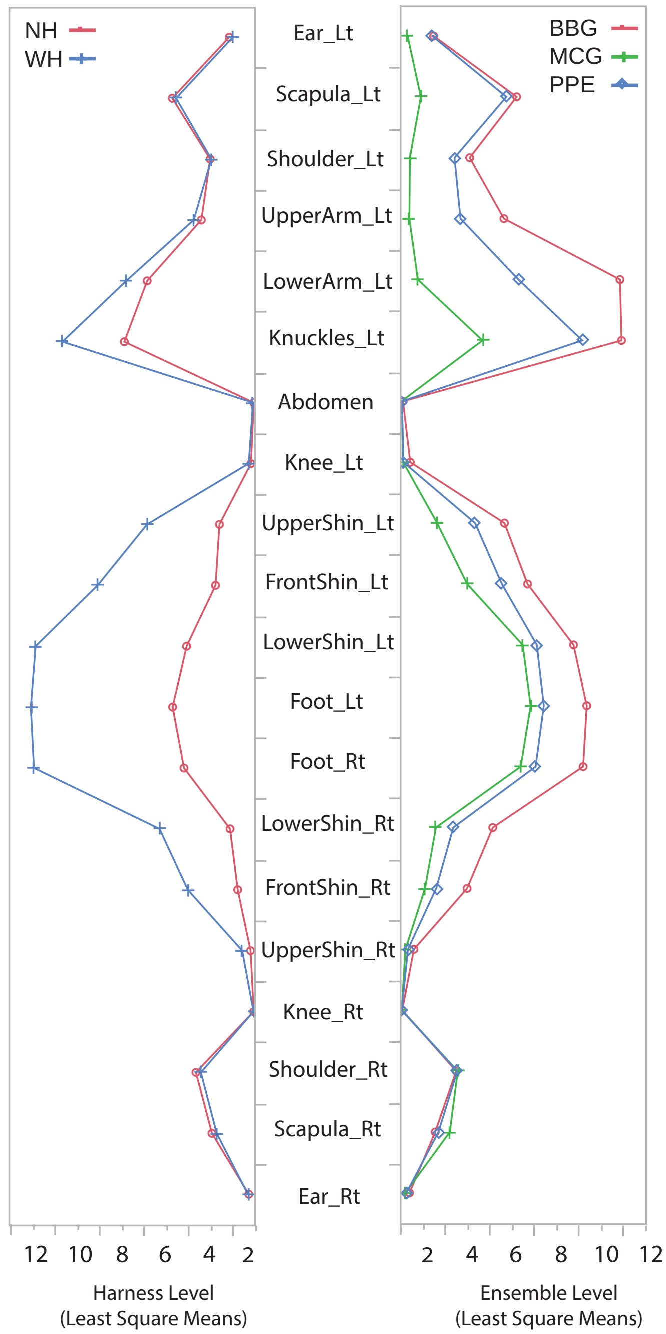

Figure 6. Comparative mean plots for the two harness and three ensemble levels across the self-reach targets.

Effect of Ensemble

Donning additional gear significantly increased the difficulty ratings for some targets (Figures 6 and 7). The mean (sd) rating differences were 1.46 (0.16), 1.36 (0.16), and 2.89 (0.16) between MCG & PPE, PPE & BBG, and MCG & BBG, respectively. Across many of the self-reach locations, significant increased rating of difficulty was observed for each increasing level of ensemble.

Among the self-reach targets, the opposing upper extremity and lower leg were found to pose the greatest degree of difficulty (Table 1). Targets located at the near the midline of the body, such as the abdomen and knees, were least affected by the addition of PPE and BBG.

Table 1. Percentage of participants *who could not reach* the target for each ensemble level (MCG, PPE, BBG), collapsed across the harness condition. Percentage values are presented as decimals. The results of the Chi^2 test are provided. Values greater than 0.5 (at least half of participants could not reach) are shaded.

	MCG	**PPE**	**BBG**	**Chi^2**
Ear_Lt	0.02	0.12	0.09	0.0381
Scapula_Lt	0.02	0.56	0.64	<0.0001
Shoulder_Lt	0.01	0.29	0.24	<0.0001
UpperArm_Lt	0.01	0.32	0.62	<0.0001
LowerArm_Lt	0.04	0.66	0.56	<0.0001
Hand_Lt	0.36	0.89	1.00	<0.0001
Abdomen	0.0	0.0	0.0	0.0
Knee_Lt	0.0	0.0	0.0	0.0
UpperShin_Lt	0.16	0.30	0.48	<0.0001
FrontShin_Lt	0.30	0.47	0.46	<0.0001
LowerShin_Lt	0.56	0.58	0.64	0.0008
Foot_Lt	0.67	0.64	0.88	0.0008
Ear_Rt	0.01	0.0	0.8	0.5969
Scapula_Rt	0.23	0.13	0.15	0.0161
Shoulder_Rt	0.23	0.23	0.23	0.9083
Knee_Rt	0.0	0.0	0.0	0.0
UpperShin_Rt	0.01	0.02	0.02	0.7887
FrontShin_Rt	0.08	0.16	0.3	<0.0001
LowerShin_Rt	0.13	0.23	0.45	<0.0001
Foot_Rt	0.52	0.60	0.67	<0.0001

Effect of Harness Constraint

An increase in median difficulty rating for the MCG, PPE, and BBG ensembles was found during trials performed with the harness restraint (Figure 7). Imposing the harness constraint onto participants donning the MCG and PPE ensembles significantly increased the perceived difficulty rating and incidence of participants who could not reach specific targets (Figure 7). However, the presence of the harness condition had less of an effect on difficulty ratings perceived during the BBG condition (Figure 7). Reach locations on the opposing extremity were inaccessible for most participants when the harness was applied regardless of gear types they were wearing; especially the left foot target which was unreachable to all participants (Table 2).

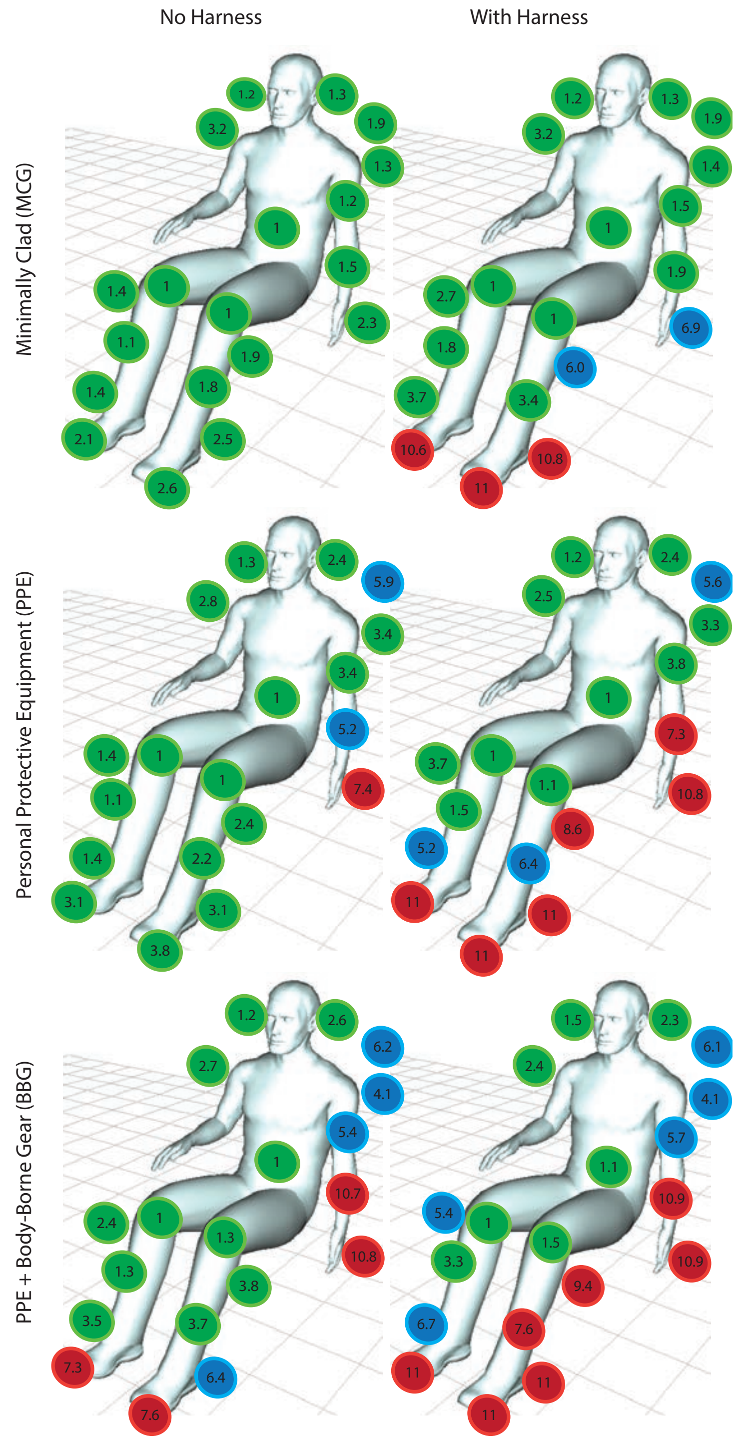

Figure 7. Median values observed for each ensemble level and harness restraint condition.

Table 2. Percentage of participants *who could not reach* the target based on absence (NH) or presence (WH) of the harness restraint, collapsed across the ensemble levels. Percentage values are presented as decimals. The results of the Chi^2 test are provided. Values greater than 0.5 are shaded.

	NH	**WH**	**Chi²**
Ear_Lt	0.08	0.08	0.8201
Scapula_Lt	0.42	0.38	0.5318
Shoulder_Lt	0.23	0.25	0.6653
UpperArm_Lt	0.31	0.32	0.6914
LowerArm_Lt	0.51	0.61	0.1083
Hand_Lt	0.62	0.87	<0.0001
Abdomen	0.0	0.0	0.0
Knee_Lt	0.0	0.0	0.0
UpperShin_Lt	0.10	0.52	<0.0001
FrontShin_Lt	0.15	0.78	<0.0001
LowerShin_Lt	0.29	0.99	<0.0001
Foot_Lt	0.39	1.00	<0.0001
Ear_Rt	0.01	0.01	1.0
Scapula_Rt	0.15	0.15	1.0
Shoulder_Rt	0.23	0.22	0.7692
Knee_Rt	0.0	0.0	0.0
UpperShin_Rt	0.0	0.03	0.439
FrontShin_Rt	0.04	0.35	<0.0001
LowerShin_Rt	0.08	0.46	<0.0001
Foot_Rt	0.35	0.98	<0.0001

DISCUSSION

This pilot study developed methods for assessing self-reach capability. The preliminary analysis indicates that, as hypothesized, self-reach is affected by body armor and the presence of a harness restraint. Adding gear generally increased the median value of difficulty rating of an individual targets, but some targets were unaffected. Rating increases were greatest for those targets located furthest from right shoulder.

Due to the extensive time to equip a participant with PPE and gear, participants were blocked on ensemble level and the harness conditions were randomly assigned within these blocks. The data are also limited in generality by the particular ensembles and harness conditions tested.

In this pilot study, the covariance from anthropometry, such as stature, body weight, and upper extremity dimensions, are not assessed. Further analysis of the influence of participant anthropometry and self-reach target location is needed with a larger population sample. The data from a larger study will permit the development of logistic regression models to predict the difficulty rating distribution for populations of interest.

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