Work 41 (2012) 422-431
DOI: 10.3233/WOR-2012-0192-422
IOS Press

The effects of functional limitations on soldier common tasks

Major John R. Bacon[a,*], Dr. Thomas J. Armstrong[b,*] and LTC Teresa L. Brininger[b]
[a]*Department of Mathematical Sciences, United States Military Academy, West Point, NY 10996, United States*
[b]*Center for Ergonomics, University of Michigan, Ann Arbor, MI 48109, United States*
[c]*Telemedicine and Advanced Technology Research Center, Fort Detrick, MD 21702, United States*

Abstract. This paper describes the findings associated with the ability of an individual to perform the United States Army's Common Soldier Tasks of: "Maintaining an M16-Series Rifle" , "Protect Yourself from Chemical, Biological, Radiological, and Nuclear (CBRN) Injury or Contamination with Mission-Oriented Protective Posture (MOPP) Gear", and "Protect Yourself from Chemical and Biological (CB) Contamination Using Your Assigned Protective Mask." The analysis was conducted using data compiled from videos of a Soldier performing the given tasks at Walter Reed Army Medical Center. The findings reflect the opinions of researchers in identifying potential elements, which impose abnormal, irregular, and/or extraneous effort when performing the tasks as outlined in STP-21-1-SMCT – Soldier's Manual of Common Tasks: Skill Level I.

Keywords: soldier, limitation, disability, task, rifle

1. Introduction

1.1 Motivation.

There exists human performance and functional limitations in Soldiers performing Common Soldier Tasks. Contributing to these limitations are the following four factors: equipment design, standardized methods and procedures, environmental conditions, and the physical and mental capabilities of the individual performing said tasks. Soldiers are subjected to many of the same types of occupational hazards faced by the general public such as repetitive motion tasks. Additionally, a Soldier's pathology is not unique; therefore, succumb to similar occupational injuries such as arthritis. With this understanding, the two objectives of this paper are to 1) determine the potential affects faced by Soldiers with specific physical limiting conditions and 2) identify alternatives in the form of equipment design and procedural methods in performing two common Soldier tasks. An increase in injury diagnosis and leader awareness of the effect these injuries have on a Soldier's ability to conduct a task have been the main motivations behind this research. This paper identifies which body part a healthy Soldier uses to perform each individual element of a given task as well as the frequency and peak force exertions required to perform each given task. These findings illustrate potential room for improvement in terms of reducing the functional limitations felt by Soldiers with common impairments associated with the back, digits, and limbs. This is done by improving the *methods* in which Soldiers perform the task and *redesigning* the equipment to accommodate a broader population size.

1.2 Background.

The United States Army uses a physical profile serial system designated as "P-U-L-H-E-S." This system stands for the following six profile categories: **P**hysical, **U**pper, **L**ower, **H**earing, **E**yes, and **P**sychiatric. During a medical evaluation, each Soldier is given a numerical rating from one to four in each of these six categories to reflect different levels of functional capacity. Although each category maintains its own unique description in this system, generally, a *lower*

• Corresponding author: john.bacon@usma.edu

numerical rating correlates to a *higher* level of medical fitness. For instance, a rating of "P1" is given to a Soldier who possesses "good muscular development with ability to perform maximum effort for indefinite periods" (AR40-501, 2009). On the contrary, a Soldier with a "P3" rating is "unable to perform full effort except for brief or moderate periods." In addition to the rating, *profile codes* are used to assign more specific limitations to a Soldier such as "limitations in running, marching, [and] standing for long periods" (AR40-501, 2009). This profile system is used to assist leaders in assigning Soldiers to duty positions, which they are capable of performing.

Professional textbooks associated with rehabilitation commonly classify human limitations into one of five categories that progress in level of severity. The first level begins with an individual's *pathology*. Examples of this include birth defects and trauma that affect the body, which serves as the underlying cause of other stages of disability. The next level is *impairment*, which is the effect of an individual's pathology on body organs, systems, and/or other parts of the body. Although, impairment commonly ceases to exist upon the removal of pathological complications, the two can coexist such as instances of vision restoration. If an impairment hinders an individual from conducting a given task, that individual is said to possess a *functional limitation*. Further, if that functional limitation prevents him/her from performing a task crucial to a specific job, he/she is then said to have achieved the fourth level – *disability*. Lastly, a person is said to have a *handicap* if the disability limits the individual from performing major life roles such as holding a job, parenting, etc. An individual's level of limitation is two-dimensional; determined by the relationship of the individual's limitation with respect to environmental aspects, and is commonly referred to as the "Person-Environment Interaction". In other words, a functional limitation can either be promoted or downgraded based on physical and social environmental aspects in which he/she experiences it (Figure 1).

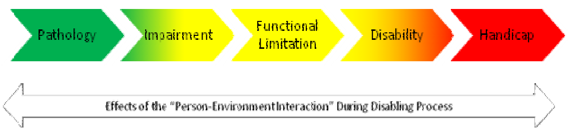


Figure 1: Progression of Human Capabilities

2. Methods

2.1 General.

Evaluating the negative effects job tasks have on workers in performing their occupation is not a novel idea. In 1915, Frank Gilbreth proposed a list of basic motions, which represented the smallest steps (greatest detail) in human-machine interaction. This list of elements called "Therbligs", although originally developed to improve worker efficiency, are helpful in dissecting jobs into measurable parts. Further, Clark D. Bridges' research in the 1940's on human limitations in the workplace provided insight on the impacts a work environment has on one's functional limitations. His findings showed that there was both a practical and financial rationale for ensuring task procedures were aligned with worker capability.

2.2 Data analysis approach.

Using a computer model (Figure 2), video footage of a Soldier performing the two common Soldier tasks was played back at 1/10th second intervals. Both the equipment and procedural methods used in this research are the same as those currently being applied by the U.S. Army. Important to note is that the Soldier analyzed had no functional impairments, and thus is designated as our initial control. Because the videos used in this analysis were recorded in a controlled environment, factors such as lighting, temperature, and combat-related challenges (excessive foreign debris, high stress, etc.) were not a factor in this analysis. By following the prescribed sequence found in the Soldier's Manual of Common Tasks: Skill Level I, the two common Soldier tasks were first separated into manageable elements. Then, using Modular Arrangements of Predetermined Time Standards (MODAPTS), each element was further refined into one of three classes[1]: movement, terminal, and auxiliary. Within each of the three MODAPTS classes, a quantifiable assessment was given using the standard methods (M1, M2, G1, etc.). Further, each class was assigned a peak force rating on a scale of 1-10 based on the estimated level of force required to execute each movement. Using the computer model, critical data such as the type of body part used, the distance and time required for the Soldier to perform each work element, and the estimated peak force used was then collected and populated in manageable spreadsheets, which was used for further analysis (Figure 2).

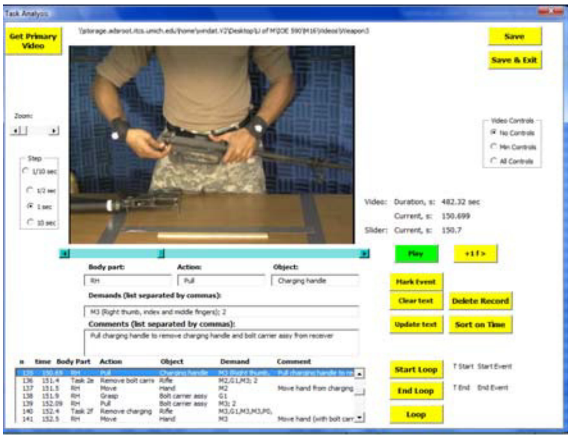


Figure 2: Time-based Video Analysis Program used in research. Video is analyzed in viewing window while Soldier actions, and demands are entered in text boxes. Data is saved to a spreadsheet, which is used for further analysis.

2.3 Task Analysis Approach.

Each of the two jobs was executed in accordance with the task numbers identified in the Army Soldier manual. The jobs were split into major tasks, which were then arranged into more manageable subtasks (elements). The subtasks were then broken down into actions (motions), which required both physical and mental coordination activities. An excerpt of the "Clearing the M16 Rifle" task is found in Table 1.

Table 1:

Partial Hierarchy for the Task "Clear Rifle" Depicting the Demands and Peak Forces Required

Task	Subtask	Action	Object	Demands; Peak Force
Clear Rifle				
	Place weapon on safe			
		Reach	Dust cover	M3
		Grasp	Dust cover	G1 (pinch);1
		Move	Dust cover	M2 (pinch); 2
		Inspect	Dust cover	D3 (sight, sound, touch, decide)
		Reach	Pistol grip	M3 (sight, touch)
		Grasp	Pistol grip	G1 (power grip); 3
		Rotate	Weapon	M2 (power grip); 3
		Inspect	Selector switch	D3 (sight, touch, decide safe)
		Rotate	Weapon	M2 (power grip); 3
		Inspect	Selector switch	D3 (Sight, touch, hear, and decide in safe position)
		Rotate	Selector switch	M1 (thumb); 4
		Rotate	Selector switch	M1 (thumb); 4
		Reposition	Hand	M2 (wrist rotation)
		Reposition	Hand	M4

3. Results and Discussion

3.1 M16 rifle task.

Nearly 70% (69.2%) of the elements were categorized in the Movement Class (M1 – M7) with nearly 60% (59.9%) requiring M1 through M3 movements with an average distance of movement being less than or equal to 6." Terminal Activities such as "Get" and "Put" comprised of over 25% (25.4%) of the elements, and Auxiliary Activities comprised of the remaining 5% of work elements. This illustrates that the majority of the work elements associated with Maintaining an M16-series Rifle require little or infrequent use of "whole arm", "extended arm", and/or "trunk movement" actions; therefore, Soldiers with back injuries will have minimal to zero complications in completing this task successfully. On the contrary, dexterity of fingers and hands are essential in performing this task.

Additionally, over 61% of the peak force exertions were limited to three or less (on a 10-point scale); with less than 7% of the exertions requiring a peak force greater than five. This illustrates that minimal force is required to accomplish the majority of this task. Although, the peak force required to accomplish this task was 10, this maximum exertion occurred only four times out of 161 work actions (during the elements of removing and installing the handguards on the rifle). Furthermore, although the *actual* time spent accomplishing work elements associated with the handguards (Removing – 18.89 seconds; Installing – 85.7 seconds), our MODAPTS analysis shows that the time *required* to remove the handguards is 5.3 seconds and the time to install the handguards is 6.7 seconds, for a total time of 12 seconds. This large contrast in *actual* versus *required* time is due to current design of the handguard assembly.

Further dissecting the data into each of the three subtasks, we find that for the subtask "clearing the rifle", over 93% of the movement elements required an M3 or less movement with a maximum peak force of only six. Additionally, 72% of all of the "decide" MODs for the entire M16 task were found in the "clearing the rifle" subtask. This illustrates that although force requirements may be low in accomplishing this subtask, much finger manipulation and binary decision making is required. Analysis from the second subtask, "disassembly", showed 87% of all the movement elements involving an M3 or less movement with a maximum peak force of only five (when handguard disassembly element was omitted from analysis). Similarly, for the third subtask, "assembly", movement classes constituted over 2/3 of the activities with 81% of all the movement elements requiring an M3 or less movement. Further, over 98% of peak force exertions were five or less (when handguard assembly element was omitted from analysis) with the only outlier (peak force = 7) being the method in which the Soldier used to "unlock the bolt" prior to inserting it into the upper receiver. In addition to the emphasis on movement activities M3 and below, this illustrates that peak force exertions can be reduced within the overall M16 task by improving the methods in which a Soldier uses to remove/install the handguard assembly and unlocks the bolt.

3.2 CBRN protective equipment task.

Our findings show a distribution that resembles a "bell-shape" for the movement and terminal classes. The most frequently occurring movement class was M3 (55 occurrences) compared to the second most common movement classes of M1 and M4 (29 occurrences each). Additionally, we found that over 42% of the movement elements (when B17 MOD was factored in) required the Soldier to use "extended arm", "trunk", or "bending" movements in order to accomplish the task. Further, over 44% (44.5%) of the elements required a movement of 6" or less with over 42% of movements in excess of 12". This was in strong contrast to the M16 task, which required less than 16% of movement elements to be in excess of 12". Although there is still a large number of elements in the CBRN protective equipment task, which requires use of hand and finger manipulation (56), there are 98 other movements involving forearm and higher manipulation. Further, the most significant analysis shows the contrast in the peak force requirement between the two tasks. Whereas the M16 task required a maximum peak force of 10, with over 33% involving a force greater than two, only 2% of force requirements for the protective equipment task required a force greater than two.

4. Areas of improvement

4.1 General.

Due to the nature of the two tasks analyzed, recommendations are limited to six of the ten dimensions listed in the Functional Capacity Index (FCI); locomotion, hand and arm manipulation, bending/lifting, visual, auditory, and cognitive. The tasks analyzed during this research are largely affected by these types of disabilities. Soldiers with poor dexterity in their fingers trying to manipulate small weapon components as well as Soldiers who have back problems trying to quickly don a protective suit could benefit greatly from improvements in the design of the equipment and prescribed methods in which these tasks are conducted. Although visual, auditory, tactile, and even multi-modal types of recommendations show promising improvements in performance, recommendations focus on design changes and process modifications, which require more physical interactive methods.

4.2 M16 rifle: proposed changes in task methods and design.

Little detail is given in the methods used in performing the three tasks analyzed for the M16 rifle. It is recommended that standardized work methods are further detailed and codified describing the "one best method" in performing these tasks. By first describing in detail the best methods for performing a given task followed by conducting rigorous training instruction, Soldiers will have a better understanding of the most efficient methods in performing a given task. For example, by describing the ideal placement of hands as well as which body parts to use when removing handguards, unnecessary movements can be eliminated and peak force requirements lessened, thus reducing Soldier injuries, equipment/part damage, task completion time. Another example for a process change is the method one uses to "unlock" the bolt prior to inserting it into the upper receiver. The current method of "whipping" the bolt carrier in a downward manner requires an approximate peak force of seven. By teaching Soldiers the approved method of unlocking the bolt is by grasping the bolt carrier in one hand and pulling the bolt out with the other, the peak force required to perform this element will be reduced from seven to three.

The execution of this task is constrained largely by the current design of the handguard assembly (Figure 3). By redesigning the handguard assembly, peak force can be drastically reduced and the overall time to complete this task by 92.6 seconds. Potential modifications in redesign is to replace the current locking mechanism (slip ring), which holds the handguards in place, with a collar similar to one which holds weights on the ends of a barbell.

It is estimated that the time to remove the handguards will be reduced from 24.30 seconds to approximately four seconds (84% reduction). Additionally, assembly of the handguards can be reduced from 94.20 seconds in the video to about four seconds (96% reduction). Furthermore, the peak force requirement can be reduced from 10 to approximately five, depending on the tension set on the collar. Lastly, this will positively impact the MODAPTS assigned by alleviating several types of holds and exertions required.

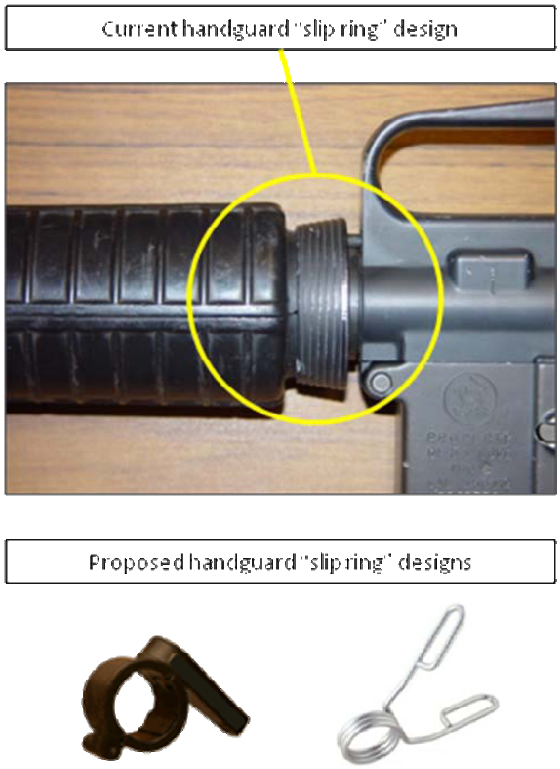


Figure 3 – Proposed Slip Ring Design

Another design change recommended for the M16 rifle concerns the bolt. The current process of inserting the bolt cam pin requires the bolt be aligned in a specific way inside the bolt carrier. There are two possible ways a Soldier can insert the bolt into the bolt carrier, but only one way that will allow for the bolt cam pin to properly fit. Although there is a small detent located next to the opening on the bolt, which Soldiers use as a guide when inserting it into the bolt carrier, this is often confused or forgotten due to its non-informative design. It is recommended that a recognizable "mark" (such as a star) be placed on both the outer rims of the bolt and bolt carrier, which can be used to align the two "marks" up while inserting the bolt into the bolt carrier. This will mitigate the probability a Soldier will improperly align the openings in the bolt and bolt carrier prior to trying to insert the bolt cam pin resulting in a reduction in overall assembly time. Although the Soldier in the video was recorded as requiring an abnormally high time of 41.71 seconds to insert the bolt cam pin due to the openings being improperly aligned, it is likely that this error still occurs frequently. Incorporating this change eliminates this error from occurring, thus reducing assembly time to approximately one second.

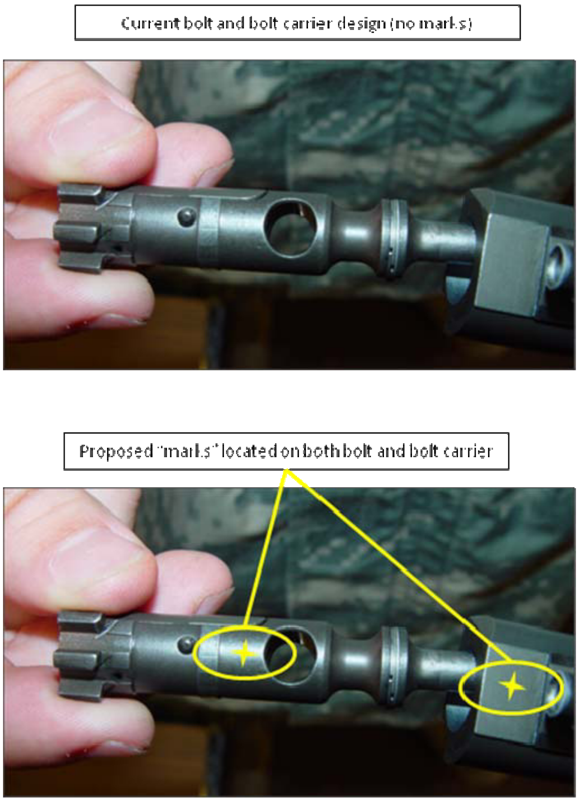


Figure 4 – Proposed Bolt Carrier Design

The last proposed engineering change concerns the charging handle. It is estimated that the task element of "charging the rifle" requires a peak force of six. This moderately high level of exertion is inherent in order for the weapon to perform optimally. Thusly, the force required to pull the charging handle back cannot be reduced through any change in the method. However, it is proposed that the charging handle design is changed to be equipped with a 1-1/2" pull bar that extends vertically from the rear of the charging handle to a location, which does not hinder the Soldier's vision when looking through the rear sight post (Figure 5).

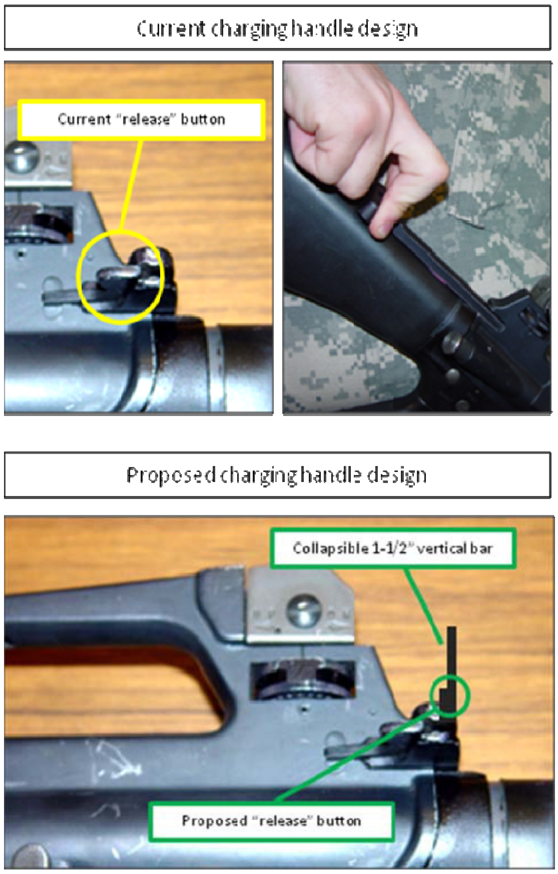


Figure 5 – M16 Rifle Charging Handles

This allows the Soldier to grasp the charging handle using a "palm-type" grip instead of his/her index and middle fingers. This change is estimated to reduce the force level required by the Soldier to charge the rifle from six to approximately five.

4.3 CBRN Equipment: proposed changes in task methods and design.

The hook on the protective mask waistband would benefit from ergonomic design modifications (Figure 6). The actual time required to complete the subtask of "secure waistband" (12.9 sec) was twice the amount of time expected by our MODAPTS analysis (6.06 sec). Additionally, although still generally low, the required peak force of five estimated to depress the hook was the highest of any other element in the entire task. The next highest peak force rating was three, which only occurred four times in the 240 elements assigned a peak force rating. Lastly, this was the only work element in the entire task to be given a MODAPTS rating of “X4”, requiring additional force and effort to secure the hook to the eyelet.

http://allislandwebbing.com
Figure 6 –Mask Waistband Hooks

A recommended change in the methods used in these tasks concerns itself with the critical subtask of “don mask.” Ensuring that Soldiers follow the “one best method” in performing this subtask is critical to their health and welfare. The Soldier had to perform 52 work elements, resulting in an actual time to don his mask equal to 48.8 seconds (with glasses). It is recommended that the number of work elements required to perform the task be streamlined with subsequent training given to all Soldiers of this new method. According to MODAPTS, even with this high number of work elements, the time to complete this subtask is considerably shorter at 6.8 seconds. Either improving the method of completing this task or redesigning the protective mask and/or carrier will decrease the time required to complete the task and limit the potential for human and/or equipment error.

5. Summary and conclusions

The findings showed that for the M16 task, 69.6% of the actions performed by the user involved “movement” activities. Another 25.8% of the tasks involved “terminal” activities such as “Get” and “Put” actions. The remaining involved “auxiliary” activities such as “decide” and “extra force”. Whereas minimal force is required to execute the task of clearing the rifle (peak force = 4), more frequent and higher levels of exertion is required to disassemble and assemble the weapon (peak force = 10). By incorporating our proposed changes to the rifle design, peak force requirements to perform clearing, disassembly, and assembly of the M16 rifle can be reduced to five. Further, time can drastically be reduced by standardizing and codifying the processes in which a Soldier uses to perform these given tasks. The findings for the CBRN protective equipment task showed that 61.85% of the actions performed by the user involved “movement” activities and another 31.73% of the tasks involved “terminal” activities. By incorporating our design changes to the protective mask waistband hook, we can reduce the peak force requirement to only three, which will allow for an increased number of Soldiers with functional limitations in their fingers to perform this task with less difficulty.

6. Implications for further research

There is room for improvement across four areas: gaining institutional knowledge on MODAPTS, expanding the data capture/analysis platforms, increasing the sample size, and integrating these techniques within the military force.

Although MODAPTS is a respected method of documenting and calculating work performances, analysis can be improved using researchers with a greater depth of understanding of the MODAPTS definitions and criteria. By obtaining more formal institutional knowledge on MODAPTS, researchers can be synchronized resulting in consistent analysis among several researchers.

Next, we were constrained by the limitations given to us by the computer and data programs used in synthesizing the tasks. By expanding the computer program to allow researchers to input angles of joint rotation experienced by the task performer as well as cross-referencing the data with anthropometric standards, more detailed MODAPTS analysis can be determined across a broader range of subjects such as 5th and 95th percentile males/females. More attention can be made to recording video in a more controlled and sophisticated environment. "Human error" and "abnormal actions" were found in analyzing the data. Further, the use of high resolution cameras shot simultaneously at several vantage points as well as incorporating eye tracking devices will be of benefit in the collection and analysis of the data.

Also, garnering a larger sample size between 20-50 subjects of various physical and mental capabilities will allow for comparison with respect to the control to determine if indeed the findings and recommendations presented in this paper are valid. Careful analysis should be done prior to obtaining subjects to ensure the number of subjects and the limitation of each subject match research objectives.

Lastly, being able to integrate this practice in analyzing *all* Soldier Common Tasks as well as prioritized non-standard tasks will impact the entire military force. Ultimately, it can be envisioned to obtain video (from handheld/portable devices) of Soldiers performing non-routine tasks during deployment operations. This video can be sent back to a reachback center who can determine the one best way for the task to be performed most efficiently, safely, and universally given left/right limits of human capability.

Endnotes

[1] "The Movement Class pertains to actions of the body that result in a changing the location or position of the fingers or hands. There are seven movement subclasses based on which part of the body is involved – finger, hand, forearm, arm, shoulder or trunk, which require 1, 2, 3, 4, 5, and 7 MODs respectively. Movement classes are almost always followed by a Terminal Class element. There are two terminal subclasses – Get and Put. These elements pertain to gaining control over a work object with the hand or placing an object is already in the hand at a particular location or orientation. Auxiliary Class elements pertain to those actions that can be performed at the same time as Move or Terminal class elements. This class includes Read, Juggle, Extra Force, Walk, Foot Action, Bend and Arise, Sit and Stand, Crank, Vocalize, Use, Eye Control, Hand Write, Load Factor, Decide, Count, and Machine Cycle Time" (Armstrong, 2009).

References

[1] Armstrong T.: (2009). Measurement and Design of Work Course Pack – Chptr 8: MODAPTS. University of Michigan.

[2] Armstrong T., Brininger T.: Analysis of Task Demands for Rehabilitation of Injured Soldiers. The First Scientific Conference on Work Disability Prevention and Integration, Angers, France, September 2-3, 2010.

[3] Brandt, E. N., & Pope, A. M. (1997). Enabling America: assessing the role of rehabilitation science and engineering . Washington D.C.: National Academy Press.

[4] Bridges, C. D. (1946). Job Placement of the Physically Handicapped. York: The Maple Press Company.

[5] Department of the Army. (2008). Army Regulation 40-501 Standards of Medical Fitness. Washington D.C.: HQ, DA.

[6] Department of the Army. (2005). Soldier's Manual of Common Tasks: Skill Level I (pp. 3-27 - 37, 3-105, 110, 3-120 - 126, 3-328 - 355). Washington D.C.: HQ, DA.

[7] Fischer, H. (2009). United States Military Casualty Statistics: Operation Iraqi Freedom and Operation Enduring Freedom. Washington D.C.: Congressional Research Service.

[8] Gilbreth, F. B., Gilbreth, L. M. et al. 1953. The writings of the Gilbreths. Homewood, Ill., R.D. Irwin.

[9] Heyde, C. G. (1990). Modular Arrangements of Predetermined Time Standards (MODAPTS). Int'l MODAPTS Association.

[10] Smith, R. V., & Leslie Jr., J. H. (1990). Rehabilitation Engineering. Boca Raton: CRC Press.

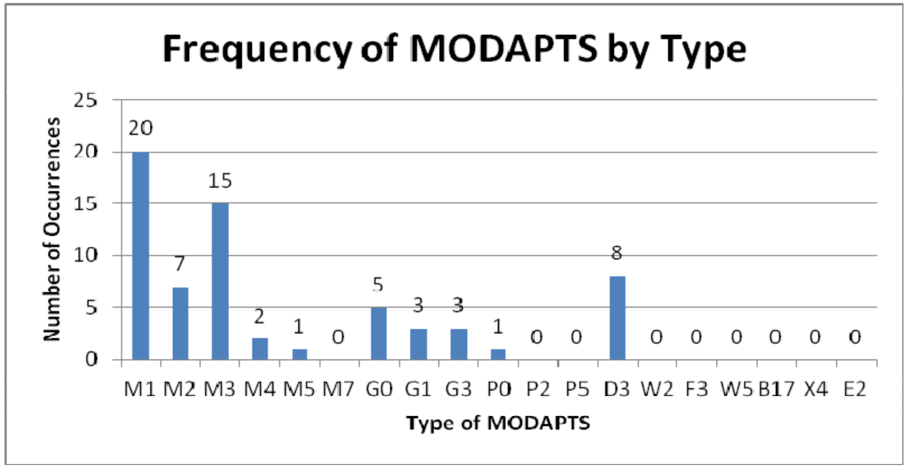
n	Time	Delta t	Body Pt	Action	Object	Demands	PF	Comments	MODAPTS ASSESSMENT																		
									M1	M2	M3	M4	M5	M7	G0	G1	G3	P0	P2	P5	D3	W2	F3	W5	B17	X4	E2
1	0.00		Start	Start video				General: Make a MODAPT field separate from demand tab																			
2	11.90		Task 1	Clear Rifle	Rifle			Clear rifle prior to disassembly																			
3	12.40		Task 1a	Place weapon on safe	Rifle	M3,G1,M2,D3,M2,D3,M1,M1,M2,M4; 4		General comment: MODAPTs doesn't include closing dust cover subtask																			
4	13.59	0.41	BH	Close dust cover	Rifle	M3,G1,M2,D3; 2	2	Closing dust cover is an unnecessary step for the task of placing weapon on safe																			
5	14.00	0.59	RH	Reach	Dust cover	M3		Move RH to close dust cover			1																
6	14.59	0.31	RH	Grasp	Dust cover	G1 (pinch);1	1									1											
7	14.90	0.10	RH	Move	Dust cover	M2 (pinch); 2	2	Close dust cover		1																	
8	15.00	0.09	RH	Inspect	Dust cover	D3 (sight, sound, touch, decide)		Metallic click													1						
9	15.09	0.50	RH	Reach	Pistol grip	M3 (sight, touch)					1																
10	15.59	0.51	RH	Grasp	Pistol grip	G1 (power grip); 3	3									1											
11	16.10	0.20	BH	Rotate	Weapon	M2 (power grip); 3	3	Dust cover skyward (unnecessary step)		1																	
12	16.30	0.20	BH	Inspect	Selector switch	D3 (sight, touch, decide safe)		Unnecessary step. Selector switch is on opposite side of rifle SM is currently viewing													1						
13	16.50	1.10	BH	Rotate	Weapon	M2 (power grip); 3	3	Rotate weapon so that selector switch is skyward		1																	
14	17.60	1.40	BH	Inspect	Selector switch	D3 (Sight, touch, hear, and decide in safe position)		Metallic click, orientation of switch													1						
15	19.00	0.50	RH	Rotate	Selector switch	M1 (thumb); 4	4	Safe to semi (Unnecessary step; weapon was already on safe)	1																		
16	19.50	0.89	RH	Rotate	Selector switch	M1 (thumb); 4	4	Rotate selector switch from semi back to safe (Unnecessary step; weapon was already on safe)	1																		
17	20.39	1.11	RH	Reposition	Hand	M2 (wrist rotation)		Reposition hand on pistol grip		1																	
18	21.50	1.00	RH	Reposition	Hand	M4		Reposition hand on pistol grip (SM does this to get buttstock between forearm and body)				1															
19	22.50		Task 1b	Remove magazine	Rifle	M1,M3,G1,M1,M3,M5,M1,P0,M2,M3,G0; 5																					
20	22.60	0.09	RH	Move	Index Finger	M1		To magazine ejector button	1																		
21	22.69	0.31	LH	Move	Hand	M3		To magazine			1																
22	23.00	0.19	LH	Grasp	Magazine	G1 (Palm pinch); 1	1	Bottom of magazine								1											
23	23.19	0.31	RH	Press	Magazine ejector button	M1; 5	5	Button	1																		
24	23.50	0.10	LH	Pull	Magazine	M3; 4 average (depends on the tightness of fit with magazine in weld)	4	Pull down on magazine while button is depressed to release magazine			1																
25	23.60	0.09	LH	Move	Magazine	M5; 1	1	To table					1														
26	23.69	0.41	RH	Move	Finger	M1		Remove finger from magazine ejector button	1																		
27	24.10	0.09	LH	Position	Magazine	P0 (Sight, touch); 1	1											1									
28	24.19	0.31	LH	Release	Magazine	M2				1																	
29	24.50	0.10	LH	Move	Hand	M3		On upper receiver			1																
30	24.60	0.90	LH	Hold	Upper receiver	G0 (Palm of hand and fingers); 3	3	General comment: MOD for Hold?							1												
31	25.50		Task 1c	Lock bolt open	Rifle	M3,G3,M3,G0,M4,M1,M1,M1,M1,M1,M3; 6																					
32	25.50	0.10	RH	Reach	Charging handle	M3					1																
33	25.60	0.40	RH	Grasp	Charging handle	G3 (Middle and index finger); 1	1	General comment: may be G1									1										
34	26.00	0.10	LH	Move	Hand	M3		To magazine weld			1																
35	26.10	0.79	LH	Hold	Magazine weld	G0 (Power pinch); 6	6								1												
36	26.89	0.11	RH	Pull	Charging handle	M4 (Index and middle finger); 6	6					1															
37	27.00	12.20	LH	Move	Thumb	M1		To bolt catch	1																		
38	39.20	0.09	RH	Release	Charging handle	M1; 3	3	Slowly release charging handle approxmately 1/2" to allow bolt to lock into place	1																		
39	39.29	0.50	LH	Press	Bolt catch	M1 (thumb); 2	2	Depress bottom portion of bolt catch (abnormal length of time to to several attempts to lock bolt to rear)	1																		
40	39.79	0.10	LH	Move	Thumb	M1 (thumb) move		Remove thumb from bottom portion of bolt catch	1																		
41	39.89	1.90	RH	Move	Charging handle	M1 (thumb); 1 (once bolt is locked, no tension on charging handle)	1	Return charging handle to closed position	1																		
42	41.79	1.50	LH	Move	Hand	M3		To upper receiver			1																
43	43.29		Task 1d	Ensure selector switch is on safe	Rifle	D3; 0																					
44	43.39	5.31	None	Inspect	Selector switch	D3 (Sight, decide on safe)		General comment: Body part: none?													1						
45	48.70		Task 1e	Inspect receiver	Rifle	M3,G0,M3,M2,D3; 2																					
46	49.29	0.21	BH	Move	Rifle	M3; 2	2	To stomach level			1																
47	49.50	1.00	BH	Hold	Rifle	G0 (Power pinch); 2	2	General comment: MODAPT for hold							1												
48	50.50	0.89	BH	Move	Rifle	M3; 2	2	Closer to eye level			1																
49	51.39	0.11	BH	Rotate	Rifle	M2 (Hand/wrist rotation); 2	2			1																	
50	51.50	8.70	BH	Inspect	Chamber	D3 (Sight and decide chamber empty (clear))															1						
51	60.20		Task 1f	Allow bolt to go forward	Rifle	M1,M1,M1,M1; 3																					
52	61.20	1.00	LH	Move	Thumb	M1 (thumb)		Move thumb to upper portion of bolt catch	1																		
53	62.20	0.46	LH	Press	Bolt catch	M1 (thumb); 3	3	Press lower portion of bolt catch to release bolt	1																		
54	62.66	1.93	LH	Move	Thumb	M1 (thumb)		Move thumb back to original location	1																		
55	64.59	5.00	RH	Pull	Trigger	M1; 3	3		1																		
56	69.59		Task 1g	Place selector switch on semi	Rifle	M1; 4																					
57	69.70	0.30	RH	Rotate	Selector switch	M1; 4	4	Move selector switch from safe to semi	1																		

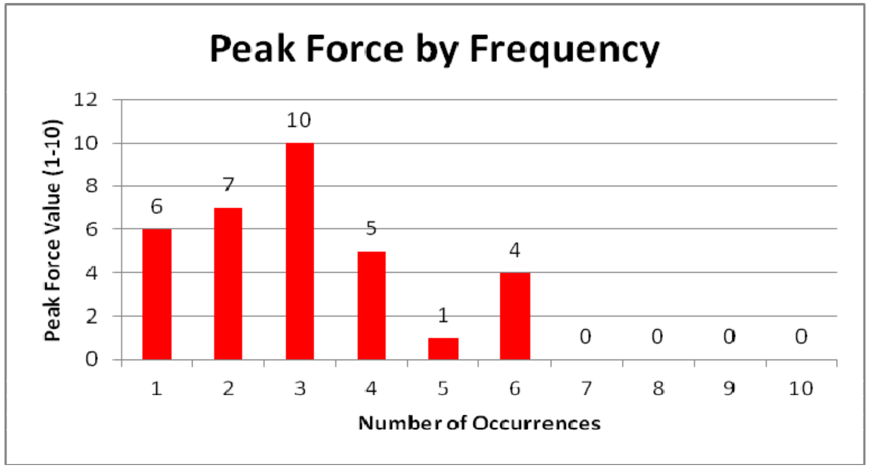
Appendix 1: Excerpt from M16 Job Data Collection and Analysis – Task 1 (Clearing the Rifle), pg 1 of 2

58	70.00		Task 1h	Squeeze	Trigger	M1,D3; 3		Squeeze trigger using index finger																			
59	72.29		Task 1i	Charge Weapon	Rifle	M3,G3,M1,M1,M3,G0,M1,D3; 6		SM charging a second time not included in overall MODs																			
60	73.70	0.80	LH	Reach	Charging handle	M3					1																
61	74.50	0.50	LH	Grasp	Charging handle	G3		General comment: G1?									1										
62	75.00	1.29	LH	Move	Charging handle	M1; 6	6	Move charging handle to rear	1																		
63	76.29	0.50	LH	Release	Charging handle	M1			1																		
64	76.79	0.61	LH	Reach	Upper receiver	M3		Move hand back to upper receiver			1																
65	77.40	0.50	LH	Grasp	Upper receiver	G0									1												
66	77.90	3.50	BH	Squeeze	Trigger	M1,D3; 3	3	SM mistakenly fired weapon preventing the weapon from being placed on safe. This requires the SM to charge weapon for a second time.	1												1						
67	81.40	1.00	RH	Squeeze	Trigger	M1,D3; 3	3	SM fires weapon when he shouldn't have resulting in him having to charge weapon for a second time	1												1						
68	82.40	0.50	LH	Reach	Charging handle	M3		Move hand to charging handle			1																
69	82.90	0.39	LH	Grasp	Charging handle	G3		General comment: G1?									1										
70	83.29	0.41	LH	Pull	Charging handle	M3; 6	6	Pull charging handle to rear			1																
71	83.70	0.50	LH	Release	Charging handle	M2				1																	
72	84.20	0.09	LH	Reach	Upper receiver	M3		Back to upper receiver			1																
73	84.29	1.21	LH	Hold	Upper receiver	G0; 3	3								1												
74	85.50		Task 1j	Place weapon on safe	Rifle	M1,D3; 4																					
75	86.20	2.00	RH	Rotate	Selector switch	M1,D3; 4	4	Selector switch to safe	1												1						
76	88.20		BH	Wait				Task 1 complete																			

PEAK FORCE		
	1	6
	2	7
	3	10
	4	5
	5	1
	6	4
	7	0
	8	0
	9	0
	10	0

	TOTAL MODAPTS ASSESSMENT FOR TASK 1-3																			
	M1	M2	M3	M4	M5	M7	G0	G1	G3	P0	P2	P5	D3	W2	F3	W5	B17	X4	E2	TOTAL
TOTAL MODAPTS BY TYPE	20	7	15	2	1	0	5	3	3	1	0	0	8	0	0	0	0	0	0	65
% MODAPTS BY TYPE	30.8%	10.8%	23.1%	3.1%	1.5%	0.0%	7.7%	4.6%	4.6%	1.5%	0.0%	0.0%	12.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
TOTAL TIME IN SECONDS (# MODS X 0.129 SEC)	2.58	1.81	5.81	1.03	0.65	0.00	0.00	0.39	1.16	0.00	0.00	0.00	3.10	0.00	0.00	0.00	0.00	0.00	0.00	16.51
% TIME TO ACCOMPLISH TASK PER MODAPTS	15.6%	10.9%	35.2%	6.3%	3.9%	0.0%	0.0%	2.3%	7.0%	0.0%	0.0%	0.0%	18.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
ACTUAL TIME TO ACCOMPLISH TASK IN VIDEO	69.2%						16.9%			1.5%			12.3%							68.31
	100.0%																			





Appendix 1: Excerpt from M16 Job Data Collection and Analysis – Task 1 (Clearing the Rifle), pg 2 of 2