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Report No. 00-04

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SUMMARY OF FINDINGS FOR INITIAL TASK IDENTIFICATION FOR MILITARY OPERATIONS IN URBAN TERRAIN (MOUT)*

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Progress Report
17 Nov 99

*Technical Report 00-04 supported by the Office of Naval Research and Bureau of Medicine under Work Unit No. N63706 M0096.002-6716. The views expressed are those of the authors and do not reflect the official policy or the position of the Department of the Navy, Department of Defense, or the U.S. Government. Approved for public release; distribution is unlimited.

Summary

Background

Demographic and geopolitical trends make it certain that urban settings will be the site of military conflicts more often in the future than in the past. An Enhanced Human Physical Performance (EHPP) workshop was held at Quantico, VA, 13-14 Oct 1999, to identify the physically demanding tasks in military operations in urban terrain (MOUT).

Workshop Findings

Fighting Load. Marines may carry a different combat load in MOUT operations than in other settings. Expert opinion indicates that Marines most likely will carry a fighting load only. The weight of this load was estimated at 59 pounds. This figure is substantially less than would be expected for a full marching load.

MOUT Tasks and Ratings. Sixteen subject matter experts (SMEs) identified the most physically demanding tasks for offensive and defensive operations and for specific physical activities (e.g., lifting, jumping). Forty-six tasks were identified then rated on 7-point scales for level of physical demand, importance, and frequency of performance.

Statistical Analysis

Tasks were grouped based on a cluster analysis of the average SME ratings. A three-cluster solution provided the most useful task classification. One cluster consisted of tasks with high ratings on all three scales. A second cluster consisted of tasks with high physical demand ratings, but moderate frequency and importance ratings. The third cluster consisted of tasks with low importance and frequency ratings.

Critical Tasks

The first task cluster became the primary reference point for physical ability requirements in MOUT because the tasks were physically demanding, occurred often, and were important when they occurred. This cluster included casualty evacuation, movements through windows, climbing over walls, moving supplies and ammunition up and down stairs, fire and movement, and lifting weights overhead. MOUT operations in extreme expeditionary environments was discussed as a factor that made task performance more difficult.

Physical Conditioning Implications

Exercise physiologists summarize physical abilities in terms of three broad categories. Muscle strength is the maximum force generated by a muscle or group of muscles. Muscle endurance is the length of time that a person can maintain a submaximal force or the number of continuous repetitions of a movement involving submaximal force. Aerobic capacity is the ability of the cardiorespiratory system to deliver oxygen to and remove waste products from working muscles.

MOUT should place exceptional demands on Marines' muscle strength and muscle endurance, particularly in the upper body. Upper body strength and endurance will be needed to move through windows and over walls and to lift weights overhead. Leg power and endurance will be needed to move up and down stairs and to sprint short distances. Aerobic capacity may be less important in MOUT than in other operational settings because sustained efforts by large muscle groups (e.g., marching) are required less often.

Conclusions

MOUT physical conditioning programs should focus on upper and lower body muscle strength and endurance, particularly bursts of power lasting 10-20 seconds. Normal preparations for the Physical Fitness Test should provide adequate aerobic capacity. Obstacle courses may be a useful means of developing the required strength and muscle endurance.

Background

The Enhanced Human Physical Performance (EHPP) Workshop held at Quantico, VA, 13-14 Oct 1999, included a number of activities designed to identify the physically demanding tasks occurring in Military Operations in Urban Terrain (MOUT). The workshop included subject matter experts' (SMEs) nominations for tasks that are the most physically demanding. The SMEs also provided ratings of the tasks to indicate how demanding each task was, how frequently it had to be performed, and how important it was. This summary reports the results of initial analyses performed to summarize the SME information.

Definition of a Fighting Load

The task identification elements of the workshop focused on specific behaviors that Marines must perform in MOUT. The task identification proceeded with the understanding that each activity would be performed while carrying a fighting load. This fighting load represents the expected weight of clothing and basic combat gear, including weapon, ammunition, helmet, body armor, and 782 gear. An earlier presentation at the conference made a distinction between a combat and marching load, where the individual would carry additional items (e.g., food, clothing, shelter) to the operational site, and a fighting load. The fighting load would consist of the minimum equipment necessary to carry out a tactical combat mission.

The information provided to workshop attendees indicated that the anticipated fighting load was 59 pounds. Ongoing programs may increase this weight. For example, work on an ongoing project titled "Future Warrior Architecture (FWA)-Infantry," being conducted at the U.S. Army Soldier Systems Center, is exploring system concepts that would place significantly heavier loads on soldiers (i.e., 75-106 pounds). However, those systems are not currently in place. Substantial redesign could take place before any new system is actually fielded. For the immediate future, therefore, conditioning programs can be based on the assumption that Marines will have fighting loads of 59 pounds.

The precise accuracy of the assumed fighting load may not be critical to determining the nature of the required conditioning programs. The required structure of these programs probably depends more on the precise nature of the physical activities that must be performed (e.g., lifting self and the fighting load) than it depends on the weight of the fighting load. The actions will determine which muscle groups are involved. Weight of the fighting load will determine the forces that must be generated and also could influence how long some activities continue (e.g., the length of time required to climb in a window). These effects of variation in the fighting load are more important for setting standards and target levels for determining when a conditioning program has produced the required capabilities than for determining the general structure of the programs. The intensity and duration of the programs can be adjusted at a later time to allow for changes in the fighting load as modifications are introduced. For these reasons and because future fighting loads cannot be accurately forecast at this time, the task identification was undertaken with the explicit assumption that each task or activity would be performed with a fighting load of 59 pounds.

Task Identification

SMEs identified the physically demanding tasks in a MOUT environment. SMEs were asked to nominate tasks or activities that occurred in the MOUT setting that would represent significant physical demands on Marine Corps personnel. To begin with, task identification proceeded by asking the experts to consider MOUT in general. When no more tasks were identified under this set of instructions, one of the experts suggested systematic consideration of the different general categories of activity occurring in this setting (e.g., offensive, defensive). Finally, a set of action verbs that had been identified from Marine Corps manuals and the general ergonomics literature was reviewed to ensure that these actions either were covered in the existing list or were not sources of significant physical demands in the MOUT environment. The resulting initial task list consisted of 58 tasks.

Task Refinement

After tasks were identified, the overall list was reviewed with two primary objectives in mind. First, overlapping or highly similar task statements were identified to eliminate redundancy. Second, the original statements were modified to include distances, weights, or other specifications when the experts felt these were necessary to define the tasks well enough to make it possible to rate the physical demand levels involved. Some tasks were removed from the list at this point because they could not be stated with sufficient precision or were judged equivalent to other tasks in the list once the clarifications had been added. Some tasks were collapsed into a single category (e.g., different methods of breaking through a door) during this process. The final set consisted of 46 tasks.

Task Rating

Sixteen SMEs rated each task in the list on three 7-point scales. One scale asked about the level of physical demand involved in the task (1 = Easiest, 7 = Most difficult; ratings relative to other MOUT tasks/activities). A second scale indicated the importance of the task or activity (1 = Least important, 7 = Most important). The third scale indicated the frequency with which the activity was likely to be performed (1 = Monthly, 7 = Daily).

Data Analysis

Analysis of Variance. The first analysis step was a task-by-rater evaluation of these ratings. A two-way analysis of variance was performed with SPSS-PC General Linear Model subroutine (SPSS Inc., Chicago, IL). The analysis model was restricted to main effects of task and rater. Task and rater were treated as random effects variables because each factor was represented by a sample of entities from a potentially larger universe of tasks and raters. The analysis model was restricted to the main effects of rater and task so that the task-by-rater interaction could be used as an error term in the analysis.

Task and rater significantly affected each of the three ratings. The effects of task and rater were stronger for the physical demand and frequency ratings than for the importance ratings.

The fact that the ratings were sensitive to differences between tasks was the key finding. This result meant that there was some consensus among the raters regarding which tasks were most physically demanding. This element of the ratings was crucial given the general objective of developing suitable physical conditioning programs to ensure adequate task performance. If the physical demand ratings had not differed significantly, the results would have suggested that either all tasks were of roughly comparable difficulty or the ratings were too unreliable to indicate which tasks were most difficult. The significant findings suggest that some tasks are more physically demanding than others and that raters agree to some extent about which tasks are most demanding. While this result is consistent with common sense, empirical confirmation of this point is an important starting point for scientific validation of the ratings.

Cluster Analysis. Cluster analysis is a statistical procedure that is designed to group objects into categories. Entities within a category have similar, but not necessarily identical, attributes. Objects in different categories have distinct patterns of attributes. The purpose of the present cluster analysis was to group the tasks into a few general categories based on the ratings of physical demand, frequency, and importance. The results of the task identification and rating procedures then could be described by examining first general categories, then individual tasks within each category.

A series of cluster analyses were conducted to describe the general structure of the task data. A hierarchical agglomerative clustering algorithm was applied first. Group assignment was based on average within-group distances. Squared Euclidean distance was the similarity measure employed. Cluster assignments for each task were determined for two- to five-cluster solutions. This range of cluster solutions was examined because cluster analysis ordinarily does not split sets of items into groups of equal size. Thus, although the average group size for 46 tasks divided into five groups would be 9.2 tasks per group, it was expected that one or two clusters would include as few as four or five tasks by the time five clusters were extracted. Clusters with fewer than five tasks would be of limited interest as, for example, examining 15 or 20 clusters, each with two or three tasks, would be little different from examining 46 individual tasks. Thus, extending the analysis to a five-cluster solution was expected to push the cluster size to the low size limit for a useful solution.

The hierarchical agglomerative procedure pointed to a three-group classification as a reasonable basis for dividing the tasks. Each cluster in this solution included 10 or more tasks. When a fourth and a fifth cluster were extracted, one cluster consisted of a single outlier task. Thus, the three-group solution was the most detailed classification that provided clusters of reasonable size in this analysis procedure.

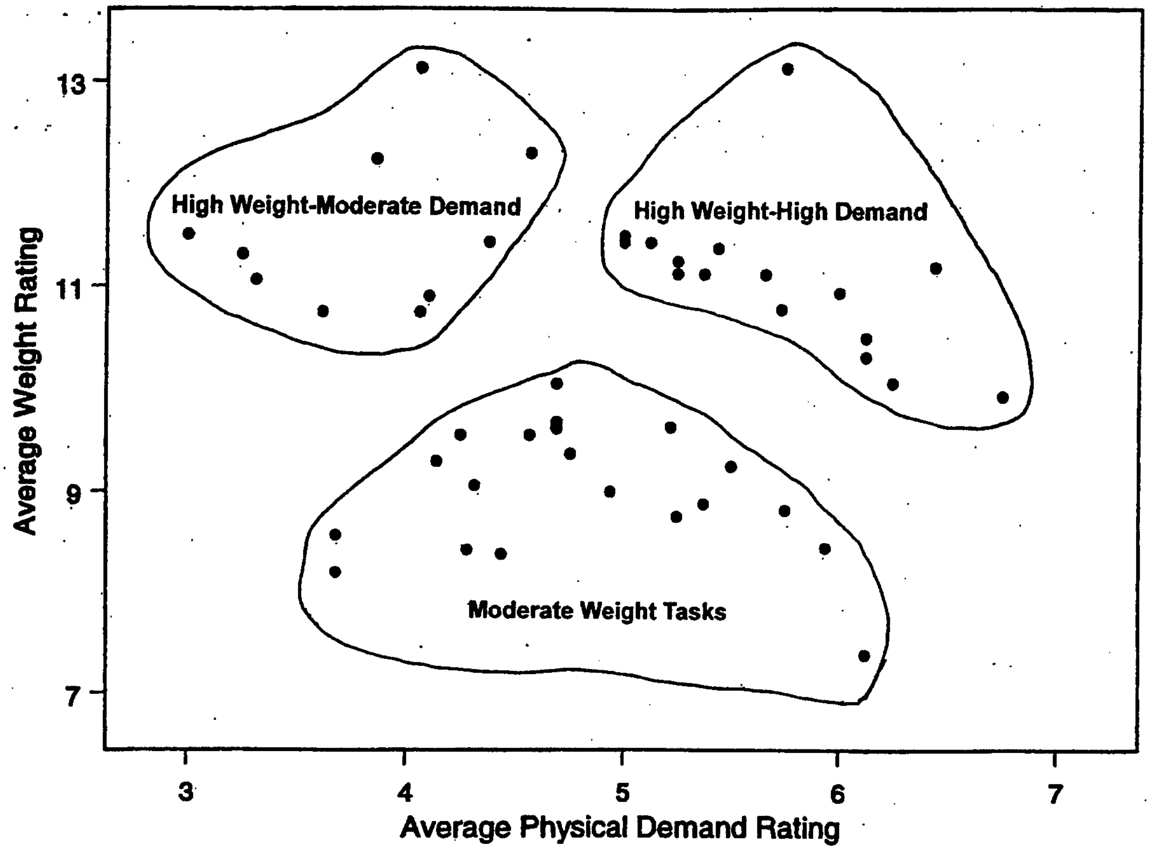
A second clustering algorithm (KMEANS) was applied to the data to determine how much cluster definitions depended on the choice of analysis methodology. Using this procedure, more than three groups of acceptable size could be identified. However, a three-group solution still was adopted. The three-group solution was adopted because the KMEANS algorithm produced the same three groups as the hierarchical agglomerative three-cluster solution. This solution, therefore, provided a relatively simple general classification of the tasks that was not dependent on the specific analysis algorithm chosen.

Figure 1 on the following page shows the three groups identified in the cluster analysis. This figure plots locations of individual tasks in a space defined by the physical demand rating for each task and a weight for each task. The weight variable was the average of the importance and frequency ratings for the task. These two ratings were averaged for several reasons. One reason was that averaging made it possible to present a simple two-dimensional representation of task space. A second reason was that the importance and frequency ratings are conceptually related. Each of these ratings can be viewed as a qualifier that may be needed to make distinctions between tasks with comparable physical demands. If two tasks are equally demanding, the one that is more important and/or more frequently performed should be given greater weight in constructing physical conditioning programs. The third reason for combining the two was that the importance and frequency ratings were moderately strongly related for the set of tasks ($r = .71$). This result is reasonable if it is remembered that the task identification procedure was focused implicitly on identifying tasks that are at least minimally important for combat effectiveness. Given a set of tasks, all of which are at least somewhat important, it is reasonable to give higher importance to tasks that must be performed frequently. The observed correlation is consistent with this hypothesized frequency effect and indicates that the two ratings are empirically redundant. Combining them into a single indicator to provide an overview of the data, therefore, loses little information.

The task clusters consisted of three clearly defined sets located in different parts of the weight-physical demand space (Figure 1). One cluster is defined primarily by relatively low scores on the composite weight variable (range = 7.38-10.06). Physical demand scores were widely variable in this cluster (range = 3.69-6.13), so it was the weight scores that primarily differentiated this cluster from other tasks. Although the weight scores were low relative to other tasks, the values still fell near or above the midpoint on the weight scale (8.00). These tasks, therefore, were labeled the "Moderate Weight" tasks ($n = 20$ tasks).

The two remaining clusters each consisted of tasks with average weight scores of 10.00 or higher (with the exception of a single 9.94 score). These clusters, therefore, consisted of what can be labeled "High Weight" tasks. Physical demands was the factor that distinguished the items in one cluster from those in the other cluster. Tasks in one cluster received average physical demand ratings near the midpoint (4)

Figure 1. Distribution of Tasks in Weight-Physical Demand Space



of the physical demand scale (range = 3.25-4.56). Tasks in the other cluster received average ratings well above the midpoint of the scale (range = 5.00-6.75). These two clusters, therefore, were labeled "High Weight-Moderate Demand" (*n* = 10 tasks) and "High Weight-High Demand" (*n* = 16 tasks), respectively.

To summarize, the cluster analysis indicated that the tasks could be divided into three broad categories. A large number of tasks were grouped together based on a common attribute of receiving low scores on the weight dimension. A second group of tasks received high scores on the weight dimension, but those tasks were rated as only moderately physically demanding. A third group received high scores on both the weight dimension and the physical demand ratings. The high weight-high demand group of tasks logically is the primary reference point for developing physical conditioning programs. The tasks within this cluster and the other clusters are examined in the following sections.

High Weight-High Demand Tasks

Table 1 lists the high weight-high physical demand tasks shown in the upper right-hand quadrant of Figure 1. This task list contains several general themes. First, casualty evacuation is a recurrent topic.

This task clearly is one of the most demanding physical activities that will be undertaken in MOUT. The exact level of demand depends on how the casualty is carried and the movement (i.e., upstairs or downstairs). Whatever the nature of the movement, four of the top six tasks were casualty evacuations.

Movement up or down stairwells is another recurrent theme. This type of movement figures in both casualty evacuation and the movement of supplies and ammunition.

Table 1. List of High Weight-High Physical Demand Tasks

Task No.	Task Content	Rating Weight	Rating Physical Demand
3	Individual carries casualty upstairs	9.94	6.75
44	Perform fireman carry to evacuate a casualty	11.19	6.44
27	Lift 75-100 pounds overhead	10.06	6.25
19	Climb over a seven-foot wall or obstacle	10.50	6.13
4	Individual carries casualty downstairs	10.31	6.13
7	Individual drags a casualty	10.94	6.00
32	Up/down/sprint sequence for fire and movement	13.13	5.75
12	One man pulls another through a window	10.78	5.73
38	Operate in extreme expeditionary environments	11.12	5.66
5	Carry ammunition/supplies (50-75 pounds)upstairs	11.38	5.44
6	Carry ammunition/supplies (50-75 pounds)downstairs	11.44	5.13
9	Climb through a high window unassisted by pulling on sill	11.13	5.38
11	One man lifts another up to high window	11.25	5.25
10	Climb through a low window unassisted by pushing on mantle	11.13	5.25
15	Climb up five floors of stairs	11.50	5.00
8	Climb through a window unassisted by pulling on frame	11.44	5.00

Note. Tasks shown are those in the cluster appearing in the upper-right quadrant of Figure 1. The weight variable is the sum of the importance and frequency ratings.

Entering a building through a window is another recurrent element in the high weight-high physical demand tasks. Based on discussions at the workshop, the difference between the various window entry movements appears to be determined by window sill height. If a person can step up to the window sill, then use the frame to pull himself through with his equipment, the rating is 5.00. If the sill is high enough that the person must lever himself up onto the window using his upper body and arms, then push on the mantle, the rating increases (5.25). Having to reach a high window, then jump and/or pull oneself up to the point that it is possible to push on the mantle increases the rating somewhat more (5.38).

The ratings also reflect the common sense idea that it is easier to go downstairs than upstairs. Moving a casualty downstairs was rated

0.62 points lower than moving a casualty upstairs. Moving ammunition or supplies downstairs received a rating 0.31 points lower than moving the same objects upstairs. Given the likely weight of a casualty compared to the stated weight range for ammunition and supplies (50-75 pounds), the two observations can be combined to suggest that demands are higher going upstairs than down and the size of the difference increases with the weight of the load.

Three tasks stood out because they were nonrecurring activities. Lifting a heavy weight overhead, climbing over a high wall or obstacle, and performing a fire and movement sequence were tasks that occurred uniquely in the list.

One final element in the list is noteworthy in that it reflects operational factors that would not ordinarily be thought of as "tasks" in and of themselves. Operating in extreme expeditionary environments is a known source of physical difficulties. High altitudes, temperature extremes, and continuous operations are obvious environmental variables that can affect the performance of individuals. More subtle effects may be associated with terrain coefficients for movement, degree of obstruction of pathways, constriction of movement, and so on. These conditions can be expected to make difficult tasks even more challenging. Thus, this "task" is a reminder that environmental factors can act as multipliers for task demands and must be given proper weights when determining physical standards that are required to provide an acceptable safety margin.

Abstracting from Table 1, the following general types of tasks are highly weighted and pose heavy physical demands: casualty evacuation, movement through windows, climbing over walls, moving supplies and ammunition up and down stairs, fire and movement, and lifting weights (perhaps supplies and ammunition) overhead. The simplest general summary seems to be that movement of self, casualties, and supplies into and out of buildings is the most general theme. The up and down elements of movement may add to the demands as well as the fact that work must be done in constrained spaces. Movement between buildings is suggested by the fire and movement sequence. Also, there is a reminder in the task list that the demands posed by any single task can be increased by adverse environmental conditions.

Two comments are in order about the high weight-high physical demand tasks. The list qualitatively confirms some subjective summary evaluations given by SMEs during informal discussions. The vertical aspect of urban combat is reflected in the movement up and down stairs, up and into windows, and up and over walls. The ratings also reflect reasonable expectations that, for example, it is more work to climb into higher windows than lower ones and that moving objects upstairs is harder than moving them downstairs. These points provide a preliminary indication that the task ratings are at least minimally valid.

High Weight-Moderate Demand Tasks

Tasks that were given high weight but were considered only moderately physically demanding, probably will not be focal concerns when designing physical conditioning programs. This inference derives from the fact that these tasks were substantially less demanding than the highly demanding tasks. The highest physical demand rating for a task in this category was nearly half a point lower than the lowest rated task in the high demand category (i.e., 5.00-4.56 = 0.44). The average rating fell below the "Medium Difficulty" point on the scale for 5 of the 10 tasks. Given this demand level, physical conditioning that prepares the individual to perform the more demanding tasks in Table 1 would ensure that Marines have the physical capabilities required to perform the tasks listed in Table 2.

Table 2. List of High Weight-Moderate Demand Tasks

Task No.	Task Content	Rating Weight	Physical Demand
25	Carry weapon at tactical ready position for one hour	12.31	4.56
35	Move through obstructed space (agility)	11.44	4.38
14	Two men lift a third to a high window	10.91	4.10
2	Run/dash 22 yards	13.13	4.06
13	Two men pull a third through a window	10.75	4.06
24	Make quick cuts and turns (directional turns)	12.24	3.87
37	Maintain kneeling firing position for sustained period	10.75	3.63
18	Climb down five floors of stairs	11.06	3.31
33	Look upward for sustained period	11.31	3.25
36	Twist/torque body 45-90 degrees around corners	11.51	3.00

Note. Tasks shown are those in the cluster appearing in the upper-left quadrant of Figure 1. The weight variable is the sum of the importance and frequency ratings.

The preceding conclusion depends on the assumption that the same physical abilities determine how well a person can perform high weight-moderate demand tasks and high weight-high demand tasks. This assumption may be wrong. Further, the preceding conclusion also requires the assumption that physical conditioning programs are intended to improve abilities, not skill. Skill can be thought of in this context as a pattern of coordinated motor activities required to perform a task. Developing physical abilities may permit a person to perform a task with more force, perform it longer, and so on. However, acquiring task skill will require activities designed to inculcate the necessary motor habits and coordinated action sequences that comprise skilled performance. Physical conditioning programs will improve skill on less demanding tasks only if the performance requirements of the less demanding tasks involve the same motor patterns as the more demanding tasks and if the conditioning programs include repetition of the demanding tasks. In this case, task similarity will permit some transfer of conditioning effects. Note, however, that in general, physical conditioning to improve abilities is a different matter than training to develop task skill. Both skill and ability are needed for optimal performance. Physical conditioning programs could focus solely on ability development unless skill development is specifically identified as a program goal.

Moderate Weight Tasks

The list of moderate weight tasks (Table 3) is interesting in several regards. First, several tasks are ones that come readily to mind when people are asked to indicate which tasks are more likely to occur in urban combat than in other settings. These tasks include climbing a rope up the side of a building, kicking in doors, and using breaching tools.

Table 3. List of Moderate Weight Tasks

Task No.	Task Content	Rating Weight	Physical Demand
1	Climb straight rope two stories up exterior of building	7.38	6.13
30	Perform low crawl (knees and elbows) for 100 meters	8.44	5.94
46	Throw a grappling hook up two stories	8.81	5.75
40	Dig a fighting hole six-feet deep	9.25	5.50
29	Perform high crawl (hands and feet) 100 meters	8.88	5.38
34	Lower objects weighting 75-225 pounds from a height	8.75	5.25
43	Push heavy objects (e.g., furniture, vehicles)	9.63	5.22
45	Kick in a door	9.00	4.94
42	Construct barriers/barricades	9.38	4.75
28	Swing/push breaching tools for forcible entry	10.06	4.69
31	Duck-walk under exposed areas or obstacles	9.69	4.69
22	Jump down from a seven-foot height	9.63	4.69
21	Bear crawl/scramble over mound of rubble	9.56	4.56
16	Climb a ladder up to a two-story height	8.38	4.44
23	Jump across a three-foot span	9.06	4.31
41	Drive engineer's stakes	8.42	4.28
20	Climb over irregular surfaces or rubble	9.56	4.25
39	Stack heavy objects (e.g., sandbags, ammunition boxes)	9.30	4.14
26	Balance on a one-foot wide surface for a 10-foot distance	8.56	3.69
17	Climb down two stories on a ladder	8.19	3.69

Note. Tasks shown are those in the cluster appearing in the lower half of Figure 1. The weight variable is the sum of the importance and frequency ratings.

The physical demand level of several other Table 3 tasks is noteworthy. If an average rating of 5.00 identifies a task as high demand, 7 of 20 tasks would be high physical demand tasks. If the criterion were merely that the task have a demand rating higher than the most physically demanding tasks in the moderate physical demand category, five additional moderate weight tasks would be classified as high physical demand.

The demand level associated with the tasks assigned to the third task category is noteworthy because it indicates the importance of the weighting variables. Clearly, some of the tasks in Table 3 involve heavy physical demands. These tasks can be ignored when designing physical conditioning programs only if at least one of two conditions was satisfied. These tasks do not have to be considered explicitly if the physical abilities required to perform them are the same as those for the high weight-high demand tasks. If so, conditioning to improve performance on high weight-high demand tasks also will improve performance on the demanding tasks listed here.

The tasks listed in Table 3 also could be ignored when designing physical conditioning programs if the importance and frequency ratings are highly valid. In this case, low ratings would mean that it is not especially important whether the task can be performed. If the task is unimportant, it is not reasonable to invest a great deal of time and energy training to perform the task.

The tasks in Table 3 should be examined in more detail before their weight scores are taken at face value. SMEs could be asked to consider scenarios that might require each behavior, whether there were likely to be substitute procedures that would work if personnel could not perform them, and so on. Considering such specifics might lead to a reevaluation of the Table 3 tasks. The most important aspect of Table 3, therefore, may be the identification of a set of tasks that require more detailed analysis. Note that this analysis would not be required if it were known with certainty that performance on these tasks depends on the same abilities required for other demanding tasks.

Previous research can be used as a reference point to determine whether Table 3 tasks require the same abilities as Table 1 tasks. For example, the physical ability correlates of using breaching tools, stacking heavy objects, digging fighting holes, and climbing ladders have been studied previously. Prior research includes studies of the physical ability correlates of general pushing, pulling, and lifting tasks that may be applicable here. That information can be used to set approximate physical fitness objectives based on some tasks for some Table 3 tasks. Those objectives then can be compared to the requirements for the high weight-heavy demand tasks as a check on the need for specific types of conditioning or higher levels of fitness. Here again, some attention must be given to tasks in the list, such as throwing a grappling hook, that appear to involve skill elements that must be taught separately from ability development. The simplest outcome from considering these issues would be a determination that the physical ability objectives defined for physical conditioning programs would address the abilities required to perform the high demand tasks in Table 3. The validity of the weighting ratings then would be a moot point.

Discussion of Task Classification

One major impression produced by the data is that they meet a critical minimum requirement for identifying valid objectives for physical conditioning programs. The task list, particularly the high weight-high demand tasks, is consistent with experts' perceptions of the demands of MOUT. In this case, consistency means that the task list provides a reasonable basis for linking experts' general impressions of the physical abilities emphasized in MOUT to specific tasks. During visits to MOUT sites, research laboratories, and informal discussions at the EHPP workshop, several knowledgeable individuals independently have suggested upper body strength and anaerobic power as key physical abilities for MOUT. The physical demand ratings for tasks involved in maneuvering in and out of buildings and moving supplies about seem consistent with the claim that upper body strength will be required. Anaerobic power may be critical for short-term tasks requiring high power outputs from the legs and arms. This ability would appear to be important for casualty evacuation, moving loads of supplies and ammunition up and down stairs, and fire-and-move tasks.

The task list also echoes a recurrent theme of verticality in experts' descriptions of MOUT operations. The importance of the vertical dimension is reflected in climbing in and out of windows, up and down stairs, and so on. Greater upper body strength is needed in this environment, partly to deal with the need to use the arms and upper body to help with vertical movement. At the same time, common tasks in materials handling are more difficult when they involve steep upward movement than when they involve movement on the flat or relatively gentle inclines.

The broad correspondence between experts' perceptions and the task list indicates that the results are headed in the right direction. The increased specificity of the frame of reference (i.e., specific tasks, not general abilities) provides a better basis for determining the ability levels that should be the targets for physical conditioning programs.

The fact that MOUT places greater demands on upper body strength and general anaerobic power should not lead to the conclusion that other abilities are unimportant. Lower body strength seems to be required and may not be adequately captured by the anaerobic power concept. Cardiorespiratory fitness may be important in providing a basal value that minimizes the reliance on anaerobic power, even in relatively short duration tasks. The key point is that increasing the importance of some types of abilities should not be equated with eliminating other abilities as concerns. Optimal fitness still may require a type of "general fitness" that encompasses adequate levels of all of the broad ability categories.

The present analysis does not consider two important factors that certainly influence the ability to perform the tasks listed here. The tasks have not been structured into sequences at this time. Even an ordinarily simple task, such as a rope climb or a pull-up into a window, can be very difficult if it is preceded by other demanding tasks. This point is obvious, but it is not incorporated into ratings of isolated tasks. The closest the data come to illustrating this point is that fire-and-move tasks, which may involve a series of short sprints interspersed with brief resting, received a higher demand rating than did simply sprinting 22 yards. One of the next steps in moving toward appropriate fitness standards would be the identification of likely series of activities so that sequencing can be taken into account.

Physical Conditioning Implications

The task analysis was the first step in defining physical conditioning programs to prepare Marines for MOUT training and operations. The end product of the work will be a set of conditioning programs targeting specific physical abilities that are more important in MOUT than in other combat settings. The task analysis points to likely directions for those developments.

The discipline of exercise physiology recognizes a set of physical abilities required to perform different types of physical activities. These abilities are most commonly listed as strength, muscle endurance, and aerobic capacity. In some cases, the list is extended to include flexibility and agility as additional physical abilities.

Strength and muscle endurance are related in the sense that each concept refers to the output from a given muscle or muscle group. Strength generally is defined as the maximal force that a muscle or muscle group can exert. Measures of muscle force generation show that this peak force can be maintained for only a very brief period.

Muscle endurance is the ability of a muscle or muscle group to work for longer periods of time. Muscle endurance is often subdivided into "high" power or "burst" power and "moderate" power elements. Burst power is any submaximal power output that is high enough that it can be sustained for a short period of time. The time limit for activities that depend on burst power is about 20 seconds. Moderate power output involves lower levels of power that can be maintained for more than 20 seconds, but less than about 120 seconds. A distinction between burst power and moderate power is necessary because different physiological mechanisms are limiting factors for the two power types. Different conditioning programs may be needed to modify the relevant physiological mechanisms.

Strength and muscle endurance concepts are usually applied with reference to a specific anatomical site. The site must be indicated to identify the muscle or muscle groups involved (e.g., upper body strength, arm power). This common practice is important because it reflects the fact that an individual with an exceptionally high or low performance capacity in one muscle or muscle group will not necessarily have similar capacities for other muscles or muscle groups. Conditioning programs can be selectively targeted to improve the output from particular muscles or muscle groups.

Aerobic capacity is the ability to sustain work through delivery of oxygen to the muscles. The muscles are the delivery end point, but the cardiovascular and respiratory systems are the critical elements. These systems transport oxygen to the muscles and clear waste products from the muscles. The aerobic energy system is the primary source of energy for those physical activities lasting longer than two to three minutes.

Each physical ability must be considered separately when designing and implementing conditioning programs because different types of conditioning activities are required. Muscle strength and endurance are usually developed by resistance exercises (i.e., exercises that involve moving objects or the body in space). The difference between the conditioning programs for these two types of activity are the level of force required and the duration of the activity. Strength is developed by activities that require a few maximal or near-maximal contractions of a muscle group. Muscle endurance is developed by activities that require submaximal contractions (e.g., 60% of maximal contraction) repeated enough times to extend the task duration enough to produce muscle fatigue.

Aerobic capacity requires markedly different training activities. In this case, the activities ordinarily are not focused on a specific muscle or muscle group. Instead, the activities must be designed to engage a large volume of muscles at a fairly modest level of intensity for an extended period of time. Aerobic conditioning occurs when the oxygen required to perform the activity is high relative to the maximum oxygen delivery that the person is capable of achieving. This requirement can only be met by activities that involve a large enough volume of musculature to utilize large total amounts of oxygen. The minimum threshold for obtaining a conditioning effect may be close to 50% of maximum oxygen uptake in untrained individuals. The threshold may be closer to 70% in trained individuals.

Aerobic conditioning activities involve continuous, rhythmic exercise involving large muscle groups because these activities generate the required oxygen demands. Because the specific muscles involved in generating the demand for oxygen are not critical, aerobic conditioning activities can vary widely. The most common types of aerobic exercise are running, cycling, swimming, and climbing. Aerobic conditioning for military personnel also can result from common activities such as marching, particularly with a load such as a backpack or a weapon.

Inspection of the task clusters presented in Tables 1 through 3 of this report suggests that conditioning programs can focus on two of the three general physical ability domains. All of the tasks identified require primarily strength and/or muscle endurance. Within the muscle endurance domain, the tasks emphasize brief bursts of energy rather than more prolonged power outputs. Burst power, therefore, appears more important than moderate power. The strength and power needs involve both upper and lower body muscle groups.

Aerobic capacity does not appear to be critical for the performance of individual tasks. Many of the tasks involve the activity of large muscle groups, but the power outputs appear to be too high and the duration too brief to make aerobic capacity a limiting factor on performance. This conclusion applies to individual tasks; performing a sequence of these tasks could result in several minutes of the intense large muscle group activity that requires aerobic fitness. The sequence, therefore, could make aerobic capacity an important influence on performance.

The physical abilities required differ somewhat for the different groups of tasks identified in Tables 1 through 3. The high weight-high demand tasks in Table 1 require more strength and muscular endurance than the high weight-moderate demand tasks in Table 2. In contrast, tasks in the second group appear to require agility and flexibility in addition to moderate levels of strength and/or muscle endurance. This second group of tasks, therefore, must be carefully considered in the design of conditioning programs to ensure that agility and flexibility are not overlooked.

This initial qualitative analysis of the physical abilities required for particular tasks implies that physical conditioning programs must include activities designed to increase upper and lower body strength and muscle endurance training. Strength conditioning can be conducted with weights in the gymnasium or through weighted calisthenics, such as pull-ups (palms away, to mimic pulling up onto objects) and dips while wearing a loaded pack. Muscle power training can include such exercises as interval training, stair climbing with pack, and medicine ball exercises. Consideration should be given to inclusion of some pliometric training to increase tolerance to jumping to the ground, and some agility training, such as balance beam walking, tire runs, and cargo net climbing.

An obstacle course provides a conditioning option that could develop many of the abilities needed for MOUT. A properly constructed series of obstacle course activities would require the same types of activity found in MOUT (e.g., pulling the body up over objects, sprinting from station to station). The action mimicry provided by an obstacle course should ensure that agility and flexibility demands are built into the training. The fidelity of an obstacle course to MOUT conditions also could be enhanced by having Marines carry the anticipated fighting load precisely as it would be configured in combat. Properly configured, the obstacle course approach to conditioning would develop both the physical capacities and the physical skills needed in MOUT.

Existing "confidence courses" available within the Marine Corps may provide the basic setting needed for an obstacle course conditioning program. Program design issues might be limited to the problems of deciding how to structure the sequence activities to ensure that the activities were of sufficient intensity and duration to improve existing physical abilities. Current courses might be augmented with strength and agility stations (e.g., log lifting for strength, balance boards, cargo nets, tires for agility). Given a standard course, conditioning programs could be constructed that consisted of alternative sequences of activity within the course. Each sequence could be targeted at different muscle groups to ensure that adequate strength and endurance were developed. The overall conditioning program, therefore, might include several different sequences of events in the obstacle course. One sequence would be constructed to challenge upper body strength and/or endurance. A different sequence would be constructed to develop lower body strength/endurance. These sequences could be run on alternate conditioning days. The abilities that were not primary targets for a given day would be worked on at a lower level to maintain the existing level of fitness.

The obstacle course approach should not be considered a complete alternative to other common physical training programs. Programs involving weightlifting and other such activities may be needed to ensure focal development of specific muscle group capabilities. Obstacle course approaches, however, may have the advantage of supplementing these focused activities with work that provides skill training for specific activities and fosters balance and flexibility. The potential value of mixing training activities to reduce boredom should not be overlooked either.

Looking to the Future

The initial task identification process was successful. The task list was reasonable, the ratings appeared to conform to logic (e.g., going up is harder than coming down), and the list captured themes that were recurrent in discussions with experts. This initial task list should be tested somewhat further, however, to determine whether any additional tasks should be added and whether the task ratings should be modified. Potential extensions include:

A. Review previous military task analyses and task simulation work to identify reference tasks. Reference tasks could be used to anchor the rating scales. Tasks such as loading a truck; digging a fighting hole; evacuating a casualty over flat, open terrain; and carrying fuel or water cans, are commonly identified in studies that attempt to define tasks common to many military settings. Adding tasks such as these to the list would provide additional context for interpreting the task ratings. At present, only digging a fighting hole is included.

B. Review military manuals related to MOUT. These manuals typically include some indications of tactics and techniques for individual combatants. Ensuring that implied tasks are covered in the list would mean that the task list could be linked to current manuals even if experts think that some recommended procedures will be used only rarely in MOUT combat (e.g., using grappling hooks for external entry).

C. The augmented task list (i.e., the current 46 tasks plus any added by performing A and B above) could be presented to additional MOUT experts. These experts could rate the task demands to replicate the present task ratings and classification and could nominate additional tasks if they felt important activities had been left out (e.g., tunnel crawling, low crawl around rubble). The ratings could be obtained in a group setting or by computer administration of the task list.

This list of task-extension activities may appear long, but it will not take long to accomplish given that it is easy to insert a few additional tasks into the list. The limiting factor would be access to additional SMEs. These experts may be available at any of several MOUT training facilities.

Task Sequencing

Combat tasks do not occur in isolation. In many cases, perhaps even most cases, each individual task identified at the workshop would be performed as part of a larger sequence of activities. Accurate estimation of physical conditioning requirements must take into account the sequential structure of task performance. The most challenging aspect of the remaining task structure component of the project, therefore, is constructing sequences of tasks.

Defining meaningful task sequences is important because even tasks that could be performed easily in a rested condition can be hard to perform if the person is tired from performing prior tasks. The sequencing of tasks will be difficult, however, because tasks can occur in a wide variety of configurations, depending on the physical layout of an operational setting and the actions of enemy forces. Thus, attention will have to be directed toward identifying plausible sequences that might occur in combat. The key issue could be identifying a target level for the cumulative demand and duration of the sequence. This issue also arises if one considers the use of obstacle courses or other simulations as conditioning devices. The structure of the course and the time required to complete it should approximate combat expectations.

The sequencing of activities is closely related to the topic of performance measurement. When evaluating a physical conditioning program, it will be important to distinguish between gains in physical abilities from gains in task performance. There is abundant research evidence indicating that the measured gains in physical fitness programs reflect partly the acquisition of skill in performing the specific tasks that are used in conditioning. This skill component of improvement will not translate to other tasks unless they are very similar to the conditioning tasks. Measuring gains in the bench press or leg press, therefore, may overestimate the gains that can be expected in performance. A subjective assessment of the available evidence suggests that performance gains may be only about half as large as the physical fitness gains. This perception of the evidence needs to be confirmed by more systematic evaluation of the evidence. Assuming the impression is correct, the observation implies that measuring gains in physical abilities or even on specific task simulations will not be an entirely adequate basis for assessing the effects of a conditioning program. Some type of performance test will have to be constructed. Ideally, that performance test will include task sequencing.

The data provide enough information to begin considering how to construct a MOUT performance measure based on a sequence of tasks. Abstracting from Table 1, the following general types of tasks are important and pose heavy physical demands: casualty evacuation, movement through windows, climbing over walls, moving supplies and ammunition up and down stairs, fire and movement, and lifting weights (perhaps supplies and ammunition) overhead. All of these activities must be performed with a fighting load of 59 pounds with current equipment. The simplest general summary seems to be that movement of self, casualties, and supplies into and out of buildings is the most general theme. The up and down elements of movement add to the demands as well as the fact that work must be done in constrained spaces. Movement between buildings is suggested by the fire-and-move tasks. This information seems adequate to justify considering a "combat course" type of measure that could, for example, require:

A. Movement from a starting position to a target building by a series of sprints-cover-aim rifle movements

B. Entry into a building through a window or hole set high enough to require the use of the upper body to lever oneself inside

C. Rapidly climb stairs to a high point in the building (assumes good intelligence that the building is empty or that it has been cleared and secured)

D. Construction of a barricaded firing position (stacking sandbags perhaps)

E. Exit the building, then carry ammunition to a window, lift it to someone inside

F. Carry the ammunition upstairs to the firing position

G. Use a rope or other lifting system to raise supplies and equipment into the building

H. Carry a casualty up one or two floors for a rooftop evacuation

Other sequences obviously could be constructed, even just by varying the order of some tasks, but the example illustrates the potential for incorporating a series of the high-demand tasks into a physically taxing scenario.

Table 4. Examples of Potential Extensions of the Initial Task List

Reference Tasks

1. Load 60 boxes weighing 22.7 kg (50 pounds)each onto a truck bed 1.35 m (53 inches) high

2. Perform two-man stretcher carry moving an 80-kg casualty 0.75 km

3. Carry stretcher with 80-kg casualty 12.5 m to stairs, then climb up one flight of stairs and move 12.5 m farther

4. Maximum number 20-kg sandbags carried 50 m in 10 minutes

5. Low crawl 30 m, then high crawl 40 m

Potential MOUT Additions

1. Perform two-man pull to lift an 80-kg man up through a 2.5 m high window

2. Perform two-handed lift from knee height to shoulder height, keeping hands close to body, to get 80-kg man up to and through a

window

3. Move 50 m in a crouch with weapon at the ready through a tunnel or drainage system

Note. A ***reference task*** is a common military task that has been used in prior performance studies that identified the physiological correlates of performance on that task. ***Potential MOUT additions*** are tasks suggested by previous discussions with MOUT experts and/or review of MOUT manuals that were not included in the original task list.

What Next?

Meeting the project goals requires a number of steps prior to the next meeting. Ideally, the sequence would include the following:

A. Extend the task list as illustrated above.

B. Replicate the initial task ratings.

C. Use the extended task list to develop task sequences corresponding to mission segments in earlier work with the SEALs.

D. Observe trainees performing simulations of the various tasks as part of MOUT training. The objectives would be to estimate the proportion of Marines who can perform a given task without assistance and the times required for both assisted and unassisted performance.

E. For MOUT tasks very different from the tasks studied in previous research, conduct logical analyses based on physical fitness models and biomechanical analysis of the individual tasks to suggest reasonable general targets for physical conditioning programs.

F. If possible, conduct studies of the ability correlates of MOUT-specific tasks. The results would be used to verify the logical analyses and link MOUT performance to performance in other military settings. Given time and other resource constraints, the studies would have to be modest in scope, but they could help fill in critical blanks in the scientific basis for the program.

G. Constructing one or more task sequences and evaluating them as potential criterion measures for program effectiveness would be desirable. Subsequent to the validation of the task list and the sequences, the performance measures could be used as outcomes to directly quantify the performance effects of physical conditioning programs.

Not all of the above tasks have to be accomplished to provide reasonable conditioning programs. Projects A, B, and C clearly must be undertaken to ensure that the MOUT task list is complete. The possibility of extending the task list is particularly important. An incomplete list could result in misidentification of the required physical capabilities or underestimation of the level of fitness required. Because it is likely that all tasks depend on a limited number of physical abilities, an incomplete task list is more likely to result in an underestimation of requirements than the misidentification of critical abilities. In either case, it is important that the key capabilities be identified as definitively as possible and as soon as possible. Table 4 indicates some of the tasks that might be added to the list to meet these objectives.

The need for Projects D through G is uncertain at this time. Those projects focus primarily on performance measurement in MOUT. Those projects also include initial empirical validation of the logical analysis of the physiological underpinnings of performance. The final task listing may make it possible to identify suitable performance measures directly from the combination of the task analyses and previous human performance research. In this case, there would be no need for additional work that would only replicate well-known facts. Replication is desirable, but it could be incorporated in the conditioning program evaluation. Decisions regarding the need for those projects, therefore, must await completion of the task list and analysis of the relationship between the tasks and those studied in previous human performance work.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY ***(Leave blank)***

2. REPORT DATE November 1999

3. REPORT TYPE & DATE COVERED Interim Sep-Nov 1999

4. TITLE AND SUBTITLE Summary of Findings for Initial Task Identification for Military Operations in Urban Terrain (MOUT)

5. FUNDING NUMBERS
Program Element: N63706
M0096.002
Work Unit Number: 6716

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8. PERFORMING ORGANIZATION
Report No. 00-04

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Bureau of Medicine and Surgery
Code 26
2300 E Street NW
Washington DC 20372-5300

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT ***(Maximum 200 words)*** Demographic and geopolitical trends make it certain that urban settings will be the sites of military conflicts more often in the future than in the past. Sixteen subject matter experts (SMEs) identified 46 physically demanding tasks for military operations in urban terrain (MOUT). Tasks were rated for level of physical demand, importance, and frequency of performance. Cluster analysis of the average SME ratings identified three clusters. One cluster consisted of tasks with high ratings on all three scales. A second cluster consisted of tasks with high physical demand ratings, but moderate frequency and importance ratings. The third cluster consisted of tasks with low importance and low frequency ratings. Tasks in the first cluster were used to describe physical ability requirements in MOUT because these tasks appeared the most likely to be points of performance failures. These tasks primarily involve the movement of personnel and supplies through windows and up and down stairs. MOUT physical conditioning programs should focus on upper and lower body muscle strength and endurance, particularly bursts of power lasting 10-20 seconds. Normal preparations for the Physical Fitness Test should provide adequate aerobic capacity. Training on obstacle courses may be useful for developing the required strength and muscle endurance.

14. SUBJECT TERMS
military training
Marine Corps
urban terrain
physical training
physical standards

15. NUMBER OF PAGES
23

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-550

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102