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Incorporating Physical Fitness Through Rushing Can Significantly Affect Tactical Infantry Simulation Results

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INCORPORATING PHYSICAL FITNESS THROUGH RUSHING CAN SIGNIFICANTLY AFFECT TACTICAL INFANTRY SIMULATION RESULTS

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ABSTRACT

INCORPORATING PHYSICAL FITNESS THROUGH RUSHING CAN SIGNIFICANTLY AFFECT TACTICAL INFANTRY SIMULATION RESULTS

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Old Dominion University, 2011
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Physical fitness is accepted as an influence on the outcome on the battlefield; yet, research indicates that it has not been incorporated into tactical infantry simulations. Including physical capabilities may have a significant impact upon the results of a tactical simulation. Several battlefield tasks were reviewed, and rushing was selected to implement in tactical infantry simulations. A preliminary spreadsheet model was created that indicated rushing velocity would impact a tactical simulation. Two tactical infantry simulations were created: a helicopter extraction scenario where 13 soldiers rushed to extraction site while two enemies were shooting and a rushing scenario that consisted of three consecutive short rushes by two soldiers to throw a grenade while one enemy was shooting. Rushing input data were collected via an ODU IRB approved study, which also collected data for physical fitness components such as strength, aerobic fitness, flexibility, and body composition. Four rush times (3 meter rush kneeling to kneeling, 6 meter rush kneeling to kneeling, and a 15 meter rush standing to standing) were selected from participants who scored high enough to pass the Marine Corps Physical Fitness Tests and Marine Corps Combat Fitness test. The rushing velocities were used as input for a total of over 160,000 simulation runs which varied the enemy shooting accuracy from 10-30% and varied the enemy shooting cadence from .5 to 3.5 shots per second. Logistic regression was used to analyze the output results. Rushing velocity had a

significant impact upon the probability of success (casualty limit or accomplish task) of the soldiers proving that including physical capabilities may have a significant impact upon the results of a tactical simulation.

This dissertation is dedicated to my husband Doug; my daughters, Heather and Shannon; my parents; my brother, David; and my in-laws. My family has been very supportive throughout this endeavor.

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Courtney Butowicz, certified strength and conditioning specialist, helped me with data collection. Courtney reviewed all of the tests to ensure the testing order flowed appropriately. She demonstrated the fireman carry to all of the participants and ensured all they were comfortable with the fireman carry before attempting to perform it in the combat fitness test. She performed all body fat test measurements using the caliper method, performed the other tests, and taught me to administer the other tests correctly. Courtney helped with testing on both the pilot and rushing studies.

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NOMENCLATURE

ABS	Agent Based Simulations
APFT	Army Physical Fitness Test
ARI-IFRU	Army Research Institute Infantry Forces Unites
ARI-SSRU	Army Research Institute Simulator Systems
ARL-HRED	Army Research Laboratory Human Research and Engineering Directorate
ARL-CISD	Army Research Laboratory Computational Information Sciences Directorate
ATU	Arbitrary Training Units
BEP	Basic Elements of Performance
BMI	Body Mass Index
CASTFOREM	Combined Arms and Support Task Force Evaluation Model
CFT	Combat Fitness Test
CGF	Computer Generated Forces
DVTE	Deployable Virtual Training Environment
DyCoN	Dynamically Controlled Network
ERM	Elemental Resource Model
GSPT	General Systems Performance Theory
IIT	The Infantry Immersion Trainer
IRB	Institutional Review Board
ISSWG	Infantry Skills Simulation Working Group
IWARS	Infantry Warrior Simulation

JCATS	Joint Conflict and Tactical Simulation
MANA	Map Aware Non Uniform Automata
METL	Mission Essential Task List
OneSAF	One Semi-Automated Forces
PCE	Performance Capacity Envelope
PEO	Program Executive Office
PerPot	Performance Potential
MPFT	Marine Physical Fitness Test
QRF	Quick Reaction Force
STO	Science and Technology Objective
STMS	Tactical Mission Systems
STRICOM	Simulation, Training, and Instrumentation Command
TES	Tactical Engagement Simulations
TRADOC	Training and Doctrine Command
USAPFS	United States Army Physical Fitness School
ViSSA	Virtual Soldier Skills Assessment System
VO_{2max}	Volume per Time Oxygen Maximum

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I INTRODUCTION

Physical capabilities of infantry may have a significant impact upon the results of a tactical simulation. In real life, physical fitness will affect the outcome of a tactical engagement. An accurate representation of a real life tactical situation should mirror this property. Physical capabilities can affect the outcome of an infantry simulation, and cannot be ignored.

A. Background

Warriors have always needed to study and prepare for military engagements dating at least as far back as biblical times [1], and combat modeling specifically is documented as far back as the Prussian Kriegsspiel in 1811 designed to train officers in the Prussian army [1]. Combat simulation is a method of testing available theories and knowledge in anticipation of battle [1] and today is performed as a part of military battle simulations on computers [1]. Tactical battle computer simulations model battle conditions in a tactical battle relating to small scale actions serving a larger overall purpose. The simulations can be a small confrontation between a few soldiers, or an entire battle encompassing thousands of soldiers in a task that contributes towards the overall effort of a war campaign or military goal. Representation of individual soldiers within tactical simulations has evolved more slowly than other battlefield components [2], but is now becoming more important as current engagements often involve smaller groups of individual soldiers and the need to analyze new technology used at the soldier level increases [2]. Tactical computer simulations can be used to study the effect of weapons or technology in a specific scenario[3-4], to train soldiers and officers [5-7], or to rehearse a battle plan against an enemy before its implementation [7-8]. [1]

Several projects are currently investigating the use of modeling individual infantrymen in battle for developing new technology from both investment or acquisition and tactical perspectives [2-4]. A soldier tactical mission system (STMS) is anything a soldier uses or carries as a part of a soldier fighting system: weapons, load-bearing equipment, communication devices, GPS, sensors, etc [9]. The Program Executive Office (PEO) Soldier wants these technologies implemented at the individual soldier level but then analyzed at the platoon-level for operational effectiveness [4]. The individual soldier is modeled with STMS, but the affects of using these systems are aggregated and assessed at higher levels [4, 9]. New STMS are implemented in simulations and investigated as part of the acquisition process before investing too heavily in the technology development [9-10]. The main STMS characteristics of interest are mission capability, survivability, and trustworthiness [9]. Physical fitness affects survivability on the battlefield [11], and should be a system of concern by the STMS characteristics of interest and could affect analysis of other systems simulated.

Tactical simulation is an important training tool used by the military. The importance of training using Tactical Engagement Simulations (TES) is demonstrated in statistics as far back as the 1970's when TES-trained units consistently outperformed conventionally trained units in a series of tests documented by the Army Research Institute [12]. While simulation cannot replace live infantry training [13], simulation training has higher fidelity or realism than classroom training, is cheaper than field

[1] IEEE Editorial Style Manual used for Formatting, http://www.ieee.org/documents/stylemanual.pdf, March 2011

training, damages the environment less than field training, is easier to exercise design and construction than many field training exercises, has better repeatability of conditions than field training, can include analysis and after action review or replay, and finally can have controlled timing [6]. Tactical simulation training for dismounted infantry can be tailored for specific types of operations. Urban operation is one of the greatest challenges in the simulation training community [14] and requires situation awareness that can be practiced and tested. Dismounted Infantry Decision Assessment software enables realistic training in decision making for leaders to command a platoon, squad or fire team using the Virtual Soldier Skills Assessment System (ViSSA) [15]. This software is safer and cheaper than real time training, enables repetition of specific training scenarios, and assesses decision making and team coordination. However, there is no description of physical fitness models for the infantry modeled. Physical fitness could affect the outcome of tactical situations changing decisions made as a battle plan is executed.

Mission rehearsal has incorporated the Livermore simulations in Operation Just Cause in Panama, Operation Desert Storm in Mideast, and in combat planning for Somalia and Bosnia[16]. JCATS (Joint Conflict and Tactical Simulation) has been used to rehearse possible combat options in support of the 1999 Kosovo conflict. JCATS takes into account fatigue, inclement weather, low food supplies, and poor visibility [16] and can model scenarios in an urban environment. Urban exercise is difficult due to the civilian population and abundant hiding places for enemies [16]. By 2020, 70% of the world's population will live in cities and at least 80% of those cities will be located within 300 miles of the coastline necessitating training specific to urban areas [16]. Another type of simulation trainer is the Deployable Virtual Training Environment

(DVTE) laptop simulation trainer. It has an Infantry Tool Kit which hopes to program exact terrain models of locations where units deploy to enable rehearsal of missions before they engage [7]. Neither JCATS nor the DVTE take into account the physical fitness attributes or capabilities of the infantry they model.

It is widely acknowledged within the military that physical fitness can contribute towards success on the battlefield [17-19]; this encourages the military to maintain fitness standards [19-23]. Examples of real life situations where fitness contributed towards the battle outcome include Task Force Smith of 1950 in Korea [24], Lieutenant Colonel H. Jones at the Battle of Goose Green [25], and the 2-14 Infantry QRF in Mogadishu on October 3-4 of 1993 [17]. A good physical fitness program promotes combat survivability for those stationed in Iraq [21] . Yet despite the importance of physical fitness on the battlefield, and use of tactical infantry simulations, no existing simulations include physical fitness level or physical capabilities as a determinant of individual soldier behavior and abilities. Individual Infantryman attributes are represented as inputs or controls [4], but little is mentioned with regard to physical fitness capabilities.

It is known that physical fitness impacts the outcome of battles [17, 21, 24-25], so a valid implementation of physical fitness within tactical simulations can serve as a more predictive model of battlefield physical performance by infantry than a tactical simulation without this information. A predictive model of battlefield physical performance can aid military leaders in planning by enabling leaders to 1) learn the capabilities of their troops [26] 2) help select appropriate personnel for physically demanding posts [26] 3) identify abilities essential to battlefield performance [26], 4) evaluate military training programs [26] , and 5) increase the validity of infantry simulations. Because physical fitness impacts battle, it is hypothesized that fitness impacts a tactical infantry simulation in the same manner. Simulations using actual physical fitness or physical capability parameters will yield more accurate results and could be used as a predictive model of battlefield performance that meets these five criteria.

B. Problem Statement

There is currently little information about representation of actual physical capabilities or physical fitness in tactical infantry simulations. There is effort to identify accurate modeling of the individual soldier, and it includes descriptions of important factors for three basic functions: decide, assess, and act [27]. These functions are further devided where the solder can choose to act by engaging, communicating or moving [27]. But within all of these there is no mention of physical fitness and its affect upon the ability to perform battlefield actions [27]. There are simulations that implement fatigue [28-29], heat stress [28], load [28], hydration [28], the impact of weather [28] and terrain [28], but these attributes are not the same as implementing physical fitness. There has not been information available regarding the implementation of individual physical capabilities within an infantry simulation. There are three questions researched regarding representation of physical fitness in a tactical infantry scenario that should be addressed when considering whether to model physical capabilities. 1) How can physical capabilities be represented in an infantry simulation? 2) Do physical capabilities have an impact upon the outcome of a tactical infantry simulation? 3) If physical capabilities have an impact, how can they be quantified for future use by others?

C. Approach

To implement physical capabilities, battlefield tasks potentially affected by physical fitness or capabilities were identified and the battlefield task of rushing was selected for representation in a tactical simulation. Two agent based tactical infantry scenarios were created that incorporate the selected task. A spreadsheet model built for rushing success prediction was used to verify the two simulations. For purposes of verification and validation of rushing input data, an IRB application was submitted to the Old Dominion University Institutional Review Board to enable data collection of volunteers' rushing times in military gear and administer standard physical fitness tests. The Rushing Study data were analyzed to determine if physical fitness measures were correlated with rushing performance, the range of physical capabilities with respect to performance, and how performance will be represented in a simulation. The two simulation scenarios were run for preliminary data and a power analysis performed on the initial survival percentages to determine the number of runs needed for the sensitivity desired for logistic regression. Logistic regression was used to analyze the simulation output with respect to infantry performance and scenario outcome. The results are presented within this dissertation.

D. Contributions

This research demonstrates that including physical capabilities of infantry has a significant impact upon the outcome of a tactical infantry simulation. As a result of this effort, a valid conclusion is that if infantry tasks are being represented, a simulation without a model of physical fitness or physical capabilities may not valid. It is the hope of the author that others will review other battlefield tasks such as crawling, shooting, and casualty evacuation to determine similar models that can also easily be incorporated into a tactical simulation. By using these models, the author hopes that the following five benefits can be achieved through tactical simulations: 1) learn the capabilities of troops [26] 2) select appropriate personnel for physically demanding posts [26] 3) identify abilities essential to battlefield performance [26], 4) evaluate military training programs [26] and 5) increase accuracy of infantry simulations.

II Literature Review

A model is a physical or logical representation of a system, entity, or process [30]. A simulation is a model of a system, often created for purpose of understanding the system or analyzing strategies for working with the system [30]. There are two basic types of simulations: static and dynamic, where dynamic models incorporate change within the system over time [30]. The simulations discussed within this dissertation are all dynamic, and there are three basic types of dynamic simulations: live, virtual, and constructive [6, 30-32]. Live simulation incorporates human role players in an artificial scenario, such as military exercises [30-31], or as a subsistent simulation where simulators are mounted on actual weapons [12]. In a live simulation, the simulation takes place in a real environment, but the effects of the equipment are simulated[6]. A virtual simulation immerses a person in an artificial environment, most often for training but these can also be used for experimental purposes [6, 30-31]. A virtual simulation has a human-in-the-loop interacting with the simulation [6, 30-31]. The user interacts with the simulation via an interface that represents the soldier's equipment and tries to give the soldier a simulation of a real interaction with a fake world [6]. A constructive simulation has simulated people that perform tasks within a virtual environment [31]. A constructive simulation may have a live person interacting with the simulation (open-loop, human-in-the-loop) or may be executed without a live person interacting with the simulation (closed-loop) [30-32]. In a constructive simulation, the human interaction consists of direction of units or broad control of the scenario, but does not simulate controls of a real system [6]. In a live simulation or field exercise, physical fitness is represented by virtue of the physical fitness of the humans involved in the exercise. They run, kneel, shoot, and perform physical tasks during the exercise, just as they would on the battlefield. Virtual and constructive simulations are different, and do not logically or mathematically model physical fitness.

In the past, constructive combat modeling has been used for large-scale battles with unit level analysis [27] often modeled for command groups mathematically [12] using Lanchester differential equations [1] or using game theory [1] without modeling the individual soldiers. The representation of infantry soldiers has developed more slowly than other components of battle [2] . When representing the individual soldier, his behavioral and decision processes need to be modeled [27]. Agent based simulations are used to incorporate behavioral models [1] with representations of the individual soldiers as agents and are a shift from the force-on-force attrition calculations [33]. Today much is being done with Agent Based Simulations (ABS). In many agent based simulations, tanks, planes, infantrymen, ships, etc., are modeled as individual entities occupying a location within the virtual world, having specific attributes, and performing functions or having behaviors that might be modified or affected by these attributes. Instead of using only statistics or mathematics, the results depend upon the interaction of the agents [10].

There are many different types of agent based simulations: IWARS, VR Forces, MANA, and Pythagorus are just a few. In MANA (Map Aware Non Uniform Automata), the agents maintain a memory of the battlefield, and thus are "map aware" [33]. In Pythagoras, agents can sense and react to the operational environment; the rules for agent behaviors are not concrete, but incorporate fuzzy logic with traceability features [34]. Pythagoras is an agent-based simulation developed by Northrop Grumman to support Project Albert and it incorporates soft decision rules, behavior changing triggers, dynamic sidedness (agents can change sides), and nonlethal weapons [34].

The Joint Conflict and Tactical Simulation (JCATS) is a stochastic model and can be used as human in the loop or closed-loop. It has been used to rehearse for combat situations in the 1999 Kosovo conflict and for exercises in the San Francisco Bay area [9, 16]. It is both virtual for combat situation training and constructive in approach [9, 35]. JCATS can also simulate scenarios for drug interdiction, disaster relief, peace keeping, counter terrorism, hostage rescue, and site security, and can be used for training both officers and enlisted [16]. JCATS can simulate up to 60,000 entities and can work on a laptop enabling use in the field. It can have up to 10 factions with varying rules of engagement [16]. JCATS has Autonomous Agent Based Modeling Capability [35]. While JCATS can model the individual combatant, none of the articles about JCATS described modeling physical fitness within infantry [2, 4, 16, 35].

The Program Executive Office Soldier (PEO Soldier) wants high resolution simulation capability to model each infantry soldier and his individual abilities [2]. PEO emphasizes the need to model deciding and acting and in particular the actions that occur as a result of these two processes [2, 9]. The actions in particular are **move**, **sense**, **communicate**, **engage**, and **enable**. PEO wants to be able to compare Soldier Tactical Mission Systems (STMS), with respect to mission capability and survivability consisting of lethality, mobility, protection, communications, and situational awareness [2, 4, 9]. Within all of the articles reviewed with respect to PEO Soldier, none of them mentioned physical fitness as a system to be modeled as a part of the simulation [2, 4, 9, 36], although physical fitness could directly affect the **move** and **engage** tasks. Various simulations, not all agent based, were reviewed to determine the best simulations for use by PEO Soldier: Agent Based Simulations, Combined Arms and Support Task Force Evaluation Model (CASTFOREM), Janus, Joint Conflict and Tactical Simulation (JCATS), One Semi-Automated Forces (OneSAF) Testbed Baseline (OTB), CombatXXI, Infantry Warrior Simulation (IWARS), Objective OneSAF (OOS), modified CombatXXI (Mod CbtXXI), modified IWARS (Mod IWARS), modified OOS (Mod OOS), and finally an enhanced linkage between Combat XXI, IWARS, and OOS together to get a new simulation called New Sim [2]. None of these described physical fitness as a system modeled within their software at the time of this research [2, 9, 15-16, 28, 37-39].

Virtual simulations immerse the user in a simulated environment to give him the experience of being in the real situation. They can be used to train for specific tasks or as mission rehearsal. The implementation of an infantry virtual simulation is particularly difficult for infantry as they are totally immersed in the battlefield, physically moving, and using various weapons [6] . A pilot or tank operator can be inside a cockpit interfacing with a machine or equipment that can have out-the-window visual displays, utilizing computer graphics, and replicated instrumentation of the machines for user input [6]. In addition, representing infantry behavior requires incorporating infantry tactics and human behavior [6].

Head mounted displays, instrumented gloves, spatial tracking, and voice recognition systems are components that can contribute towards a realistic interface in a virtual environment of an infantry scenario by enabling voice commands, arm signals, virtual tools, and virtual weapons [8]. The head mounted display enables the soldier to view his environment from the scenario in 3D, and as he turns his head, the scene updates itself to display the information based upon the new viewpoint [8]. This enables the soldier to communicate with other Computer Generated Forces (CGF) and practice maneuvers [8]. Pointman™ is a locomotion control that uses a duel joystick gamepad, tracked head mounted display, and sliding pedals to interface with an infantry simulation [5]. The pedals influence the avatar's stride and stepping cadence, thus slow movement will cause walking and fast movement will cause running. It is conceivable that the pedals could be set to implement inclined terrain, and provide enough resistance to make the participant fatigue in a manner similar to how one fatigues while walking, running, crawling, etc, but there is no mention of this in the articles read [5, 40].

The U.S. Army Research Institute Simulator Systems (ARI-SSRU) and Infantry Forces Research Unites (ARI-IFRU), the U. S. Army Simulation, Training, and Instrumentation Command (STRICOM), the U. S. Army Research Laboratory Human Research and Engineering Directorate (ARL-HRED), and the Computational Information Sciences Directorate (ARL-CISD) are jointly involved in a Science and Technology Objective (STO) "Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal" [41]. This simulation research includes simulation locomotion and body positions [41]. It incorporates use of a platform that has realistic perception of movement and energy expenditure utilizing an Omni-Directional Treadmill (ODT), enabling the soldier to walk or run in any direction [41]. This would be used in training scenarios, and could incorporate physical fitness naturally into the simulation. A less fit person would not be able to walk or run as far or fast as a person who is fit. There is no mention of incorporation of physical fitness attributes directly, or changing the slope or tension of the treadmill to accommodate changes in the environment.

The Infantry Skills Simulation Working Group (ISSWG) plans to use simulation systems to improve infantry skills [7]. The Infantry Immersion Trainer (IIT) is adaptive, interactive and incorporates full-immersion reproducing sights, sounds, and smells. But this is not deployable, and it is a live simulation, not virtual [7]. Distributed Advanced Graphics Generator & Embedded Rehearsal System (DAGGERS) is a new simulation in development that will provide a wearable training/mission rehearsal system for infantry [7]. The Deployable Virtual Training Environment (DVTE) is a laptop simulation that will enable squads to plan and rehearse missions or training exercises and perform after-action reviews [7]. It requires a joystick device to be mounted on a weapon for controlling locomotion. There was no information regarding physical movement or physical fitness [7].

Research indicates that physical fitness is naturally incorporated in live simulations, where natural infantry battle movement is a part of the simulation. Physical fitness could be integrated through a physical interface such as sliding pedals or the omni-directional treadmill, but no direct mention of this is made in any of the systems researched. If they were implementing physical fitness, they could vary the resistance or slope of these machines to match the environment. The soldiers could also wear simulated gear to match the weight and distribution of standard gear while using the simulations. None of these attributes are mentioned. There was no information about incorporation of physical fitness models in any of the constructive or virtual simulations. There was however mention of including fatigue, heat stress, load, hydration, etc. in some of the simulations, such as IWARS [28], JCATS [16], and Pythagoras [34], but these are not physical fitness attributes, but may be affected by physical fitness attributes [42]. No direct research was found that indicates that including physical fitness in a simulation will impact the results of the simulation.

Integrating physical fitness models into an infantry simulation requires determining when and how physical fitness affects infantry performance. Current physical fitness and performance models need to be evaluated to decide how they could be implemented effectively in a tactical simulation. The fitness parameters used for various tactical scenarios should be tuned to be representative of the military, and then varied to analyze whether it truly affects the outcome of the simulation and the degree of the effect. This section reviews the definition and types of physical fitness, how physical fitness is assessed, how the military measures physical fitness, and finally ways that military tasks have been analyzed with respect to performance and physical fitness.

A. Physical Fitness Definition

Physical fitness has several components that contribute towards performance of physical activities [43]. These physical fitness components have been investigated in many studies [44] and consist of separate categories of performance needed to achieve success on a specific physical activity. Strength, stamina, body composition, and flexibility are the primary dimensions of fitness [44]. The United States Army Physical Fitness School (USAPFS) uses strength, endurance, and mobility as dimensions of physical fitness where mobility includes balance, flexibility, coordination, speed, and agility [43]. Within many models of fitness, strength and stamina are divided into additional factors or the factors are named differently. For instance strength consists of maximal muscle strength: the maximum load a muscle can produce, endurance: performance of a task over time, and power: the ability to exert force rapidly to displace a mass [43, 45]. Muscle contractions can be broken into eccentric, isometric, and concentric contractions [24]. Stamina refers to aerobic endurance or capacity and is often measured by VO_{2max} [46]. Body Composition refers to the percentage of fat verses lean body mass and has been shown to impact performance of many physical activities [42]. Flexibility is the ability to move muscles and bones their full range of motion [22]. Some versions of physical fitness with respect to a particular task's performance also include coordination [47] and physical work capacity [48]. Different measurements of the dimensions of physical fitness often predict how a person will perform tasks with varying measures of success.

A diagram illustrating physical fitness and task relationship in Fig. 1 is derived from the introduction of the Banister model [49] but is modified with more current terms and is simplified. Physical task performance inputs include aerobic capacity, strength as measured by maximum strength, endurance, and power, flexibility, body composition, and skill or coordination. Environmental attributes and psychological state also affect task performance. The optimum input states for task performance vary based upon the task. For instance, the fitness criteria for a gymnast, marathon runner, and NFL lineman are all different. The performance of the task also serves as input back into the psychological state to continue to affect task performance.

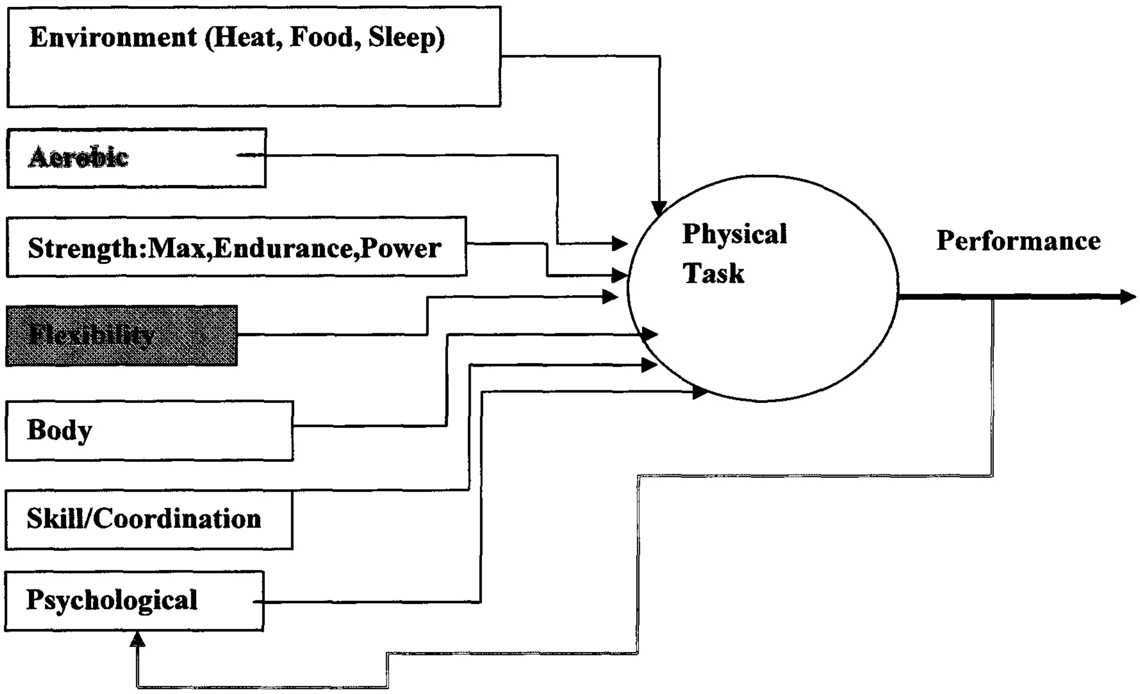


Fig. 1. Physical Attributes Affecting Task Performance.

B. Physical Fitness Assessment

Physical fitness is often measured according to the task to be performed. For the general public, physical fitness is measured according to cardiovascular, strength, and flexibility attributes to facilitate health maintenance [50-52]. For athletes, physical fitness measurements become much more specific to indicate performance potential and areas for improvement to increase performance [53-55] with respect to the specific sport. Fitness tests may include the Arm Dynamometer, Handgrip, Pull-Ups, Broad Jump, 50 Yard Dash, Sit and Reach, Step Test, etc. Today, VO_{2MAX} is a widely accepted form of measuring aerobic fitness, but if the equipment is not available, timed runs or the beep test can be used [23, 55-56].

C. Military Assessment of Physical Fitness

Each of the U. S. military organizations incorporate a variety of physical fitness testing that includes testing aerobic capacity through running, upper body strength endurance from push-ups or pull-ups, core endurance using sit-ups or crunches, and a body composition test using weight and height or BMI as shown in Table 1.

Table 1. Physical Fitness Tests Used By U.S. Military Organizations.

Event	**Air Force**	**Army**	**Coast Guard**	**Marines**	**Navy**
Body Composition or Weight	X	X	X	X	X
Combat Fitness Test				Score	
Flex Arm Hang				Timed	
Pull-Ups				2 minutes	
Push-Ups	1 minute	2 minutes	1 minute		2 minutes
Crunches	1 minute	2 minutes	1 minute	2 minutes	2 minutes
Sit & Reach			Distance		
Timed Run	1.5 miles	2 miles	1.5 miles	3 miles	1.5 miles
Tread Water, Swim 500 m			X		

Scoring for the physical fitness tests is different for each branch of service and varies according to sex and age. The physical fitness tests are given at regular intervals: twice per year for the Army, Marines, and Navy, and once per year for the Air Force. The APFT measures aerobic capacity, muscular strength, and muscular endurance [23]. Strength as the maximal force a muscle can perform in a single effort is not measured in the physical fitness tests. The military environment requires muscular endurance and strength but there are correlations between the two with respect to absolute and relative muscular endurance [23]. A review of data suggests that the endurance components (push-ups, sit-ups, and pull-ups) demonstrate adequate testing of strength/endurance [23]. However, there is a lack of details on test administration criteria that make it difficult to relate the APFT testing data to other research studies [23]. The Marines have debated the merits of the physical fitness tests and have determined that functional fitness [57] should also be measured with respect to combat tasks via the Combat Fitness Test (CFT) in addition to the standard Marine Physical Fitness Test (PFT). The physical fitness tests are similar across the branches of service, and each service gives the tests on a regular basis.

If a correlation can be determined between standard physical fitness tests and performance in battlefield tasks, then the standard measurements can be used to determine input parameters for simulations that include physical fitness within the infantry model. If the standard physical fitness tests are found to be adequate for prediction of task performance, abundant data is available for determining the current fighting ability. In addition, the military services are currently developing a database for computerized physical fitness and weight management [20] that could potentially be used for measuring performance of various groups of soldiers. If the current physical fitness tests are not found to be adequate for prediction of tasks performance, then measurement of the task itself as a physical capability can be used until measurements or predictors of performance are determined.

D. Task Analysis and Physical Fitness

The definition of physical fitness relates to performance of specific activities or tasks. For purpose of this paper, the tasks are battlefield tasks. To accurately assess the ability to use military physical fitness measurements, the validity of the measurements must be determined. This section reviews efforts of the past towards analyzing the physical fitness tests and training and the physical fitness attributes used in tasks performed by infantry.

The APFT has been assessed to determine its ability to gauge soldier readiness for combat [24]. Exercise Explorer Software was used to analyze the muscles tested by the APFT, and they were compared to the muscles used in tasks TRADOC identified as performed in combat: lifting from the ground, lifting overhead, pushing, pulling or climbing, rotating, jumping and landing, marching, running and changing direction [24]. The muscles tested were also compared to the muscles exerted during performance of the six most important combat tasks identified by the U.S. Army majors in Intermediate Level Education Class 08-01: 1) move from one covered and concealed position to another, 2) lift a weight from the ground (stretcher) 3) drag a casualty to safety, 4) conduct a fireman's carry, 5) continuous movement under combat load (road march) and 6) climb over a wall [24]. The APFT tests muscular endurance but the TRADOC and combat tasks identified used muscular strength [24].

Physical training programs for infantry, including the APFT have been analyzed to determine if they prepared soldiers for the physical rigors of combat [17]. A representative exercise can help improve a combat critical individual task if it works the same muscle groups or physical readiness components [17]. A pull-up would improve ability to climb a rope because it works the same muscle groups. The most physically demanding individual tasks performed by light infantrymen on the battlefield derived from the mission essential tasks lists (METL) are the following: foot march, climb, sprint, high/low crawl, carry, dig, three-five second rush, and run [17]. The strength, endurance, and mobility required to perform these tasks were assessed and infantry units completed questionnaires regarding physical training [17]. These were reviewed, and the physical training tasks were compared to battlefield tasks with regard to muscles used, duration, and intensity [17]. Training programs are adequately preparing light infantry soldiers [17]. The only exception was with regard to motor efficiency and mobility: speed agility, muscle power, eye-hand coordination, and eye-foot coordination [17].

Forty-seven male participants were assessed to determine the physical characteristics: body composition, upper and lower body aerobic and anaerobic power, strength, and endurance that contribute toward optimum performance on an eleven-item obstacle course [58]. This course included low crawling, running through tires on the ground, vaulting a vaulting horse, climbing onto a shelf, climbing up a wall, shimmying along a suspended horizontal bar, running, traversing a balance beam, a forward roll, climbing a ladder, climbing a rope, and carrying a medicine ball [58]. The participants were divided into three groups based upon obstacle course completion times [58]. The physical characteristics of the fastest group were more homogeneous than the slow group [58]. Performance was correlated to body weight, percent body fat, and VO_2 of arms and legs relative to body weight [58]. Even so, the best three-variable multiple regression equation only accounted for 35% of the variance in the obstacle course score [58]. It was hypothesized that the remaining variance was because of the differing physical characteristics measured by the obstacle course [58].

The evolution of physical fitness standards and the need for combat readiness have been reviewed with the goal of determining the physical demands of combat [22]. While advancements in technology have helped modern soldiers, there are still many needed components of physical fitness [22]. Muscle strength is a large component of the physical demands of one-third of all enlisted occupations [22]. The most physically demanding infantry tasks are described as casualty evacuation, ammunition box carry, jerry can transport and use, digging a foxhole, and weighted road march [22]. The primary muscle strength and endurance challenge for these tasks is upper-body strength [22].

Important to determining the current physical fitness measures to use are not only how soldiers perform today, but how they will perform given equipment changes. The gradual increase of loads carried by Marines include changes to weaponry, food, water, and armor [59]. There has been an increase from 113.79 lbs in 1997 to 196.3 lbs in 2007 in soldier load [59]. Soldiers today need to be much stronger than in the past, and this need for strength should be accounted for during training [59]. Strength is a quality mentioned in every paper describing soldier fitness in the combat environment [17, 22-24, 60].

Scores from standardized military fitness tests could be used as input into infantry simulations, which would then determine how well infantry would perform battlefield tasks. The components of the standardized military fitness tests adequately test endurance, but lack of details on test administration criteria creates an issue in relating the data to that collected in studies [23]. Different types of strength have been described, including maximum strength with respect to muscle capacity, as important for maximum performance of battlefield tasks [17, 22, 24, 59]. This could pose a potential issue in using data from the standard military physical fitness tests. Regression equations have been calculated to predict task performance for four battlefield tasks (30-meter rush, 400-meter rush, obstacle course, casualty recovery) with mean R values in [0.769, 0.821], but power measurements vertical jump and horizontal jump were added to the physical tests and used as a regression independent variable, and they are not a part of any of the standardized tests used by the military [26].

E. Current Physical Fitness Models

Given the multidimensional characteristics of physical fitness with regard to task performance, deriving a valid model for implementation in a simulation is not straightforward. Investigation into physical performance prediction yielded several models, with regression being the best technique for implementing a fitness model into a simulation. Fitness models found during research are reviewed here to give physical performance theory background, facilitate understanding of how achieving fitness works, and to illustrate why regression is the best choice for modeling physical performance on the battlefield.

1) Banister Model: The Banister Model theory of performance prediction describes how human performance tends to improve quickly, more slowly, and then reach a limit [49]. It explains human performance changes from training and incorporates inputs from cardiovascular, strength, skill, and psychological attributes, and has a feedback loop for the psychological attribute [49]. The Banister Model has been used for exercise therapy applied to post-infarct coronary artery disease patients and training of athletic swimmers, to improve theory on the components of human performance [61], to predict running performance [62], to model the effects of taper or reduced training [63-64], and to determine the intensity and frequency of training to reach a specific performance level at a specific time [65]. The Banister model attempts to conceptualize mathematically the result of the training process upon athletes [66]. The model consists of components for endurance, strength, and skill. Input resulting from training is in the form of arbitrary training units (ATU) determined by duration and intensity which contribute differently to each of the fitness components. The input is used to generate a change to fitness and a change to fatigue values which are used to predict performance as shown in Fig. 2.

Model Performance	=	Fitness from training model	-	K(fatigue from training model)

Fig. 2. Fitness and Fatigue Contribute Towards Model Performance.

Fitness from the training model is a function of the prior performance and the fitness response from training.

$$p_t = p_0 + k_a \sum_{s=0}^{t-1} e^{-(t-s)/\tau_a} w_s - k_f \sum_{s=0}^{t-1} e^{-(t-s)/\tau_f} w_s \quad \text{Equation 1 [67]}$$

The model and equations have evolved [68] and are described in Equation 1 above where $\mathbf{p_t}$ is the measure of performance at time **t**; $\mathbf{p_0}$ is initial performance measure; $\mathbf{k_a}$ and $\mathbf{k_f}$ are magnitude factors for fitness and fatigue; $\boldsymbol{\tau_a}$ and $\boldsymbol{\tau_f}$ are the fitness and fatigue decay time constants; and $\mathbf{w_s}$ is the training load in ATU's per unit of time (week, day, etc.). The decay parameters and multitude factors are determined based upon the individual athlete. This model has been extended to not only predict performance, but also modify training schedules to optimize performance at important competitions [65].

This is a valid research method for predicting performance in elite athletes; but to track training continuously, and determine all parameters for multitudes of individuals is unrealistic. From this model, performance is dynamic: changing is a result of training and is individual. The standard recurring testing idea used by the military is a valid method of maintaining up-to-date fitness information of troops.

2) Fuzzy Logic Model: A Fuzzy Expert System was built for identifying time-varying processes that contain uncertain data for use in physical fitness approximation [69]. This system adapts to the input and is a "learning" fuzzy system. The system "maps" an n-dimensional input space into membership groups. Functions for membership inclusion are defined as trapezoids or Gaussian functions with the number of rules equal to the number of groups to be defined. Parameter values are identified for membership groups despite noisy measurements. The uncertainty in the data is assumed to be bounded. The membership curves are created based upon the data and are prevented from overlapping. Input into the system consists of 1) body mass index, 2) body fat percentage, 3) absolute VO_2max, 4) relative VO_2max, and 5) relative physical working capacity from 160 patients. Medical experts determine the physical fitness of these patients in the range of [0,1]. Uncertainty is chosen from a uniform distribution in [-0.1, 0.1]. Membership curves are computed for each of the 5 categories using the input data. Once the data has been mapped to specific levels, it can be used to calculate the output for future patients. The model determines how the data inputs are grouped into different membership groups for each fitness attribute, which could be useful for creating tables. It is not usable for this project at this time.

3) Neural Network Model and PerPot Model: A neural Network model was used by Jürgen Edelmann-Nusser, et. al. [70], to predict the performance of an elite female swimmer in the finals of the 200-m backstroke at the Sydney Olympic Games in 2000. Input data consisted of performance data from 19 competitions, performance data from another elite swimmer, and training data for the neural network. Prediction of swimmer performance in the backstroke was 2:12:59 min:s, while the real performance was 2:12.64 min:s.

The PerPot (Performance Potential) [71-72] model uses antagonistic systems with past applications to sports science, medicine, and physiology. This model simulates the interaction between load and performance in an adaptive manner termed "antagonistic dynamics". The load increases performance and increases strain. In some ways, this is reminiscent of Banister's modeling of the effect of training to increase fitness, yet inducing fatigue. The PerPot antagonistic dynamic uses internal buffers, which delay the effect, also like the delay functions of the Banister model. Neural Network software called DyCoN, (Dynamically Controlled Network) is used in conjunction with PerPot. Each neuron in the network contains a PerPot component. The PerPot model can handle reserve, overload, and atrophy concepts.

Both the Neural Networks and PerPot models require much more training input than would be realistic for a military simulation. Also, the neural network components are a black box method that will not show how prediction is determined.

4) Kriging Model: Kriging [73] is a geostatistical technique developed by a South-African mining engineer for finding new gold mines based upon a limited number of borehole data and ore reserves from existing mines. Kriging is a least square estimation algorithm that uses an interpolation method. It starts with a finite number of known input and output values. When new input values occur, the output values are calculated according proximity to known input/output values. Kriging can cover an entire experimental area. Linear regression can initially be used to determine the most important factors to use as inputs. Then use standard experimental design methods:

factorial design, Latin hypercube, etc., to collect the initial data input and output points. The model consists of **N** old data points with observed outputs for X, and a new input X_{n+1}. The formula for estimation of the output for X_{n+1} is found in **Equation 2** below [73]:

$$\hat{Y}(X_{n+1}) = \sum_{i=1}^{n} \lambda_i \cdot Y(X_i) = \lambda' \cdot Y \qquad \text{Equation 2}$$

Where $\sum_{i=1}^{n} \lambda_i = 1$, $\lambda=(\lambda_1, \ldots, \lambda_n)'$ and $Y=(Y(X_1), \ldots, Y(X_n))'$. Input data is highly correlated with other input data that is in close proximity or close in value. The covariance functions decrease in value towards 0 as the input gets farther away from each other. If the old data points tend to be uniformly distributed and dense, kriging gives good estimates, minimizing error more than regression. If the prior data is clustered in spots with large gaps, estimates will be unreliable for new data outside the cluster areas. Determination of the data points for collection via experimental methods is one of the most important parts of this model.

Within a fitness model, multivariate kriging could be used to determine performance values for specific tasks based upon input from fitness values. Kriging could be used also with the resultant data from the simulation to create survivability tables based upon the fitness of the infantry in certain scenarios. Kriging does not promote understanding the data, only dealing with uncertain data for which no causation is known. While Kriging could create a model with less error, the fitness model requires use of multivariate factors, which is easier with regression analysis.

5)Miscellaneous Model Ideas for Modeling Human Performance: A discrete event system could be used to model human performance [74]. Each training event would be input and changes the state of the system which indicates performance ability. This model is not conducive towards implementation in a system with many soldiers, each requiring their own resource.

The Elemental Resource Model (ERM), which models human performance, has roots in General Systems Performance Theory (GSPT) and monadology [75-76]. The ability to perform a task is based upon **B**asic **E**lements of **P**erformance (BEPs) within subsystems called functional units. Each functional unit subsystem is measured in **D**imensions **O**f **P**erformance (DOP) and the characterization of performance is the **P**erformance **C**apacity **E**nvelope (PCE). Each basic element of performance is defined as the functional unit and one of the many dimensions of performance. For instance, you might have a functional unit of knee flexor and the dimension of maximal strength. Other dimensions might be power or speed. This system can be made hierarchical. So basic levels would incorporate knee flexors, and then higher level systems would incorporate a combination of the basic elements: lifting or rushing would incorporate more than the knee flexors strength, power, or speed to complete a task. The demand on the lower level indicates a given level of performance for the higher level task. The basic elements of performance should represent desirable quantities so a larger numerical value indicates better performance to create the performance capacity envelope. This model is a good way to set standards for lower levels of performance, but is not easily implemented and tested in a military tactical simulation.

6) Regression Models: Regression models were the most common performance models found during the course of research. These models measured 1) physical fitness attributes that were potentially linked with performance of a task and 2) performance of that task for a group of participants. Then, regression analysis was used to determine equations to predict performance based upon the physical fitness attributes. There were regression studies to 1) predict maximum box-lifting ability based upon height, weight, and body composition [77], 2) identify performance criteria for distance runners [78], 3) describe the effect of anthropometric measures upon performance of motor endurance tasks [79], 4) predict battlefield performance based upon APFT tests, horizontal jump, vertical jump, height, and mass [26], and 5) predict performance of women on an obstacle course wearing a fighting load using APFT measures, VO_{2max}, and anthropometric measures [80]. While infantry is composed of men, women also contribute in combat situations, and thus must be fit. While men and women perform differently, the same fitness model structures used on men can also be used on women [81]. Thus, it is possible that women can be included in these studies, as long as the same measurements are being used.

Other regression models include the linear mixed model, which was used to predict performance for 13 competitive swimmers [67], and the latent growth model, used for repeated measures data that was introduced as an option to predict human performance [82]. These both use statistical techniques to measure and analyze change. They both 1) enable analysis of individual and group levels, 2) can create trajectories of change for both the individuals and groups 3) can account for measurement errors, and 4) can include multiple predictors of change. These are good models for training programs with groups of people who have changing measurements. The mixed model is compared to the Banister model [67]. The mixed model and latent growth model require training data for performance prediction and would be difficult to incorporate in a military simulation.

After reviewing all of the options found during research, a regression model would be the easiest to implement and use. Measured data can be used to generate equations for task fitness based upon standard scores from fitness tests and anthropometric measurements. Sensitivity analysis can be performed: if the R and R^2 values from regression are low, then a larger range must be tested for sensitivity compared to when R and R^2 are high (R close to 1.0). Values for fitness with respect to performance of certain activities can be easily generated and stored for use whenever required.

III Methods

Incorporation of physical fitness into a tactical simulation started with selecting a battlefield task that was affected by physical fitness. Measures of task performance were determined and the performance of the task reviewed, measured, and analyzed in combination with standard military physical fitness measures. A statistical model was developed to confirm that rushing speed affects survivability. Then, an agent-based tactical simulation was implemented that used these performance measurements within two battle scenarios that are relevant in current conflicts. These results were then analyzed to determine if survivability was affected by rushing speeds.

A. Physical Fitness Task Selection

There is ongoing research into which components of physical fitness dimensions affect key battlefield tasks [17, 26, 42, 57, 80]. However, there is not currently a standard method for converting physical fitness measurements into battlefield task performance usable in simulations. The following battlefield tasks were identified as potentially influenced by physical fitness after reviewing military manuals [83-85] and published literature [17, 22, 24, 26, 58-59, 80] : shooting accuracy, casualty evacuation, ammunition box carry, low crawl, high crawl, and rushing.

Research indicates that shooting accuracy can be influenced by physical fitness immediately following exertion [86-87]. Casualty Evacuation has been identified as one of the most physically demanding tasks of infantry [22]. A study in prediction of fatigue development in ambulance work found that VO_{2max} and isometric back endurance were significant predictors for fatigue which could apply to casualty evacuation [88]. The ammunition box carry is a physically demanding task [22] and is in the new Marine Core

Combat Fitness Test (CFT), but it is difficult to model in a simulation. Movement is also a key component of infantry and includes the low crawl, high crawl, and rushing. Body Mass Index (BMI) has been found to affect crawling rates [89]. The rush consists of sprinting from one covered location to the next as fast as possible. This distance must be short and the velocity fast to avoid injury from the enemy. Physical fitness can affect travel velocity in rushing [26], and rushing velocity is predicted to influence survivability [83, 90]. Given the current emphasis on Urban Warfare, movement up and down stairs was also considered. Most infantry simulations include movement velocity as a part of their implementation. Using incorrect velocities could influence the results of a tactical simulation and is a good starting point towards representing physical fitness. At the beginning of this effort, it was decided that a form of movement should be modeled: low crawl, high crawl, stairs, and rushing and these were selected for a Internal Review Board (IRB) Pilot Study. After the Pilot Study and review of most common potential scenarios, rushing was selected.

B. Preliminary Investigative Model

An investigative model of rushing survivability was written in a spreadsheet (Microsoft Excel, Microsoft, Redmond, WA) that calculated the probability of survival while rushing varying distances with velocities ranging from 2.35 m/s to 4.65 m/s, enemy shooting accuracy of 20%, and shooting cadence from .5-3.5 shots per second [90]. **Equations 3-5** calculated the ***time*** it takes for the rush to be completed in seconds while shooting occurs using the ***distance*** of the rush in meters, ***velocity*** of the rusher in meters/second, and the ***reaction time*** it takes for the enemy to see and shoot at the rusher the first time. The number of ***shots*** taken by the enemy during the rush was calculated using the ***shooting cadence*** in shots per second taken by the enemy, ***time*** calculated in Equation 3, and adding a ***1*** for the first shot taken after the reaction time. The final probability of survival was calculated using the ***accuracy*** or probability the shooter will hit the target on each individual shot and the number of shots calculated in Equation 4. Equation 4 was updated after the publication of [90]. Fig. 3 [91] illustrates the total **time** which was ***distance/velocity***, ***reaction time*** or time until reaction and **shots** during the time of shooting.

$$Time = \frac{Distance}{Velocity} - Reaction\,Time \qquad \text{Equation 3}$$

$$Shots = Time * Shooting\ Cadence + 1 \qquad \text{Equation 4}$$

$$Probability\ of\ Survival = (1 - Accuracy)^{Shots} \qquad \text{Equation 5}$$

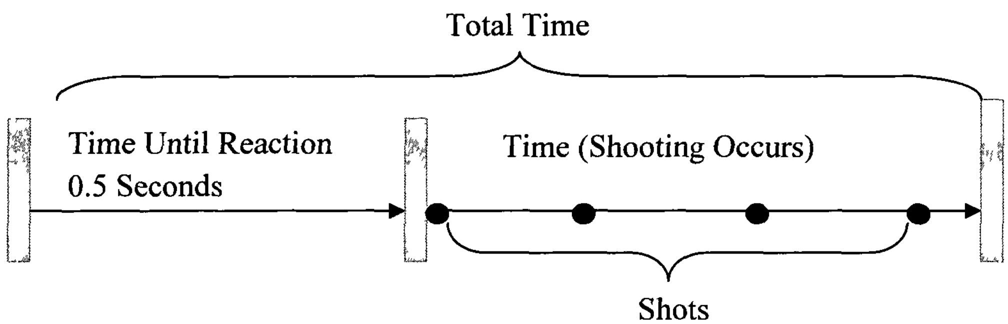


Fig. 3. Calculation for Number of Shots [91].

Two versions of the spreadsheet were created. For the first version, four velocities used in the spreadsheet were based upon data from two sources. The first two velocity points came from data collected, where participants rushed 12 yards (10.97 meters) from prone to prone position wearing simulated interceptor body armor, helmet, and weighted rubber M16 for a total of 14.4 kg (IRB # 09-105 at Old Dominion University). The slowest and fastest average velocities of 2.337 and 3.778 meters per second were rounded to 2.35 and 3.8 meters per second for the simulation runs. The second two rushing velocities were derived from times collected for five 30 meter rushes, prone to prone, with five second pauses between each rush [26] where participants wore 18 kg of gear consisting of an armored vest with ceramic plates, fighting vest with dummy ammo, dummy M-16 rifle, helmet, and boots. The twenty seconds of pause time described [26] were subtracted from the final times of the thirty meter rushes, and then the standard deviation of 3.5 seconds were used to determine two estimated points that would be better and worse than 90% of the population for a normal distribution to get data points of 3.249 and 4.624 which were rounded to 3.25 and 4.65 meters per second for the simulation.

The second spreadsheet model came from data collected (IRB # 10-076 at Old Dominion University) to validate the rushing velocities for the specific rushes in the scenarios. This study had a rush of 3 meters kneeling to kneeling, 6 meters kneeling to kneeling, and 15 meters standing to standing. The rushing velocities used as input were the two fastest velocities, the median velocity, and slowest velocity from participants who passed the Marine Core Physical Fitness Test. For the 3 meter rush, the velocities were (1.224, 1.429, 1.639, 2.307) m/s; for the 6 meter they were (1.893, 2.12, 2.5, 2.777) m/s; and for the 15 meter rush they were (3.106, 3.497, 4.05, 4.31) m/s.

C. Scenario Development

Because rushing was selected as the task to examine, and the spreadsheet model suggested that rushing speed would affect survivability, simple generic situations that would occur in normal battle situations and included rushing were developed. The scenarios were implemented in an agent based simulation. While the variables described in section 3.2 were used, the scenarios did not use equations 3, 4, or 5 as the actions for enemies and soldiers are modeled separately.

The first scenario was a helicopter extraction (Fig. 4). It consisted of a single rush of 15 meters by an entire squad of marines (13 soldiers). A Chinook helicopter blade diameter is 60 feet, or 18.29 meters, and has a radius of 9.145 meters; a rush of 15 meters from cover to the helicopter would be possible. Many areas of our current battles in Afghanistan are in difficult terrain necessitating the use of helicopter transport, making this scenario extremely relevant. It is more likely that a rush to a helicopter would be longer than 15 meters. In section 4.2, the maximum difference in survivability for a single rush is found to be 25-30 meters. To be conservative in the estimate of the impact of physical fitness upon a rush to a helicopter, a short 15 meter rush was used as a minimum possible distance. Casualties are the measure of success in this scenario.

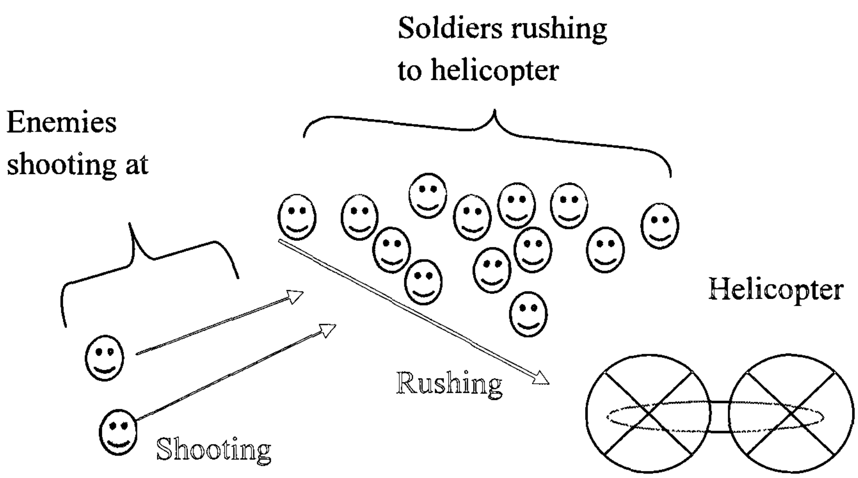


Fig. 4. Helicopter Scenario Diagram.

The second scenario consists of three rushes in a battle by two friendlies to get close enough to fix the enemy with a grenade (Fig. 5). The distances for the rushes were determined by reviewing a series of pictures from Afghanistan and determining a reasonable short distance a warrior might rush while under fire. The first soldier 1) rushes 3 meters, 2) waits for the second soldier to rush 3 meters 3) rushes 6 meters 4) waits for the second soldier to rush 6 meters, 5) rushes the final 6 meters to throw the grenade. If the first soldier was wounded, then the second soldier must get to the point at which the grenade can be thrown. If the grenade was thrown, the scenario was considered to be successful, otherwise, the scenario was not considered to be successful.

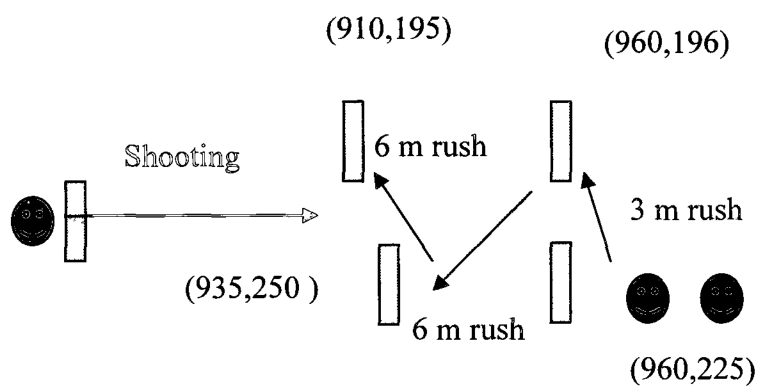


Fig. 5. Grenade Scenario Diagram.

These scenarios do not include features such as decreased enemy shooting accuracy for increased rushing velocity, decreased enemy shooting accuracy during response with friendly cover fire, casualty evacuation, or return fire with decreased accuracy due to fatigue. Each of these behaviors could increase the effect of faster rushing velocity and the effects of physical fitness level. These scenarios are meant to be simple and straightforward to find a "minimum value" for the potential effect of increased physical fitness.

D. Physical Fitness Data Collection

Data were collected for two separate Internal Review Board approved studies. IRB application # 09-105 was approved in September of 2009 as a Pilot Study to collect needed physical fitness data, and to obtain preliminary data for investigative models and will be referred to as the **Pilot Study**. The second set of data from IRB application #10-076 approved in June of 2010 and will be referred to as the **Rushing Study**. The IRB applications, approved informed consent forms, data collection forms, and health screenings are found in Appendix A.

Both sets of data included components of physical fitness obtained from the US Marine Corps, US Army, US Navy, and Coast Guard. Specifically, the US Marine Corps Physical Fitness Test (PFT -3 mile run, pull-ups, curl-ups), Marine Combat Fitness Test (CFT – Appendix D), push-ups (Army Physical Fitness Test (APFT) and Navy Physical Readiness Test), and the sit & reach (Coast Guard Physical fitness tests) were included. By using standard tests, if correlations are found, a model predicting performance could be built for future use in military simulations for actual infantry using data already collected. Body Composition (i.e., percent body fat) was included because it has been shown to influence physical tasks [42]. The vertical and horizontal jumps were both found to have a significant correlation ($p<.01$) with 30 meter rushing performance [26], and were also included in the data collection.

Data collection occurred over two days during the pilot testing. Participants were instructed to wear comfortable clothes and shoes for exercise on both days. Day 1 of data collection consisted of collecting demographic data and movement data (high & low crawl, and rushing) in room 1007 of the Student Recreation Center; ascent and descent of stairs in the stairwell at the end of the hallway near room 1007; and finally the Marine Corps CFT at Powhatan Field. Participants wore a vest that simulated interceptor body armor, a helmet, and carried a weighted rubber M16 for a total of 31.75 lbs or 14.4 kg during the movement tests, but not during the CFT. The low crawl, high crawl, and rush were each performed for a distance of 12 yards, which was the longest distance that could be performed in the room. The participants wore no military gear on Day 2 and data collection consisted of standard physical fitness tests such as curl-ups, push-ups, vertical and horizontal jumps, sit & reaches, and the 3 mile run. The data collected during the Pilot Study is found in Tables 2-4. Pictures illustrating simulated military gear and data collection are shown in Fig. 6.

Table 2. Demographic Data Collected During Pilot and Rushing Studies.

Measurement	**Category**	**Method**	**Units**
Date	Environment	Calendar	MM/DD/YY
Sex	Demographic	Question	M/F
Age	Demographic	Question	Years
Height	Anthropometric	Height Rod	Inches
Weight	Anthropometric	Scale	Pounds
Body Fat Percent	Body Composition	Calipers	%

Table 3. Movement Data Collected First Day of Pilot Study.

Task	**Attributes**	**Measurement**
Low Crawl (3 trials)	12 Yards	Time from starting to ending point in seconds
High Crawl (3 trials)	12 Yards	Time from starting to ending point in seconds
Rush (3 trials)	12 Yards	Time from starting to ending point in seconds
Stairs Ascent (3 trials)	2 Flights	Time from starting to ending point in seconds
Stairs Descent (3 trials)	2 Flights	Time from starting to ending point in seconds
Marine Combat Fitness Test	Do not wear backpack, helmet, vest, or carry rubber M16. Wear these in Rushing Tasks Only.	Measure performance according to Marine standards.

Table 4. Physical Fitness Data Collected During Pilot and Rushing Studies.

Measurement	Category	Method	Units
Push-Ups	Upper Body Strength-Endurance	# in 2 minutes	Number
Curl-Ups	Core Endurance	# in 2 minutes	Number
Sit & Reach (3 trials)	Flexibility	Average Using Sit & Reach Box	Inches
Pull-Ups(men)	Upper Body Strength-Endurance	# in 2 minutes	Number
Flex Arm Hang (women)	Upper Body Strength-Endurance	Time	Seconds
Vertical Jump (3 trials)	Lower Body Power	Vertec	Inches
Horizontal Jump (3 trials)	Lower Body Power	Tape measure	Inches
3 mile run time	Aerobic Capacity	Stop Watch	Seconds

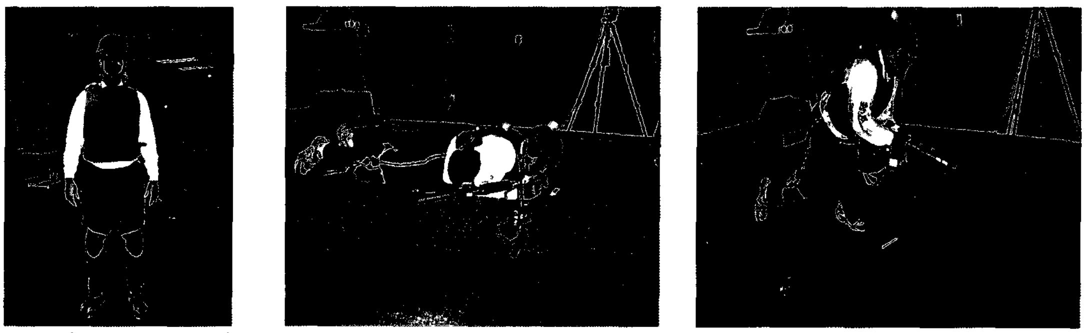


Fig. 6. Pictures of Pilot Study Data Collection.

After the Pilot Study data were collected, and implemented into the spreadsheet model (Section 3.2), an additional IRB application #10-076 was approved. Data were collected from August through October of 2010 where the main purpose was to gather real data to use as input rushing velocities for the scenarios. In addition to gathering valid rushing input data, additional concerns addressed were to determine if there were correlations between physical fitness attributes and rushing velocity, to determine if rushing velocities vary when different starting and ending positions are used (e.g., prone, kneeling or standing), and to determined if the average velocity varied based upon the distance to be rushed (3 to 30 meters). Participants completed a health screening on the phone to ensure that they were physically fit to participate in the study before scheduling.

The movement tests were changed for the second study to collect data specifically for use in the scenarios. The standard physical fitness tests from the Pilot Study were also used: crunches, push-ups, pull-ups, etc. By using standard tests or measures of fitness, a model predicting rushing performance could be built for future use in military simulations for actual infantry using these standard measures. The participants again wore simulated body armor, a helmet, and carried a weighted M16 for the movement tests. A weighted backpack was added to simulate a fighting load with a total weight of 30 kg for men and 20 kg for women [92]. Data were collected over two days. The Marine Core CFT was scheduled on a separate day from the 3 mile run rather than risk exhausting the participants. The rushing times were collected at the beginning of the first day in random order. Rushing tests consisted of starting prone, kneeling, or standing, and ending in one of the three positions after traveling the required distances and are listed in Table 5, so that future work could include analyzing the times based upon the different starting and stopping positions. The different positions change the time to rush the distance. The rushing and CFT tests were all performed outside, and were scheduled in the same session at the Powhatan Field near Old Dominion University's Campus, which had an artificial turf. All of the rest of the testing, except for the 3-mile run was collected on the second day in room 1007 of the Student Recreation Center. After all of the indoor tests were performed, the participant ran 3 miles for the last test on the second day. The course for the 3 mile run consisted of running along Powhatan Street from the corner of Powhatan and 48th to the corner of Powhatan and 38th and back 3 times. The IRB Form, informed consent document, health screening, score form, and flyers are found in Appendix B. The data collected is found in Tables 2 and 4 above, and Tables 5-6 below.

Table 5. Environment Data Collected During Rushing Study

Measurement	Category	Method	Units
Date(Day 1 & Day2)	Environment	Calendar	MM/DD/YYYY
Time(Day 1 & Day2)	Environment	Clock	HH:MM
Temperature (Day 1 & Day2)	Environment	Weather Information	Fahrenheit
Humidity (Day 1 & Day2)	Environment	Weather Information	%
Clouds (Day 1 & Day2)	Environment	Weather Information	Weather Standard
Precipitation (Day 1 & Day2)	Environment	Weather Information	
Wind Speed (Day 1 & Day2)	Environment	Weather Information	
Wind Direction (Day 1 & Day2)	Environment	Weather information	Degrees

Table 6. Rushing Study Data Collected on First Day.

Task (All Day 1)	**Measured Task**	**Measurement**
3-5 Second Rush	15 Meter Rush – Standing to Standing	Time from Standing to Standing
3-5 Second Rush	10 Meter Rush – Standing to Kneeling	Time from Standing to Kneeling
3-5 Second Rush	5 Meter Rush – Standing to Kneeling	Time from Standing to Kneeling
3-5 Second Rush	3 Meter Rush – Kneeling to Kneeling	Time from Kneeling to Kneeling
3-5 Second Rush	6 Meter Rush – Kneeling to Kneeling	Time from Kneeling to Kneeling
3-5 Second Rush	12 Meter Rush – Prone to Prone	Time from Prone to Prone
3-5 Second Rush	30 Meter Rush – Prone to Prone	Time from Prone to Prone
3-5 Second Rush	12 Meter Rush – Kneeling to Kneeling	Time from Kneeling to Kneeling
3-5 Second Rush	30 Meter Rush – Kneeling to Kneeling	Time from Kneeling to Kneeling
3-5 Second Rush	12 Meter Rush – Standing to Standing	Time from Standing to Standing
3-5 Second Rush	30 Meter Rush – Standing to Standing	Time from Standing to Standing
Marine Combat Fitness Test	Do not wear backpack, helmet, vest, or carry rubber M16. Wear all of these in Rushing Tasks Only.	Measure performance according to Marine standards. 880 YD run in time as MM:SS. Ammunition Can lift was # lifts in 2 minutes. Maneuver under fire was in time as MM:SS.

After the data was collected, the participants were scored according to the Marine Corps PFT and CFT. The overall rushing consistency and ability needed to be analyzed.

The times could not be totaled, as the three 30 meter rushes would dominate the total time. The participants' scores were ranked according to performance across all rushes and totaled. The ranks for the rushes were compared with the overall rushing rank and rushing ability was found to be consistent between the low and high performing rushers. Spearman's correlation coefficient was calculated for the overall rushing rank and the rank each of the physical fitness tests.

E. Agent-Based Simulation

Only agent based simulation software was considered for modeling the scenarios to enable simulating each individual friendly soldier moving from one point to the next. Four separate software packages were reviewed and tested: IWARS (US Army Materiel Systems Analysis Activity, Robert Auer Natick Soldier Center), VR-Forces (MÄK Technologies, Cambridge, MA), NetLogo (Wilensky, U.), and AnyLogic(XJ Technologies, St Petersburg, Russia).

Infantry Warrior Simulation (IWARS) models soldier and small unit interactions. It has human behavioral parameters such as facing direction, health, observed firing, posture, and speed. When a human agent was created during this research, IWARS requested physiological data such as sex, height, weight, age, and body fat. There was no mention, of how they were used within the capabilities of the agent. There was information pertaining to load calculations, but not much detail about their impact upon movement of the infantryman. Speed of movement was one of the most important characteristics within a battle situation and would be used to implement rushing physical abilities [26]. Therefore, a scenario was run on IWARS for a human of speed 7 meters/second, and then the human was changed to have a speed of 20 meters/second.

Both scenarios showed the human reaching the same distance points at the same time with respect to the simulation clock. Thus, the speed was not clear how to implementing the changes to speed. While there was much help and support from the committee to enable its use, the software contractor writing the code could not give the support needed for an academic endeavor. The information was unavailable to determine how the speed was used and when shots were taken. The human interface with this simulation software was very well written to create a flow of tasks for the soldiers, but without the ability to see the code and documentation, it was difficult to access the detail needed for purposes of this project. Therefore, this software was not chosen as a candidate software package for this dissertation.

VR-Forces by MÄK Technologies could run simulated battlefield scenarios incorporating planes, ships, tanks, and infantry. VR-Forces included the B-Have Module for human artificial intelligence and Lua scripting (Lablua, Rio de Janeiro, Brazil) for customizing the simulations. Lua scripts were used to change the velocity of soldiers moving in the line of fire of the enemy. Preliminary scenarios were designed and run to test the accuracy of the enemy verses friendlies, and determine if there were any unknown differences in how the enemies and friendlies fired and the effect of changing the speed of a friendly rushing across a line of fire. These showed no differences in the results of the simulation based upon order of creation of entities or entity allegiance. There were expected differences in results based upon firing weapon used i.e. AK-47 verses M16. Further testing showed that specific features of human behavior were not modifiable within the B-Have Module and Lua scripts. For example, a soldier could not be programmed to advance and hide in a specific manner. Access to software support and some of the functionality and ability to make some of the changes was difficult with an academic license. Other software options needed to be pursued to enable access to the parameters and behaviors needed.

NetLogo was also investigated as an option. The Pac-Man Level Editor was used as a model to write software that could create an environment that represents a battlefield: buildings, uneven terrain, trees, etc., Fig. 7. Friendly and Foe agents were created, and basic scenarios were started. Agents could be made to move in the manner desired. During this effort, AnyLogic was also reviewed and found to be easier to use for this purpose and enabled quicker implementation than NetLogo. Thus further implementation in NetLogo was halted.

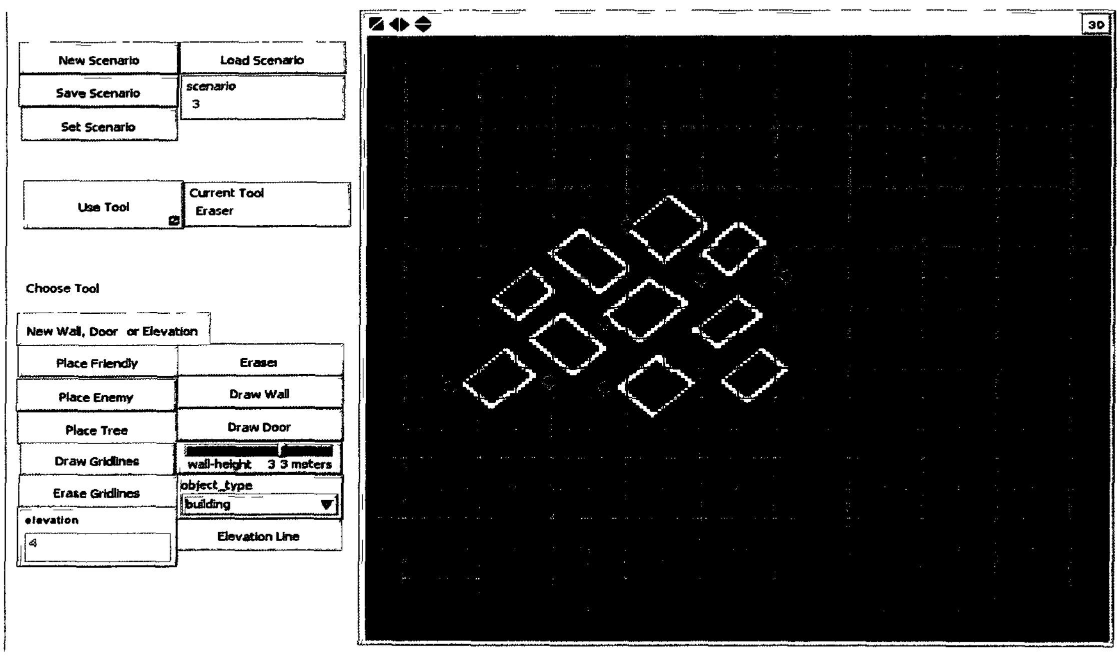


Fig. 7. NetLogo Scenario Editor.

AnyLogic is Java-based and can be used to create System Dynamic, Discrete Event, Discrete Event Network-Based, Agent-Based, and Pedestrian Dynamic simulations. The initial modeling skeleton is via a visual interface. There are windows within each object created for specialized code. Agents were created to represent the enemy and friendly warriors. Inputs into the AnyLogic simulation allowed regulation of shooting cadence, location and movement of friendly soldiers and the accuracy of the shooters. Each agent type was programmed using state machines. Two separate project files were created, one for each scenario.

1) Helicopter Evacuation Scenario: The Helicopter Evacuation Scenario consisted of three types of agents: the helicopter agent, the friendly agent, and the enemy agent. The state charts for each of these agents were shown below in HeliMove, WarriorMove, and EnemyAction respectively of Fig. 8 and a diagram depicting the scenario was shown in Fig. 4. The scenario started with a static helicopter then after a timeout of zero seconds, it moved towards a clearing. Upon reaching the clearing, it sent a message to the other agents that it had arrived. Upon hearing the message, the thirteen warriors rushed fifteen meters towards the helicopter. The enemy noticed the warriors running and started to shoot after a reaction time of 0.5 seconds had passed. The enemy alternated between shooting and pausing according to the shooting cadence. The enemy notified the warrior if he/she has been shot. Once all of the warriors had either reached the helicopter or been wounded, the helicopter left and the scenario ended. Data related to the parameters of the scenario, number of soldiers wounded, distance traveled by soldiers, shots taken, etc were written to an Excel file for analysis.

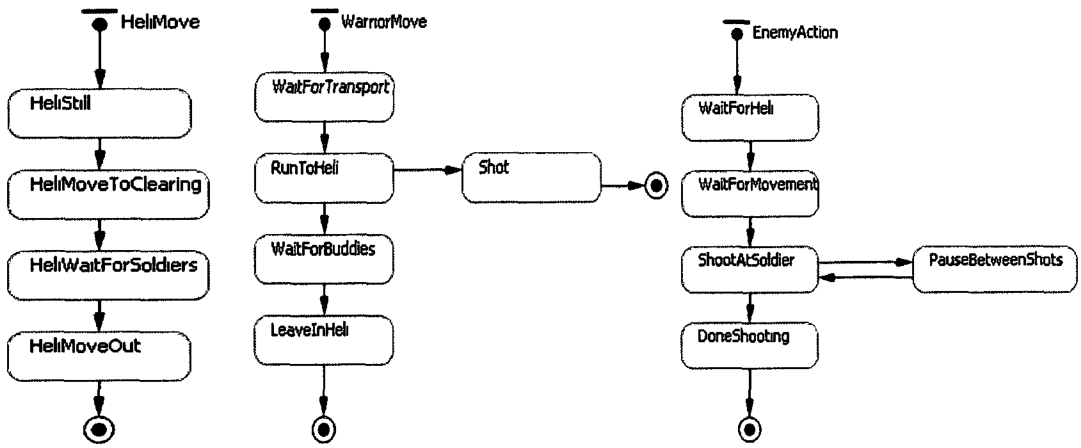


Fig. 8. State Diagrams for the Helicopter Scenario.

2) Grenade Throw Scenario: The Grenade Throw Scenario contained three types of agents: the friendly warrior, the enemy agent, and the grenade agent (shown in Fig 9). A diagram depicting the scenario is in Fig. 5. The first warrior agent started behind cover with the second warrior and ran towards the second cover while the second warrior remains in place. The enemy had a reaction time of 0.5 seconds, then started shooting at the soldier while pausing between shots according to the shooting cadence. Once the rushing soldier reached cover, he waited for the second soldier to rush to join him. If a soldier was shot before reaching cover, a healthy soldier will start the next rush. If a soldier reached cover that was closest to the enemy, a grenade was thrown at the enemy, who was then destroyed. The grenade was also an agent that traveled from the soldier to the enemy when it was thrown. The scenario ended when either all of the soldiers have been shot, or a grenade had been thrown at the enemy. Data related to the parameters of the scenario, number of soldiers wounded, distance traveled by soldiers, shots taken, grenade thrown, etc. are written to an Excel file for analysis.

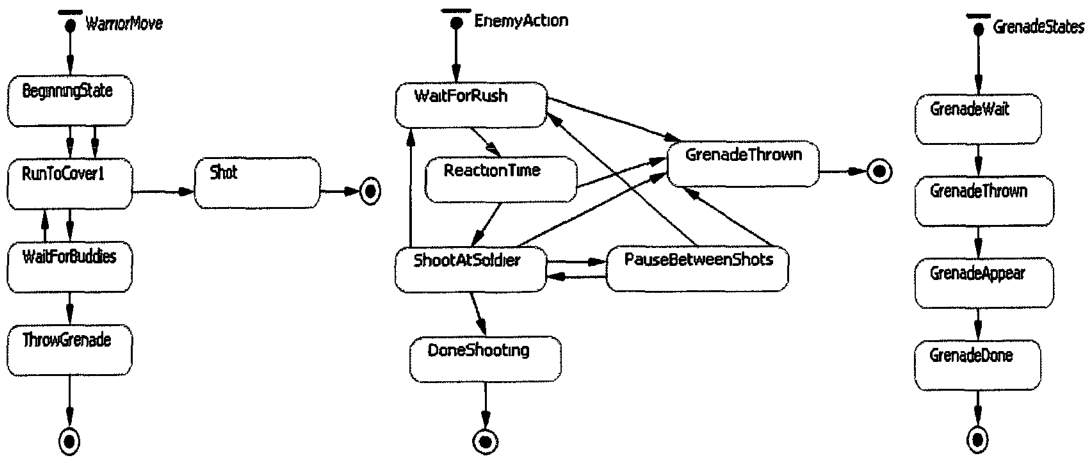


Fig. 9. State Diagrams for the Grenade Scenario.

F. Plausibility, Validation, and Verification

Validation consists of ensuring the model was translated or coded correctly to support the intended purpose [93]. The purpose of the scenarios in this effort was to evaluate the impact of modeling physical fitness through rushing velocity upon the results of a tactical infantry simulation. In this dissertation, the scenarios were actually vignettes, which are small mini-scenarios [32]. It is difficult to completely validate a military scenario: they involve human behavior that is very difficult to put into equations and are never truly generic [32]. Each scenario has a specific set of information about the environment and military agents that may not be seen in every battle [32]. A scenario is written to define a setting that enables quality analysis of the results [32]. The scenarios and their components were compared to battlefield situations to ensure the system was modeled appropriately to achieve usable and plausible results. Data validation consists of ensuring the data needed to build, evaluate, test, and conduct experiments using the model are sufficient and correct [94] . Data validation was performed by reading literature, varying input parameters, and performing data collection. Input parameters were reviewed to ensure they were reasonable numbers given the context of the situation. Verification consists of ensuring the model was translated correctly into its usable or implemented form [94-95]. Desk checking of the scenarios [95] was performed as a part of the verification process and the results compared with output from the scenarios. The scenarios were designed with animations of the agents to aid in the verification process via visualization [94]. The data written to an excel spreadsheet were reviewed for correctness. The output data from validation and verification runs were compared with results from preliminary predictions, and the logistical regression process was run to assess prediction ability.

1) Scenario Plausibility: Scenario creation consisted of ensuring that the correct entities as well as their necessary attributes and features are included in a model to serve the users' needs for making decisions when reviewing the output [96]. The referent system for these scenarios is a tactical battle, and a referent system contains the best data describing the characteristics and behavior of the system [93]. The goal of this research was to determine if modeling physical fitness had an impact upon the results of a tactical scenario. The rushing task was selected for modeling physical fitness and rushing performance is likely to be affected by physical fitness attributes. Each scenario included rushing by friendlies as a component where one scenario has multiple rushers, and the other scenario had only one person rushing at a time. During the rushing movement, if there was no weapon fire, the rusher was not at risk, and the velocity may have little outcome in the results of the scenario. In both scenarios, there was gunfire during rushing movement. The weapon fire was adjustable to determine if and how rushing velocity impacted the tactical scenario during different types of fire: light, medium, heavy, etc., where light fire is in the range of (0, 1.0) shots per second, medium is (1.0, 2.5) shots per second, and heavy fire is greater than 2.5 shots per second. The accuracy was adjustable to determine if rushing velocity had an impact if the enemy is more/less accurate with weapon fire.

Helicopter insertion or extraction has been used recently in the mountains of Afghanistan for the battle of Tora Bora (12/2001), Operation Anaconda, (3/2002), Battle of Chora (2007), Battle of Wanat (7/2008), Angoor Ada (9/2008) and in past wars or events such as by the Infantry QRF in Mogadishu on October 3-4 of 1993. A rushing distance of 15 meters was selected as the minimum distance a soldier might rush from cover to a helicopter extraction or insertion. Section 4.2 shows the results of a rushing survivability model and the maximum difference in survivability for rushing using the preliminary data is 25-30 meters. A more conservative distance was selected here to ensure that the distance was not picked to exaggerate the difference in survivability. The rushing distances for the grenade throw scenario were chosen after looking at pictures of Afghanistan and Iraq (Fig. 10) and trying to determine distances for closer urban situations and looking at maps from Google Earth (Fig. 11). Longer rushes such as very wide streets were not chosen because an infantry man would not cross a wide street under heavy gunfire. Distances were minimized to make it more difficult to prove the effect of faster rushing velocity.

Fig. 10. Photographs from MilitaryPhotos.net. These were reviewed during the process of constructing the scenarios. Features include men moving towards a helicopter, men rushing down streets, men rushing in rural areas, and men using cover. The street at bottom left was not a street one would cross in the middle of battle without assistance (smoke, tanks, etc). A soldier would move short rushes the distances between the small tent fronts along the sides of the street. The bottom two pictures show close doorways and hiding places for cover.

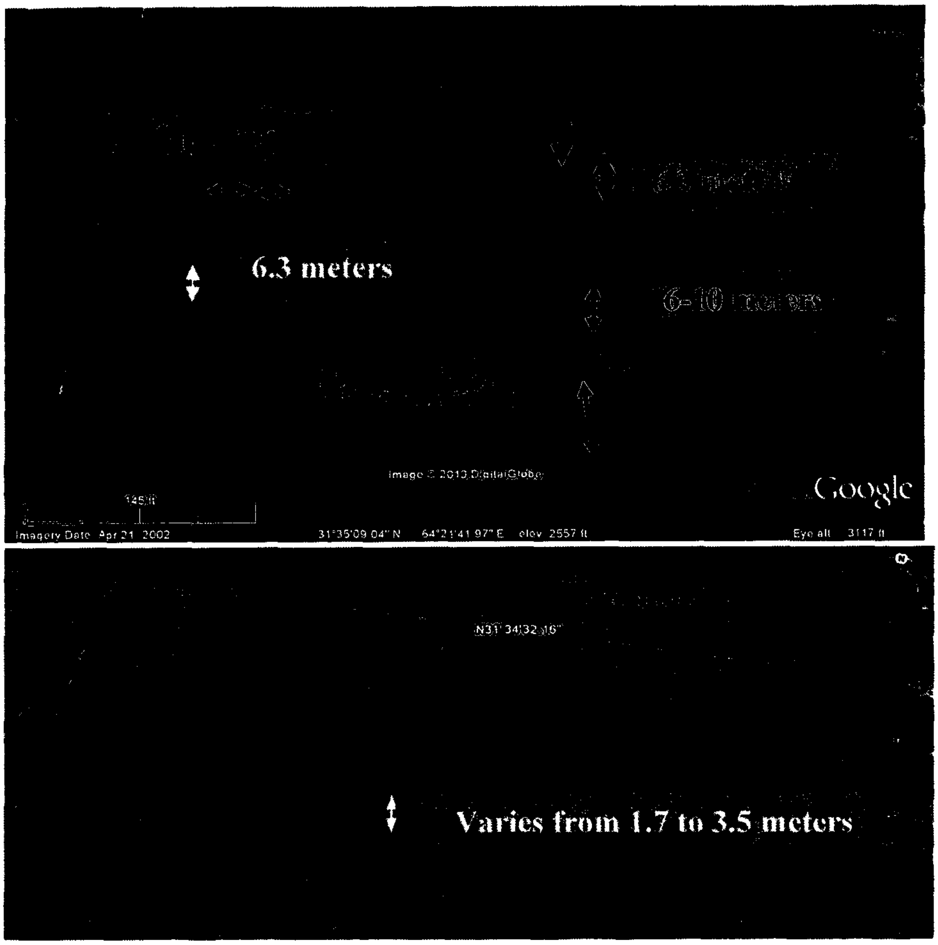


Fig. 11. Street and Open Distances in Lashkar Gah Estimated Using Google Earth Scale.

These scenarios did not include features such as decreased enemy shooting accuracy for increased rushing velocity, decreased enemy shooting accuracy during response with friendly cover fire, casualty evacuation, or return fire with decreased accuracy due to fatigue. Each of these behaviors could increase the effect of increased rushing velocity and the effects of physical fitness level. These scenarios are meant to be simple and straightforward to find a "minimum value" for the potential effect of increased physical fitness. Adding these extra features would complicate the situation and could exaggerate the potential positive effects of modeling physical fitness within a tactical simulation.

2) Data Validation: Data validation checks to see that each input data model is accurate and consistent with the objectives of the simulation study [97]. Equations 3, 4, and 5 were not implemented in the agent-based model built using AnyLogic. But, they show attributes that control how agents behave. The distance rushed by the soldiers was a part of the scenario design: 15 meters for the helicopter rush, and distances of 3 and 6 meters for the consecutive rushing scenario. Other important data elements are the reaction time, rushing velocity, shooting cadence, and shooting accuracy (See Section 3.2). The time it takes to complete the rush and the number of shots fired during rushing was computed as the agents performed their tasks. The reaction time, rushing velocity, shooting cadence, and accuracy needed to be researched to ensure valid inputs for the system. The probability of mission success was calculated based upon the ratio of number of runs where the soldiers successfully met the metric of success verses the total number of runs.

The reaction time affects when the enemy makes the first shot at the rushing warrior and when subsequent shots are taken. A longer reaction time would decrease the number of shots taken by the enemy. A reaction time of 0.5 seconds was the average reaction time from four reaction time studies: an experiment that measured reaction time for a hand to leave a button (.22 -.24 seconds) and move to a new manual aiming location (.28-.3 seconds) [98], another experiment measured task according to location in field of view with reaction times from .259-.514 seconds [99], an experiment on the difference of reaction times based upon simple and complex tasks that found mean reaction times between .58 and .678 seconds [100], and finally a task performing complex visual processing which had a median reaction time of .445 seconds [101]. The average of all of these was .502 seconds, which was rounded to .5 seconds. This model assumed that the friendly soldier was in the field of view for the enemy and the enemy was expecting the friendly soldier to appear.

Reaction time with respect to military shooting was not available. Additional research on reaction time found data with regard to shooting by police using hand guns [102]. This dissertation assumed that the enemy shooter has already seen the soldier and is looking right at the area where the soldier went behind cover. The average time for a policeman to fire at an unsighted target when the finger is already on the trigger is .35 seconds [102]. The average reaction time for a policeman to fire at a simple, unsighted target with a finger on the frame of the handgun is .45 seconds [102]. If the police officer must raise the handgun from a low-ready position of a 45 degree angle, acquire a sight picture, and fire one round is .83 seconds. These show reasonable expectations of .5 seconds reaction time for a person already engaged in battle and watching the area ready to engage a soldier coming from behind cover.

Velocities used for rushing were calculated based upon values found during our Pilot Study data collection, Rushing Study data collection and a previously published study [26]. The source and use of the rushing velocities are given in Table 7.

Table 7. Rushing Velocities, Their Sources, and Where Used.

Velocity m/s	Source of Velocity	Use of Velocity
2.35	Pilot Study – rounded slowest rush velocity	Rushing in Excel Model [90] Rushing in Helicopter Scenario Rushing in Grenade Scenario
3.25	Rounded top tenth percentile performance based upon numbers derived from Harman Study [26]	Rushing in Excel Model [90] Rushing in helicopter Scenario Rushing in Grenade Scenario
3.8	Pilot Study – rounded fastest rush velocity	Rushing in Excel Model [90] Rushing in Helicopter Scenario Rushing in Grenade Scenario
4.65	Rounded 90% percentile performance based upon numbers derived from Harman Study [26]	Rushing in Excel Model [90] Rushing in Helicopter Scenario Rushing in Grenade Scenario
1.224	Rushing Study Collection – slowest velocity for 3 meter rush kneeling to kneeling that also passed Marine Physical Fitness Test	Rushing in Excel Model Rush 3 meters for Grenade Scenario
1.429	Rushing Study Collection – median of velocities for 3 meter rush kneeling to kneeling.	Rushing in Excel Model Rush 3 meters for Grenade Scenario
1.639	Rushing Study Collection – second fastest velocity for 3 meter rush kneeling to kneeling	Rushing in Excel Model Rush 3 meters for Grenade Scenario
2.308	Rushing Study Collection – fastest velocity for 3 meter rush kneeling to kneeling	Rushing in Excel Model Rush 3 meters for Grenade Scenario
1.893	Rushing Study Collection – slowest velocity for 6 meter rush kneeling to kneeling that also passed Marine Physical Fitness Test	Rushing in Excel Model Rush 6 meters for Grenade Scenario
2.12	Rushing Study Collection – median of velocities for 6 meter rush kneeling to kneeling.	Rushing in Excel Model Rush 6 meters for Grenade Scenario
2.5	Rushing Study Collection – second fastest velocity for 6 meter rush kneeling to kneeling	Rushing in Excel Model Rush 6 meters for Grenade Scenario
2.778	Rushing Study Collection – fastest velocity for 6 meter rush kneeling to kneeling	Rushing in Excel Model Rush 6 meters for Grenade Scenario
3.106	Rushing Study Collection – slowest velocity for 15 meter rush standing to standing that also passed Marine Physical Fitness Test	Rushing in Excel Model Rushing 15 meters to helicopter
3.497	Rushing Study Collection – median of velocity for 15 meter rush standing to standing.	Rushing in Excel Model Rushing 15 meters to helicopter
4.05	Rushing Study Collection – second fastest velocity for 3 meter rush standing to standing.	Rushing in Excel Model Rushing 15 meters to helicopter
4.31	Rushing Study Collection – fastest velocity for 6 meter rush standing to standing.	Rushing in Excel Model Rushing 15 meters to helicopter

The shooting cadence varies from 0.5 shots per second to 3.5 shots per second or 1 shot every 2.0 seconds to 1 shot every 0.286 seconds for each enemy. In real life, the number of enemies and gun fire intensity varies constantly, even within a single battle. The cadence was varied to account for the uncertainty of shots per second during a battle, but remained constant within each execution to enable analysis of the effect of shooting cadence upon rushing survivability. There are two enemies in the Helicopter Scenario shooting at 13 soldiers for a total of 1 to 7 shots per second for 13 soldiers or .07-.54 shots per soldier per second. In the Grenade Scenario, there was only 1 shooter and 1 rushing person at any given time giving from .5 to 3.5 shots per second towards the rusher. By looking at the variation of the shooting cadence, the effect of increased rushing velocity during light or heavy gunfire can be assessed.

Published data for military shooting accuracy were not found. Data were found for police shooting accuracy. Shooting accuracy during target practice does not carry into real life battle situations [103]. Low lighting, weapon, distance, of the target, numbers of officers involved, as well as many other factors contribute to shooting accuracy [103]. The New York Police Department (NYPD) recorded an average hit probability of 15% during 1990-2000 [103]. Miami Metro-Date Police department shows a average hit probability of 35% when a revolver was used and 25% for semi-automatic weapons [103]. This ratio varied depending upon the distances in which the police officer was from the target with 38% accuracy for 0-2 yards, 17% accuracy for 3-7 yards, 9% accuracy for 8-15 yards, 8% accuracy for 16-25 yards, and 4% accuracy for distances beyond 25 yards [103]. This study assumed the enemy to be farther away than 2 yards. The Los Angeles County Police statistics showed that the shooting accuracy goes down as the number of police officers involved goes up [103]. In one study, when only 1 officer was involved, the hit ratio was 51%, but two officers had an average shooting accuracy of 23%, and if there were more than two officers, the shooting accuracy averaged 9% [103]. This trend is known as bunch shooting. Given this wide variety of shooting accuracies from police officers in the field, accuracies of 10%, 20%, and 30% are used to look at how varying the shooting accuracy affect the impact of a physical fitness model using rushing velocity.

3) Scenario Verification by Desk Checking: A preliminary desk check (step by step logic test) was performed for **one** enemy and **one** soldier at each of the four original velocities (2.35, 3.25, 3.8, and 4.65 m/s) with a shooting cadence of one shot per second and reaction time of 0.5 seconds for each of the four scenarios. This desk check gave a maximum number of shots and an ending time given survival of all shots. The number of shots and ending time given survival of all shots were compared with the actual execution output for verification at 20% accuracy and 1 shot per second shooting cadence.

The desk check for the Helicopter Scenario using the preliminary data, one enemy, one rushing soldier, a shooting cadence of 1 shot per second, and an initial reaction time of 0.5 seconds was shown in Table 8. The scenario started with the helicopter traveling to the clearing where the infantry are to be extracted and landing time equals 8.0 seconds. The rusher starts to move towards the helicopter and the enemy starts to shoot at 8.5 seconds. The rest of the actions are documented in a separate column for each velocity. For each velocity, the ending time and total shots matched the simulation verification runs.

Table 8. Desk Check of Helicopter Scenario for 1 Soldier and 1 Enemy

Time (s)	Events (2.35 m/s)	Events (3.25 m/s)	Events (3.8 m/s)	Events (4.65 m/s)
0.0	Start	Start	Start	Start
8.0	Helicopter Lands	Helicopter Lands	Helicopter Lands	Helicopter Lands
8.0	Soldier Rushes	Soldier Rushes	Soldier Rushes	Soldier Rushes
8.5 (Reaction)	Shot 1	Shot 1	Shot 1	Shot 1
9.5	Shot 2	Shot 2	Shot 2	Shot 2
10.5	Shot 3	Shot 3	Shot 3	Shot 3
11.226				Arrive At Helicopter
11.5	Shot 4	Shot 4	Shot 4	
11.95			Arrive at Helicopter	
12.5	Shot 5	Shot 5		
12.62		Arrive at Helicopter		
13.5	Shot 6			
14.38	Arrive at Helicopter			
End Time	14.38	12.62	11.95	11.23
Total Shots	6	5	4	3
Probability for Survival at 20% Accuracy From Desk Check	26.2%	32.8%	41%	51.2%

The desk check for the Grenade Scenario was conducted at the four preliminary data velocities, with one enemy, one rushing soldier, a shooting cadence of 1 shot per second, and an initial reaction time of 0.5 seconds was shown in Table 9. The locations for cover were the following grid coordinates: [(960,225), (960,195), (935, 250), and (910,195)] as seen in Fig. 5 of Section 3.3. This gave distances of 3, 6.04, and 6.04 meters. The ending time and total shots for each velocity matched between the walkthrough and the simulation runs.

Table 9. Desk Check of Grenade Scenario for 1 Soldier and 1 Enemy.

Time (s)	Events (2.35)	Events (3.25)	Events (3.8)	Events (4.65)
0.0	Start	Start	Start	
0.5 (Reaction)	Shot 1	Shot 1	Shot 1	Shot 1
0.645				Arrive Cover 1 & Start Next Rush
0.789			Arrive Cover 1 & Start Next Rush	
0.923		Arrive Cover 1 & Start Next Rush		
1.145 (Reaction)				Shot 2
1.276	Arrive Cover 1 & Start Next Rush			
1.289 (Reaction)			Shot 2	
1.423		Shot 2		
1.777	Shot 2			
1.944				Arrive at Cover 2
2.289			Shot3	
2.379			Arrive at Cover 2	
2.423		Shot 3		
2.444 (Reaction)				Shot 3
2.777	Shot 3			
3.777	Shot 4			
2.782		Arrive at Cover 2		
3.847	Arrive at Cover 2			
2.879			Shot 4	
3.243				Arrive at Cover 3
3.282		Shot 4		
3.879			Shot 5	
3.969			Arrive at Cover 3	
4.282		Shot 5		
4.347	Shot 5			
4.64		Arrive at Cover 3		
5.347	Shot 6			
6.347	Shot 7			
6.418	Arrive at Cover 3			
End Time	6.418	4.64	3.969	3.24
Total Shots	7	5	5	3
Probability for Survival at 20% Accuracy from Desk Check	20.97%	32.77%	32.77%	51.2%

Table 10. Desk Check of Grenade Scenario Using Rushing Study Velocities.

Time (s)	Event (1.224, 1.893) m/s	Event (1.429, 2.12) m/s	Event (1.639, 2.5) m/s	Event (2.307,2.777) m/s
0.0	Start	Start	Start	Start
.5	Shot 1	Shot 1	Shot 1	Shot 1
1.3				Arrive Cover 1
1.5	Shot 2	Shot 2	Shot 2	
1.80				Shot 2
1.83			Arrive Cover 1	
2.099		Arrive Cover 1		
2.451	Arrive Cover 1			
2.33			Shot 3	
2.599		Shot 3		
2.80				Shot 3
2.951	Shot 3			
3.33			Shot 4	
3.476				Arrive Cover 2
3.599		Shot 4		
3.951	Shot 4			
3.976				Shot 4
4.23			Arrive Cover 2	
4.599		Shot 5		
4.747			Shot 5	
4.949		Arrive Cover 2		
4.976				Shot 5
4.951	Shot 5			
5.449		Shot 6		
5.642	Arrive Cover 2			
5.651				Arrive Cover 3
5.747			Shot 6	
6.142	Shot 6			
6.449		Shot 7		
6.664			Arrive Cover 3	
7.142	Shot 7			
7.449		Shot 8		
7.799		Arrive Cover 3		
8.142	Shot 8			
8.83	Arrive Cover 3			
Total Max Shots	8	8	6	5
% Success	16.78%	16.78%	26.214%	32.768%

The changes in the code to use the new velocities from the data collected while wearing a fighting load in the Helicopter Scenario were very minor, as only the velocity input parameter was changed. The 3-meter and 6-meter rush velocities collected in the Rushing Study were not the same. Thus, the same variable could not be used for both rush velocities within the code. To ensure the change was made correctly and that two different velocities were being used, a second desk check was performed on the Grenade Scenario using the new velocities, and was shown above in Table 10.

4) Verification Animation: Animations were designed for both scenarios to aid in the verification process [94]. Each of the agents in the scenarios had location coordinates throughout the simulation runs. In the helicopter simulation, a picture of a helicopter moved across the screen to the extraction point. Thirteen soldiers moved towards the extraction point. The soldiers stopped moving and changed picture representation if they became a casualty. Variables and their values were visible on the screen during each of the runs. AnyLogic also enabled the user to view the status of the agents, which was used extensively during the debugging process for both scenarios. A representation of enemies was present on the screen. In the Grenade Scenario, two soldiers took location behind cover, and moved across an open area while an enemy remained behind cover shooting. If a soldier was hit, he stopped moving and changed picture representation. If a soldier reached a final point of cover, a grenade was seen traveling across the screen from the soldier position to the enemy position indicating success. Again, variables and their values were visible on the screen during execution and the status of the agents can be investigated.

5) Verification and Validation Runs: Results from a valid model [90] were compared to runs from each of the scenarios as a method of validation and verification [94]. Each scenario was executed with one enemy the number of times listed below in Table 11. The results of the prediction based upon the preliminary spreadsheet calculations [90] using truncated shots (***Spreadsheet Prediction***) were compared to the percent of runs that has mission success from the simulation(***Simulation Runs% Success***). The value for shots was truncated, as an agent based simulation can only have integer values for the number of shots. The number of runs for each scenario was listed in the column for **Simulation Runs % Success** in parentheses. A prediction of success based upon the simulation run output was calculated using logistic regression that corresponded to the spreadsheet prediction and the simulation run values (**Prediction using Logistic Regression**). The percentage of success within the simulation runs was similar to the prediction for success from the spreadsheet indicating a valid simulation. The prediction using logistic regression matches the simulation runs, indicating that logistic regression will predict accurate numbers for success based upon the runs.

Table 11. Simulation Validation Output Comparison.

Rushing Velocity	Spreadsheet Prediction	Max Shots	Simulation Runs % Success (# Runs)	Prediction Using Logistic Regression	95 % Confidence Interval Using Logistic Regression	
					Lower Boundary	Upper Boundary
Helicopter Scenario : Velocity Odds Ratio = 1.513						
2.35 m/s	26%	6	26% (246)	27%	20%	35%
3.25 m/s	33%	5	36% (252)	38%	26%	51%
3.8 m/s	41%	4	49% (242)	45%	31%	60%
4.65 m/s	51%	3	56%(243)	57%	39%	74%
3,6,6 Consecutive Rushing Scenario : Velocity Odds Ratio = 1.63						
2.35 m/s	21%	7	24% (294)	24%	18%	29%
3.25 m/s	33%	5	32% (318)	32%	24%	42%
3.8 m/s	33%	5	35% (290)	38%	27%	50%
4.65 m/s	51%	3	49% (537)	48%	34%	63%

G. Logistical Regression and Data Analysis

Logistical regression was used to analyze the results of the simulation and to determine if rushing velocity was a factor that affected the outcome of the simulation. The data regarding each run: number of soldiers, number of enemies, run identifier, distance rushed by each soldier, number of shots, etc., was written to an Excel spreadsheet. The spreadsheet output included a column containing a binary variable indicating if the mission was successful with a "1" or unsuccessful with a "0". Success for the helicopter mission was based upon the number of casualties and success for the grenade mission was based upon whether the grenade was thrown at the enemy. When analyzing these, a probability is calculated for success based upon the number of 1's for each set of independent variables: accuracy, shooting cadence, and rushing velocity. In linear regression, a line can be calculated to indicate a model of approximation for dependent value. But with a binary outcome, linear regression will not work very well

[104]. The actual probability itself also cannot be used for regression as it will be an S-shaped curve with limits at the top and bottom [104]. To create a linear model, a new value is calculated: the binary probability P called the logit using the formula Logit = ln[P/(1-P)] on which regression is performed [104]. The resulting linear relationship is found in Equation 6.

$$ln\left(\frac{P_i}{1-P_i}\right) = b_0 + b_1 x_i \qquad \text{Equation 6}$$

This is called logistical or binary regression. Regression returns the values for b_i. To translate these values into percentages, take the exponent of both sides, and solve for P_i to get Equation 7 below.

$$P_i = \frac{e^{b_0+b_1x_1}}{1+e^{b_0+b_1x_1}} = \frac{e^{b_0}\left(e^{b_1}\right)^{x_1}}{\left(1+e^{b_0}\left(e^{b_1}\right)^{x_1}\right)} \qquad \text{Equation 7}$$

The values for b_i and e^{b_i} are given as part of the SPSS output for logistical regression. The values for b_0, b_1, …, b_n are called the log odds and are negative to reflect a negative effect and positive to reflect a positive effect from increases in x_i. Also given as a part of SPSS output are the odds ratios or e^{b_i}. These are easier to interpret than logged odds and are used in Equation 7 to calculate the probabilities in the plots of this dissertation. The odds ratio is a ratio of the odds for success for each unit change of the independent variable. An odds ratio of 1 indicates no change in success when change occurs in the independent variable. An odds ratio greater than 1 indicates positive change from increases in the independent variable and an odds ratio less than 1 indicates negative change from increases in the independent variable. If the odds ratio = 1.14, then an increase of 1 unit in the independent variable will increase the chance of success by 14%.

So if the probability of success was 20%, then with 1 unit increase of the independent variable, the probability of success is now 22.8%.

Logistic regression was performed on the output of the simulation runs to determine if rushing velocity has an effect upon the probability of mission success. When the Pilot Study data was analyzed, logistic regression was used to test significance of velocity where shooting cadence and rushing velocity were both independent variables. Plots are created so the predictions can be interpreted visually. Significance was checked for each regression. The same task was performed on the Grenade Scenario output using Pilot Study data. The Rushing Study data was run, not only using 20% enemy shooting accuracy, but also 10% and 30% shooting enemy accuracy. Logistic regression was used to determine if velocity affects rushing differently as the shooting accuracy changes. Finally, for the Helicopter Scenario using the Rushing Study only, logistic regression was performed at each individual cadence using only rushing velocity as the independent variable to see how the odds ratios and significance compare to when two variables are used (rushing velocity and shooting cadence).

There are fewer assumptions for logistic regression than for linear regression. There does not need to be a linear relationship between the dependent and independent variables, the independent variables do not need to be normally distributed, and the errors do not need to be normally distributed with a mean of zero. The dependent variable must be binary: "0" or "1". Only the meaningful variables can be fitted. In this case, that means only using independent variables that might change the probabilities, and not fitting others that should not have an effect. The error terms need to be independent. For the data used in this project, when the output from a simulation was analyzed via logistic regression, if shooting accuracy was not one of the independent variables, then all of the selected data must be from runs of the same shooting accuracy. Otherwise, the results will not be a good fit: the output will reflect the effect from changing shooting accuracy, creating an error that is dependent upon shooting accuracy and not independent. Logistic regression requires much larger sample sizes than linear regression because it uses maximum likelihood estimates to determine the ratios and not ordinary least squares.

H. Simulation Runs

The sensitivity was calculated (Table 12) for each set of runs using Equations 8 and 9 from literature [105] where $\mathbf{N_1}$ was the number of runs needed based upon only the first independent variable, $\boldsymbol{\beta^*}$ was the effect size to be tested, **P1** was the event rate at the mean of X_1 (rushing velocity)and Z_u was the upper u^{th} percentile of the standard normal distribution. In the calculations, α=.05 and β in Z_β was .1. P1* = (1-Sensitivity)P1, and B*=ln(P1*/(1-P1*)).

$$N_1 = \frac{(Z_{1-\alpha}+Z_\beta)^2}{[P1(1-P1)\beta^{*2}]} \qquad \text{Equation 8}$$

A second independent variable required increased runs. To determine how many more runs were needed, a regression was run to calculate $X_1 = B_0 + B_2X_2$. The R^2 value (coefficient of determination for regression of shooting cadence and rushing velocity) was used to calculate the new number of runs. If X1 and X2 are correlated, then the number of runs increased dramatically. There was no correlation between the shooting cadence and rushing velocity, giving an R^2=0. When linear regression was run for the 3-meter and 6-meter variables, after adding the additional runs keeping one rushing velocity at the median, and varying the other rushing velocity, R^2 was equal to 0.143 for

10%, and R^2 was equal to 0.144 for 20% and 30%. Equation 9 was used to calculate a new total of runs based upon additional independent variables.

$$N_2 = \frac{N_1}{(1-R^2)} \qquad \text{Equation 9}$$

Table 12. Sensitivity Given Number of Runs Performed for Logistic Regression.

Simulation	Accuracy	N_1	Sensitivity	P1	R^2	N_2
Helicopter Validation	20%	242	5.3%	41.7%	N/A	N/A
Grenade Validation	20%	294	1%	37.5%	N/A	N/A
Helicopter Pilot Data (0 Casualties)	20%	205	1%	7.8%	0	N/A
Cadence Parameter	20%					N/A
Helicopter Pilot Data (≤1 Casualties)	20%	205	1%	22.7%	0	N/A
Cadence Parameter	20%					N/A
Helicopter Pilot Data (≤2 Casualties)	20%	205	3.2%	39.9%	0	N/A
Cadence Parameter	20%					N/A
Grenade Pilot Data	20%	240	1%	39.7%	0	N/A
Cadence Parameter	10%					N/A
Helicopter Rushing Data (0 Casualties)	10%	500	1%	29.4%	0	N/A
Cadence Parameter	10%					N/A
Helicopter Rushing Data (≤1 Casualties)	10%	500	1%	59.4%	0	N/A
Cadence Parameter	10%					N/A
Helicopter Rushing Data (≤2 Casualties)	10%	500	1%	80.3%	0	N/A
Cadence Parameter	10%					N/A
Helicopter Rushing Data (0 Casualties)	20%	500	1%	10.8%	0	N/A
Cadence Parameter	20%					N/A
Helicopter Rushing Data (≤1 Casualties)	20%	500	1%	29.86%	0	N/A
Cadence Parameter	20%					N/A
Helicopter Rushing Data (≤2 Casualties)	20%	500	11.5%	48.3%	0	N/A
Cadence Parameter	20%					N/A
Helicopter Rushing Data (0 Casualties)	30%	500	1%	4.28%	0	N/A
Cadence Parameter	30%					N/A
Helicopter Rushing Data (≤1 Casualties)	30%	500	1%	15.7%	0	N/A
Cadence Parameter	30%					N/A
Helicopter Rushing Data (≤2 Casualties)	30%	500	1%	29.7%	0	N/A
Cadence Parameter	30%					N/A

Table 12. Sensitivity Given Number of Runs Performed for Logistic Regression. Continued

Simulation	**Accuracy**	**N_1**	**Sensitivity**	**P1**	**R^2**	**N_2**
Grenade Rushing Data – 3 Meter	10%	428	19.9%	52.7%	.143	
6 Meter Rushing Parameter	10%				0	500
Cadence Parameter	10%					N/A
Grenade Rushing Data – 3 Meter	20%	428	1%	22.5%	.144	
6 Meter Rushing Parameter	20%				0	500
Cadence Parameter	20%					N/A
Grenade Rushing Data – 3 Meter	30%	428	1%	11.2%	.144	
6 Meter Rushing Parameter	30%				0	500
Cadence Parameter	30%					N/A

IV Results

Rushing was chosen as the task to be implemented into a tactical scenario because it is a very common form of movement used whenever an infantryman runs for cover. Results are given for a preliminary model in MS Excel, physical fitness data collected with rushing times for study participants, two agent based scenarios, and logistic regression analysis for the agent based scenario results.

A. Preliminary Investigative Model in MS Excel

Results of the preliminary investigative model showed differences in survivability based upon rushing velocity using the equations in Section 3.2. A sample from the spreadsheet using the four velocities selected from the Pilot Study and based upon published data [26] are shown in Table 13 where the shooting cadence was 0.5 shots per second, reaction time was 0.5 seconds, and shooting accuracy was 20% .

The survivability for the four velocities versus the meters to be rushed shows that there was little difference in probability of survival for extremely short distances (Fig 12). However, as the distance increased, the difference in probability of survival increased, with the maximum difference of 10%, 15%, and 21% for these velocities at a distance of 25-30 meters (Fig. 12-13). As the rushing distance increased beyond 30 meters, the difference in survivability decreased until each of the rushing velocities had nearly the same probability of survival. The difference in probability of survival between the slowest velocity of 2.35 m/s and the other three velocities was calculated and plotted (Fig. 13).

Table 13. Sample Preliminary Spreadsheet Model.

Speed 1	2.35	m/s
Speed 2	3.25	m/s
Speed 3	3.8	m/s
Speed 4	4.65	m/s
Reaction	0.5	seconds
Accuracy	0.2	P(kill/shot)
Cadence	0.5	shot/sec
Long Accuracy	0.2	pkill/shot
Long Cadence	0.5	shot/sec

\

time = distance/speed

shots = time * cadence

survival = (1-accuracy)^shots

Distance in Meters	1	5	10	15	20	25
Time at 2.35 m/s	0.43	2.13	4.26	6.38	8.51	10.64
Time at 3.25 m/s	0.31	1.54	3.08	4.62	6.15	7.69
Time at 3.8 m/s	0.26	1.32	2.63	3.95	5.26	6.58
Time at 4.65 m/s	0.22	1.08	2.15	3.23	4.30	5.38
Time 2.35 m/s – react	0.00	1.63	3.76	5.88	8.01	10.14
Time 3.25m/s – react	0.00	1.04	2.58	4.12	5.65	7.19
Time 3.8 m/s – react	0.00	0.82	2.13	3.45	4.76	6.08
Time 4.65 m/s – react	0.00	0.58	1.65	2.73	3.80	4.88
Shots for 2.35 m/s	0.00	1.81	2.88	3.94	5.01	6.07
Shots for 3.25 m/s	0.00	1.52	2.29	3.06	3.83	4.60
Shots for 3.8 m/s	0.00	1.41	2.07	2.72	3.38	4.04
Shots for 4.65 m/s	0.00	1.29	1.83	2.36	2.90	3.44
Survival for 2.35 m/s	100%	67%	53%	41%	33%	26%
Survival for 3.25 m/s	100%	71%	60%	51%	43%	36%
Survival for 3.8 m/s	100%	73%	63%	54%	47%	41%
Survival for 4.65 m/s	100%	75%	67%	59%	52%	46%
Difference 2.35 & 3.25	0%	5%	7%	9%	10%	10%
Difference 2.35 & 3.8	0%	6%	10%	13%	14%	15%
Difference 2.35 & 4.65	0%	8%	14%	18%	20%	21%

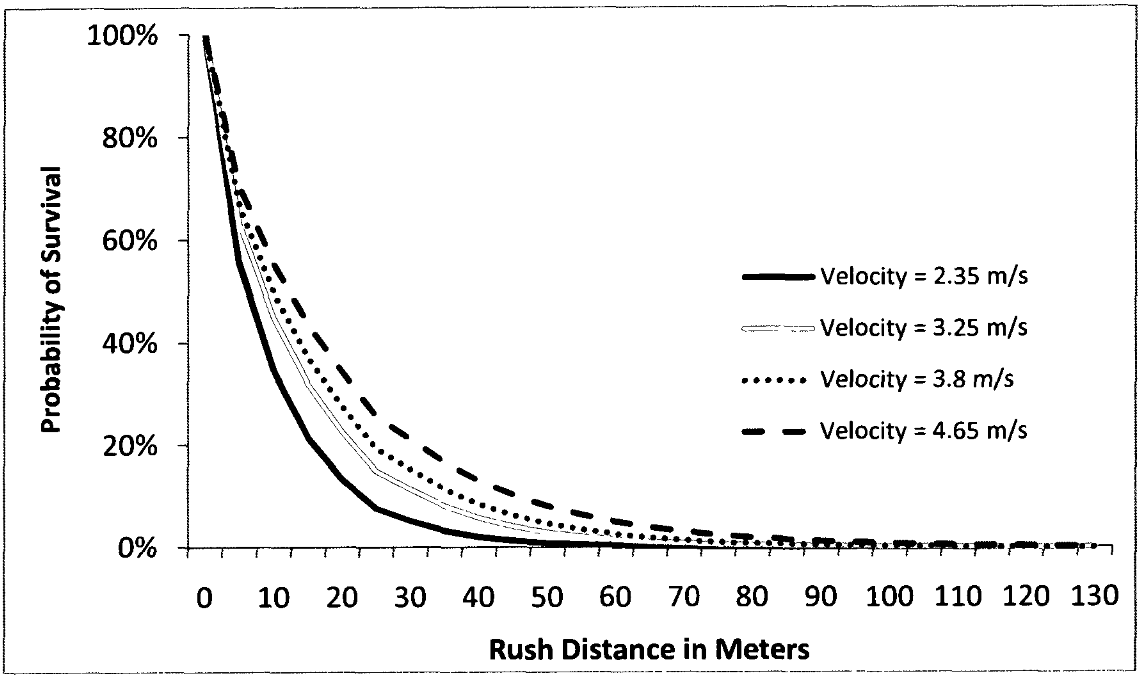


Fig. 12. Probability of Survival Preliminary Model Using Pilot Data.

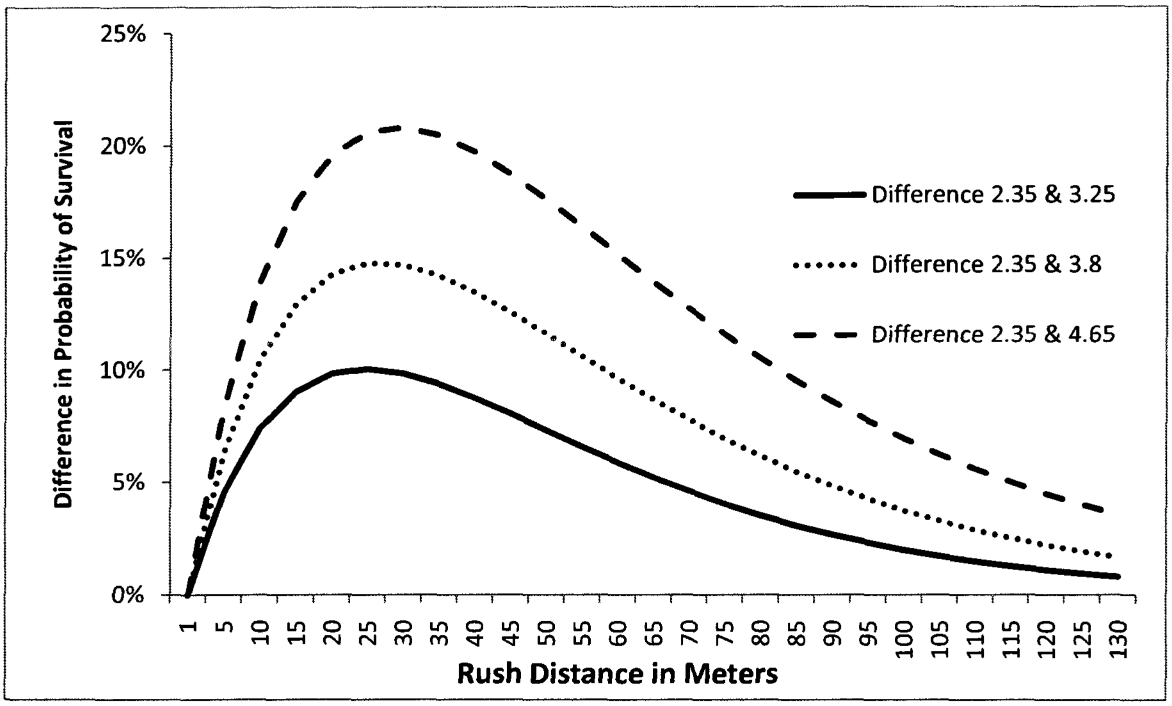


Fig. 13. Differences in the Probability of Survival from Preliminary Model Using Pilot Data.

The slowest and fastest rushing velocities of 2.35 and 3.8 m/s derived from the Pilot Study were used to investigate surviving multiple rushes. Three consecutive rushes of distances from 3-20 meters were modeled (Fig. 14). The lines with higher probabilities of survival had faster velocities (3.8 m/s), as noted by the predominance of blue lines toward the top of the survivability plots. Multiple rushes performed at 2.35 m/s had lower survivability. Therefore, a rusher traveling at a velocity of 3.8 m/s was more likely to survive three consecutive rushes of 7 meters (21 total meters) than three consecutive rushes of 5 meters (15 total meters) at a velocity of 2.35 m/s.

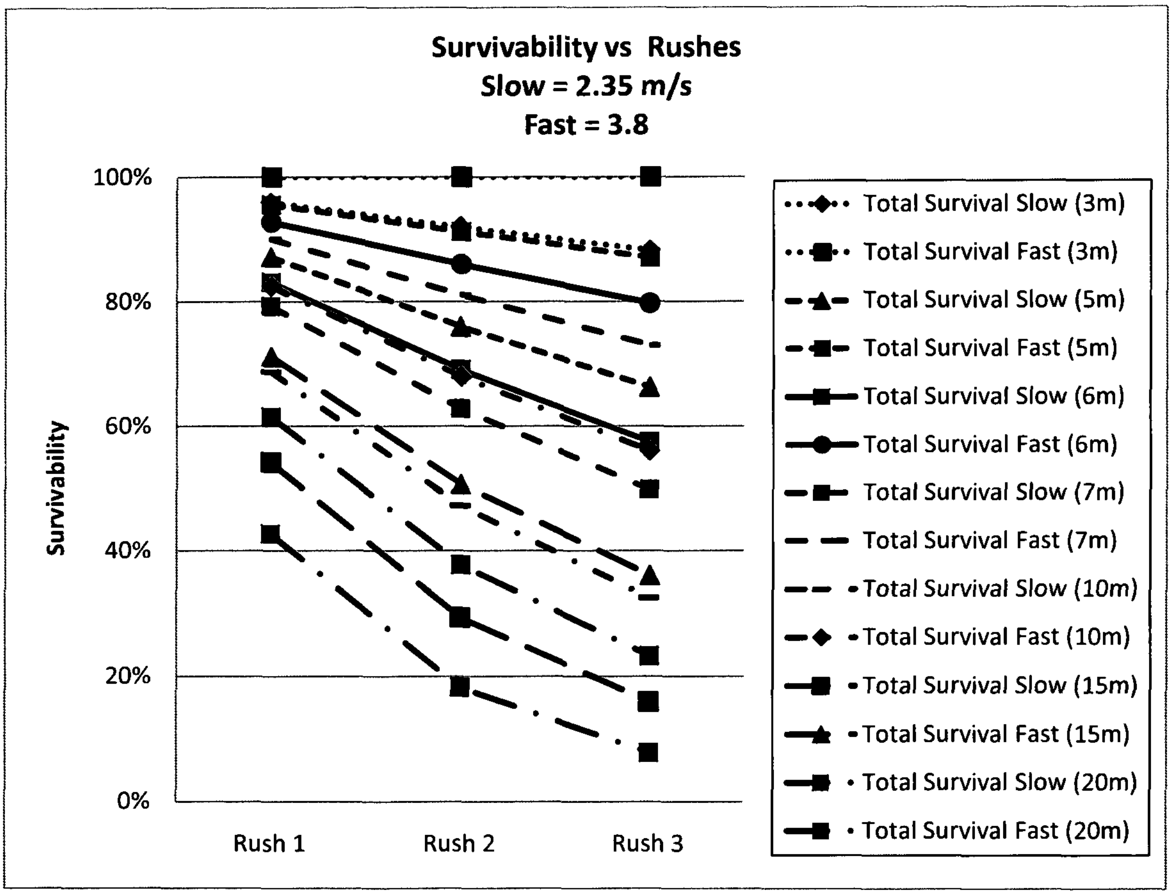


Fig. 14. Plot of Consecutive Rushes Using Preliminary Data ■ = 3.8 m/s ■ = 2.35 m/s

After data were collected from the Rushing Study which included the fighting load, the selected velocities from the 3 meter rush kneeling to kneeling, 6 meter rush kneeling to kneeling, and 15 meter rush standing to standing were used in the same spreadsheet models shown (Fig. 15-17). The three meter rush from kneeling to kneeling had the slowest velocities due to less time for the rusher to accelerate before needing to stop and the time needed to change positions between kneeling and rushing. The spreadsheet uses a reaction time before the first shot at 0.5 seconds (Equations 3 & 4). The rushing velocities collected from the 15 meter rushes all crossed the shortest distances before the reaction shot (Fig 15). The slowest two rushing velocities collected from the 6 meter rushes and the slowest three rushing velocities collected from the 3 meter rushes did not cross the shortest distances before the reaction shot (Fig. 16 - 17).

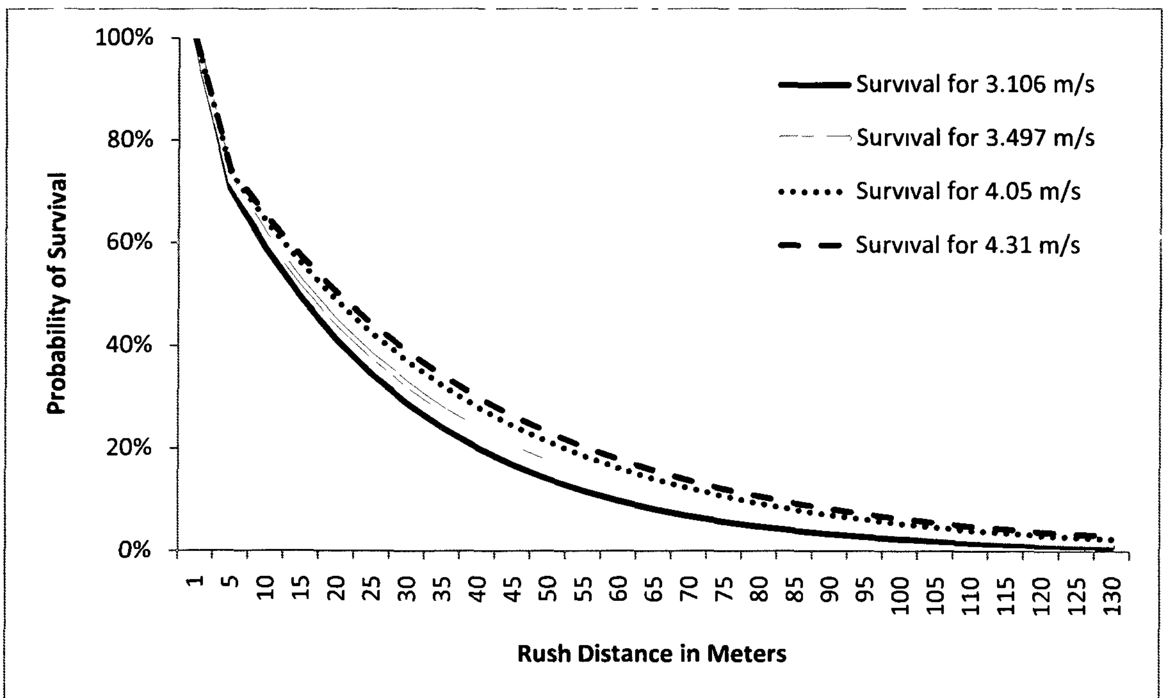


Fig. 15. Probability of Survival Using 15 Meter Rush Velocities.

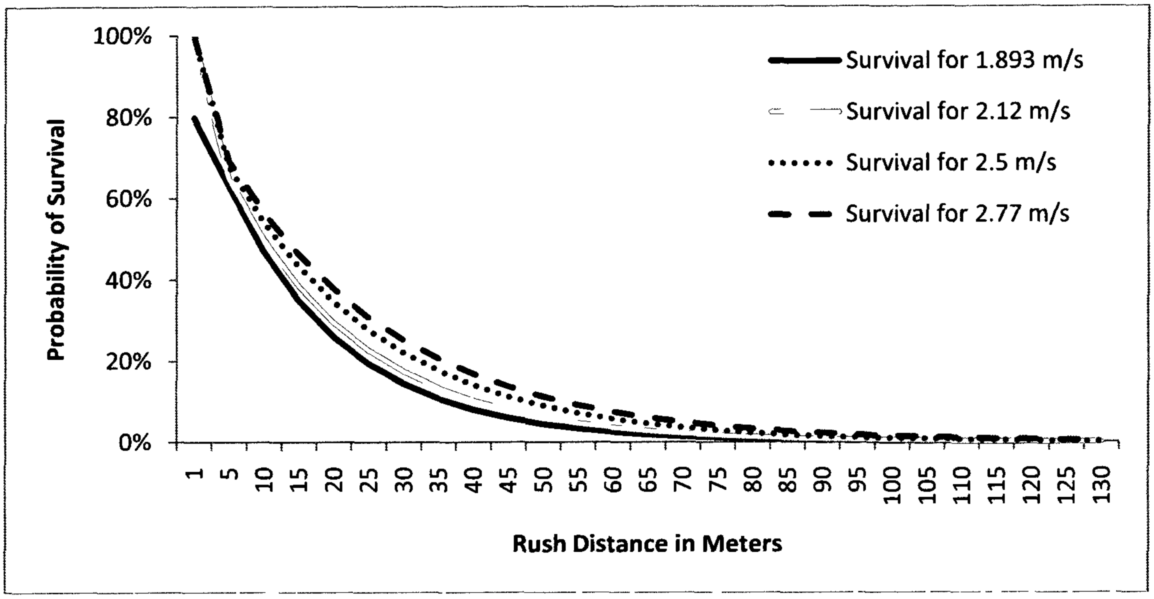


Fig. 16. Probability of Survival Using 6 Meter Rush Velocities.

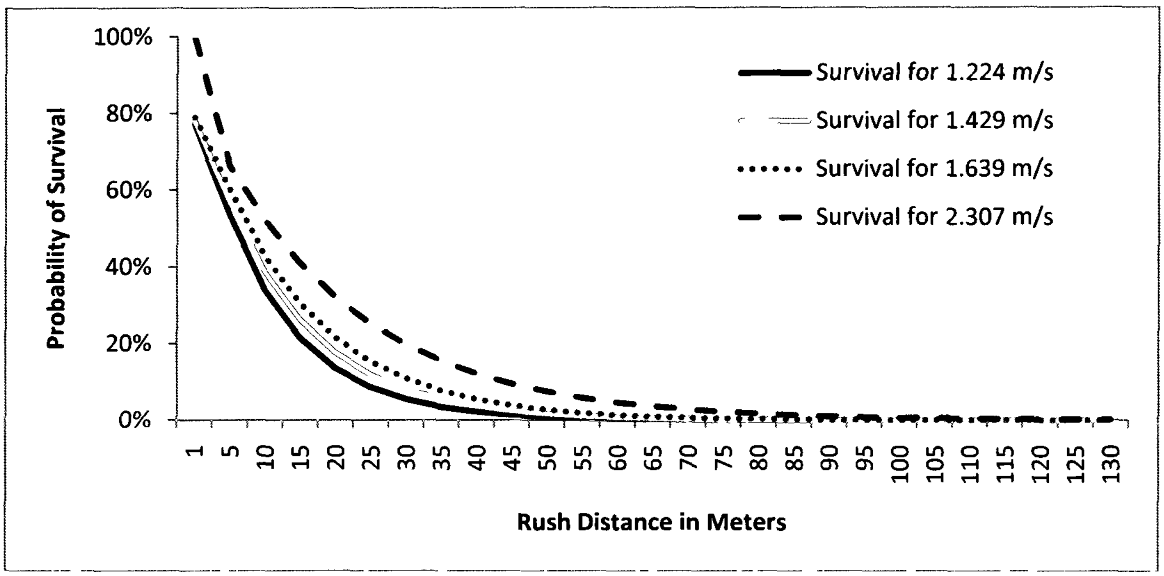


Fig. 17. Probability of Survival Using the 3 Meter Rush Velocities.

The peak difference in probability for survivability for the velocities used occurred for shorter rushing distances as the velocities decreased (Figures 18-20). The slower velocities did not clear the reaction shot at the shortest distances giving a high difference in survivability for even the short distances using the 3 and 6 meter rushing velocities.

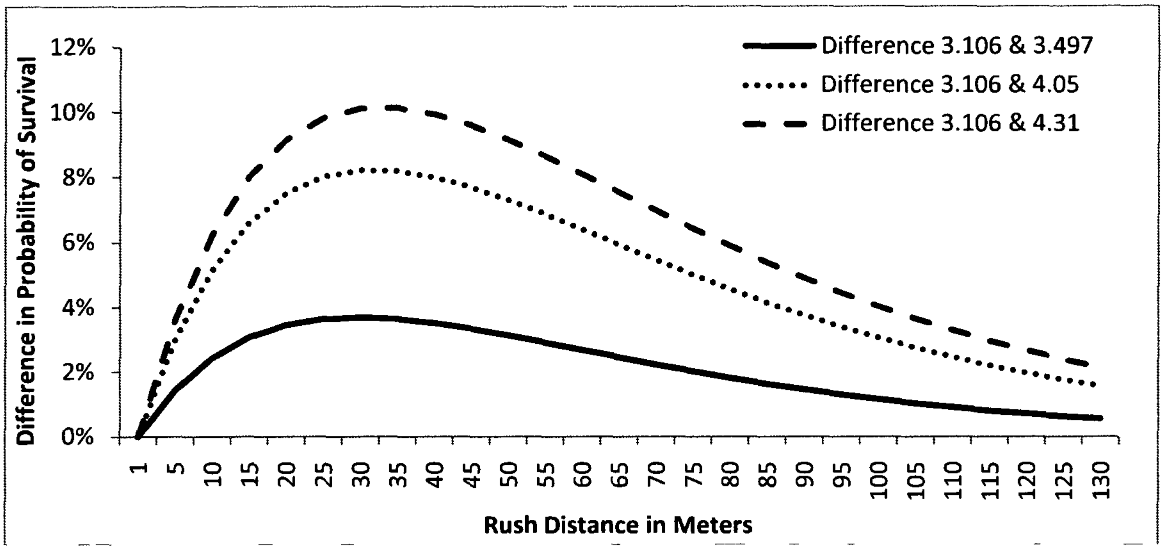


Fig. 18. Difference in Survivability Using 15 Meter rush Velocities

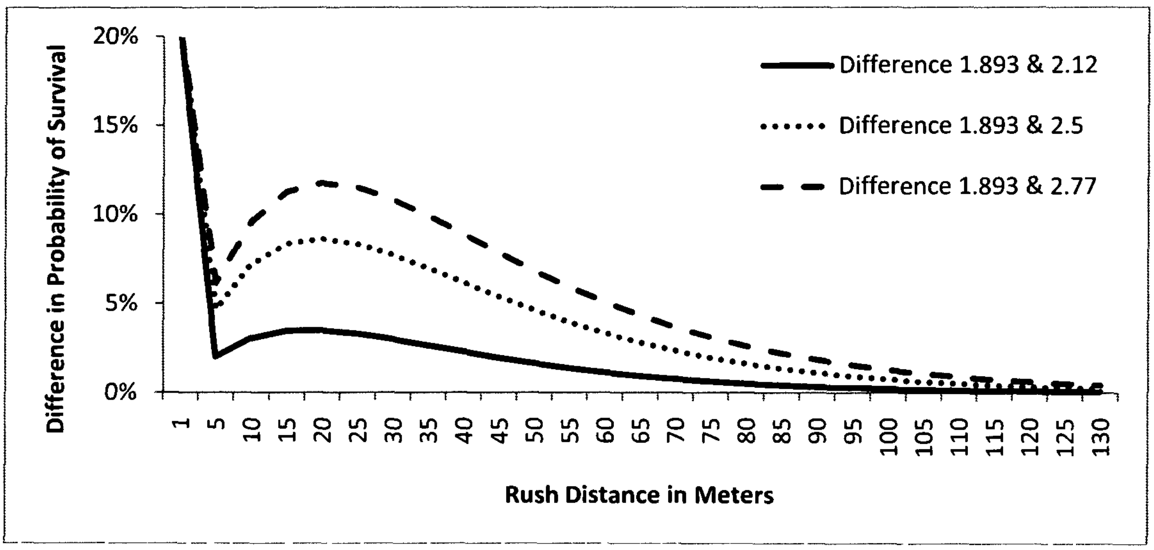


Fig. 19. Difference in Survivability Using 6 Meter Rush Velocities.

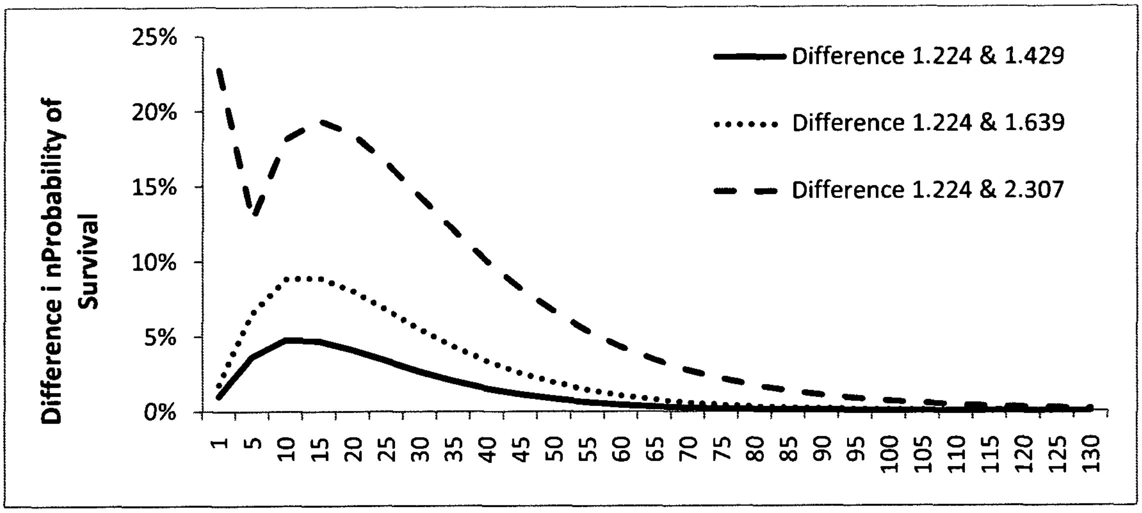


Fig. 20. Difference in Survivability Using 3 Meter Rush Velocities

B. Physical Fitness Data Results

The seven participants in the Pilot Study wore only a simulated armored vest, helmet, and carried a simulated weapon (i.e., non-functioning M16 with the proper weight of a real M16) while all the Rushing Study data were collected (Appendix C). The average of the three rush times completed were used to calculate the mean velocity in m/s, which were used as input into the simulations (Table 14).

Table 14. Rush Data from Pilot Study.

Participant ID	Gender	Age	Body Fat%	Rush 1 (s)	Rush 2 (s)	Rush 3 (s)	Average Rush (s)	Velocity (m/s)
S01MCCFT	M	23	16.5	3.35	3.36	3.63	3.445	3.18
S02MCCFT	M	27	8.4	3.18	3.23	2.3	2.90	3.78
S03MCCFT	M	27	9.05	3.13	3.16	3	3.1	3.54
S04MCCFT	M	23	16	2.54	3.18	3.33	3.02	3.64
S05MCCFT	F	26		5.18	4.27	4.41	4.62	2.38
S06MCCFT	M		21	3.99	3.87	4	3.95	2.78
S07MCCFT	F	19		4.66	4.56	4.86	4.69	2.34

Analysis of data from the Rushing Study in 2010 where participants wore a fighting load in addition to simulated armor, helmet, and carried a simulated M16 was more comprehensive. These data were used in the final simulations; therefore the experiments were designed so the data were representative of performance by infantry. Part of the analysis looked at determining if traditional measures of physical fitness in the military were correlated with the rushing score. The average rush scores, rush velocity, and standard deviations for the 3 meter kneeling to kneeling, 6 meter kneeling to kneeling, and 15 meter standing to standing times and velocities are found in Table 15. The velocities for the 3 and 6 meter rushes were different: the average velocity for the 3 meter kneeling to kneeling rush was 1.42 m/s and the average velocity for the 6 meter rush was 2.12 m/s. This meant that the same velocities could not be used in the simulation runs for the 3 and 6 meter rushes.

Table 15. Statistical Information for 3, 6, and 15 Meter Rushes.

	3 Meters Kneeling to Kneeling	**6 Meters Kneeling to Kneeling**	**15 Meters Standing to Standing**
Number of participants	31	31	31
Average Time (s)	2.147	2.854	4.364
Std Dev Time (s)	.259	.329	.419
Min Time (s)	1.3	2.160	3.480
Max Time (s)	2.77	3.960	5.45
Median Time (s)	2.1	2.830	4.29
Average Velocity (m/s)	1.42	2.1276	3.46
Std Dev Velocity (m/s)	.2	.23059	.32867
Min Velocity (m/s)	1.08	1.51515	2.75229
Max Velocity (m/s)	2.3	2.7778	4.31034
Median Velocity (m/s)	1.4286	2.1201	3.4965

To confirm that the participants in this study were at a similar fitness level as US Marines, the Marine Corps Physical Fitness Test was scored in the same manner that the Marines score it (Appendix D), with class levels (Table 16). A class level greater than 4 indicates how well the passing participant performed on the test. A Class of 4 indicates the participant did not pass.

To analyze visually how well the participants rushed versus performance in the Marine Corps Physical Fitness Test (PFT), Table 17 shows rushing scores for the 3 meter, 6 meter, and 15 meter rushes in descending order of performance. The participant ID's were color coordinated to indicate whether or not they would have passed the Marine PFT. Blue indicates passing as class 1, green indicates passing as class 2, orange indicates passing as class 3, and brown indicates not passing. Only one time was taken for each of these events, and these are not averages. Participants passing with class 1 (blue) were predominantly ranked towards the top of Table 17, and failing (class 4 or brown) were ranked towards the bottom. The top rushing velocity was much faster than the second fastest rushing velocity. Therefore, the second fastest rushing velocities (i.e. 3, 6, and 15 m velocities for second highest rushing scores), were also included in the simulations run using these data. The median rushing velocities were used as the middle rushing velocities. The bottom velocities were not used, as they may be below a representative rushing velocity due to the fact that the participants did not pass the Marine Core PFT. The third to bottom rushing score was from a participant who passed the PFT and was used as input for the rushing simulations.

Table 16. Marine Corps PFT Scores for Rushing Study.

Marine Physical Fitness Test Scores							
Participant ID	Male / Female	Age	Pull Up Score	Crunches Score	3 Mile Run Score	Total Score	Class
1	M	29	40	77	74	191	2
2	M	24	0	0	0	0	4
3	M	28	0	41	23	64	4
4	M	36	45	54	60	159	2
5	M	24	50	72	42	164	3
6	M	29	15	46	20	81	4
7	M	20	100	100	90	290	1
8	M	23	70	81	94	245	1
9	M	21	90	86	77	253	1
10	M	29	100	95	43	238	1
11	M	20	95	91	24	210	2
12	M	20	55	88	24	167	3
13	M	22	85	69	60	214	2
14	M	21	95	83	66	244	1
15	M	20	100	77	70	247	1
16	M	21	0	43	0	43	4
17	M	22	50	56	0	106	4
18	M	27	100	100	50	250	1
19	M	21	45	85	47	177	2
20	M	20	75	64	43	182	2
21	M	19	40	52	55	147	3
22	M	20	95	93	61	249	1
23	M	18	85	100	78	263	1
24	M	18	30	100	81	211	2
25	M	27	95	100	81	276	1
26	M	20	70	61	80	211	2
27	M	18	70	76	49	195	2
28	M	20	75	62	77	214	2
29	F	19	100	100	83	283	1
30	M	20	35	62	53	150	3
31	M	39	25	66	44	135	3

Tables 17. Rushing Study Data in Descending Order with PFT class.

	= Class 1 Pass		= Class 2 Pass		= Class 3 Pass		= Did Not Pass

ID	3 M Time	3 M Velocity	ID	6 M Time	6 M Velocity	ID	15 M Time	15 M Velocity
12	**1.3**	**2.3077**	**12**	**2.16**	**2.7778**	**12**	**3.48**	**4.3103**
9	**1.83**	**1.6393**	**8**	**2.4**	**2.5000**	**9**	**3.7**	**4.0541**
14	1.91	1.5707	5	2.52	2.3810	15	3.91	3.8363
15	1.91	1.5707	6	2.53	2.3715	7	3.93	3.8168
17	1.93	1.5544	9	2.58	2.3256	8	3.93	3.8168
27	1.96	1.5306	7	2.59	2.3166	14	4.03	3.7221
11	1.97	1.5228	15	2.59	2.3166	19	4.04	3.7129
20	2.03	1.4778	14	2.69	2.2305	23	4.07	3.6855
22	2.03	1.4778	11	2.73	2.1978	16	4.16	3.6058
8	2.06	1.4563	27	2.76	2.1739	10	4.17	3.5971
10	2.09	1.4354	10	2.8	2.1429	11	4.21	3.5629
16	2.09	1.4354	17	2.81	2.1352	24	4.22	3.5545
24	2.09	1.4354	19	2.81	2.1352	17	4.25	3.5294
25	2.09	1.4354	25	2.81	2.1352	5	4.27	3.5129
28	2.1	1.4286	13	2.82	2.1277	26	4.27	3.5129
31	**2.1**	**1.4286**	**23**	**2.83**	**2.1201**	**18**	**4.29**	**3.4965**
18	2.18	1.3761	20	2.84	2.1127	13	4.35	3.4483
21	2.19	1.3699	18	2.85	2.1053	21	4.37	3.4325
19	2.2	1.3636	16	2.87	2.0906	22	4.37	3.4325
30	2.21	1.3575	22	2.87	2.0906	31	4.37	3.4325
01	2.22	1.3514	1	2.88	2.0833	6	4.47	3.3557
02	2.23	1.3453	21	2.88	2.0833	20	4.6	3.2609
13	2.27	1.3216	28	2.9	2.0690	28	4.62	3.2468
4	2.29	1.3100	30	2.94	2.0408	30	4.63	3.2397
26	2.33	1.2876	24	2.99	2.0067	27	4.72	3.1780
23	2.37	1.2658	31	3.03	1.9802	4	4.73	3.1712
7	2.4	1.2500	4	3.14	1.9108	29	4.8	3.1250
5	2.42	1.2397	3	3.15	1.9048	1	4.81	3.1185
29	**2.45**	**1.2245**	**26**	**3.17**	**1.8927**	**25**	**4.83**	**3.1056**
3	2.54	1.1811	29	3.57	1.6807	3	5.23	2.8681
6	2.77	1.0830	2	3.96	1.5152	2	5.45	2.7523

The participants' scores for the 880 yd sprint, ammunition can lift, and maneuver under fire were also compared to the Marine Combat Fitness Test (CFT) passing standards (Table 18). Information regarding scoring for the Marine Core CFT can be found in Appendix D.

Similarly to Table 17, Table 19 was created to show the class of the participants who passed the Marine Core CFT compared to the rushing time order. Table 19 shows more class 4 non passers of the CFT towards the bottom of the chart. Rusher 29 (lowest 3 meter rushing velocity used) was not listed with a CFT score, as the lightest person available for the fireman's carry was 30 lbs larger than this participant, and the test requires that you carry someone who is within ten pounds of your weight, and we did not want to risk the participant's safety by carrying someone too heavy to negotiate safely. Note that this person has a score of 170, and only needed 20 additional points from the maneuver under fire to pass the CFT and passed the Marine Core PFT as a class 1. It was determined that this person would have passed the CFT if there was a person available to be carried, and so this velocity could be used as simulation input.

Table 18. Rushing Study Scores for Marine Combat Fitness Test.

Marine Combat Fitness Test Scores							
Participant ID	Gender	Age	Movement To Contact	Ammunition Can Lift	Maneuver Under Fire	Total	PASS
1	M	29	100	86	92	278	1
2	M	24	76	0	0	76	4
3	M	28	67	63	0	130	4
4	M	36	87	74	82	243	2
5	M	24	88	0	0	88	4
6	M	29	78	76	68	222	3
7	M	20	98	82	84	264	2
8	M	23	100	98	90	288	1
9	M	21	96	93	63	252	2
10	M	29	91	83	82	256	2
11	M	20	98	86	73	257	2
12	M	20	90	92	79	261	2
13	M	22	90	83	76	249	2
14	M	21	93	73	62	228	2
15	M	20	95	100	86	281	1
16	M	21	71	72	70	213	3
17	M	22	88	92	76	256	2
18	M	27	91	100	95	286	1
19	M	21	91	78	82	251	2
20	M	20	91	69	69	229	2
21	M	19	91	66	67	224	3
22	M	20	87	96	84	267	2
23	M	18	100	100	94	294	1
24	M	18	95	92	90	300	1
25	M	27	97	91	95	283	1
26	M	20	95	85	90	270	1
27	M	18	86	83	79	248	2
28	M	20	94	79	74	247	2
29	F	19	100	70	N/A	170	N/A
30	M	20	90	63	85	238	2
31	M	39	88	79	85	252	2

Tables 19. The Rushing Study Data in Descending Order with CFT Class.

	= Class 1 Pass		= Class 2 Pass		= Class 3 Pass		= Did Not Pass

ID	3 M Time	3 M Velocity	ID	6 M Time	6 M Velocity	ID	15 M Time	15 M Velocity
12	**1.3**	**2.30769**	**12**	**2.16**	**2.77778**	**12**	**3.48**	**4.31034**
9	**1.83**	**1.63934**	**8**	**2.4**	**2.5**	**9**	**3.7**	**4.05405**
14	1.91	1.57068	5	2.52	2.38095	15	3.91	3.83632
15	1.91	1.57068	6	2.53	2.37154	7	3.93	3.81679
17	1.93	1.55440	9	2.58	2.32558	8	3.93	3.81679
27	1.96	1.53061	7	2.59	2.3166	14	4.03	3.72208
11	1.97	1.52284	15	2.59	2.3166	19	4.04	3.71287
20	2.03	1.47783	14	2.69	2.23048	23	4.07	3.6855
22	2.03	1.47783	11	2.73	2.1978	16	4.16	3.60577
8	2.06	1.45631	27	2.76	2.17391	10	4.17	3.59712
10	2.09	1.43541	10	2.8	2.14286	11	4.21	3.56295
16	2.09	1.43541	17	2.81	2.13523	24	4.22	3.5545
24	2.09	1.43541	19	2.81	2.13523	17	4.25	3.52941
25	2.09	1.43541	25	2.81	2.13523	5	4.27	3.51288
28	2.1	1.42857	13	2.82	2.12766	26	4.27	3.51288
31	2.1	1.42857	23	2.83	2.12014	18	4.29	3.4965
18	2.18	1.37615	20	2.84	2.11268	13	4.35	3.44828
21	2.19	1.36986	18	2.85	2.10526	21	4.37	3.43249
19	2.2	1.36364	16	2.87	2.09059	22	4.37	3.43249
30	2.21	1.35747	22	2.87	2.09059	31	4.37	3.43249
1	2.22	1.35135	1	2.88	2.08333	06	4.47	3.3557
2	2.23	1.34529	21	2.88	2.08333	20	4.6	3.26087
13	2.27	1.32159	28	2.9	2.06897	28	4.62	3.24675
4	2.29	1.31004	30	2.94	2.04082	30	4.63	3.23974
26	2.33	1.28755	24	2.99	2.00669	27	4.72	3.17797
23	2.37	1.26582	31	3.03	1.9802	4	4.73	3.17125
7	2.4	1.25	4	3.14	1.91083	29	4.8	3.125
5	2.42	1.23967	3	3.15	1.90476	1	4.81	3.1185
29	2.45	1.22449	26	3.17	1.89274	25	4.83	3.10559
3	2.54	1.18110	29	3.57	1.68067	3	5.23	2.86807
6	2.77	1.08303	2	3.96	1.51515	2	5.45	2.75229

Each of the times selected as input in the simulation were as good as or better than participants who passed the Marine Corps PFT and CFT.

Only one measurement was taken for each rush to avoid fatigue due to the large amount of data collected. If the time for all of the rushes was totaled and regressions run, the time for the sum of rushes would rest primarily on the 30 meter rushes. To give each rush the same weight of importance, the rushing times were ranked for each rushing event where 1 was the best performer with the fastest time and 31 was the slowest. The ranks were totaled to get a sum of the ranks and then the rushing totals were ranked again to get a final rank. These were sorted by performance in Table 20. The ranks are color coded according to quartile of performance of each event. The rushers were consistent in their performance across rushing events, particularly in the top and bottom quartiles. If a rusher was in the top quartile in one rush, they were likely to be in the top quartile for other rushes. The Spearman's rank correlation coefficients were calculated for the overall rushing rank and each of the physical fitness tests. The Spearman's correlation coefficients that were found significant at the .01 and .05 levels (2-tailed) are listed in Table 21. The correlation coefficient for the vertical and horizontal jumps and the total rank were both greater than .7, which is considered very large [106].

Table 20. Sum of Ranks for Rushes in Descending Order.

	= Top Quartile		= 75% Quartile		= 50% Quartile		Bottom Quartile

ID	Rank											Sum of Ranks	Rank of the Sum
	3 M KK	5 M SK	6 M KK	10 M SK	12 M PP	12 M KK	12 M SS	15 M SS	30 M PP	30 M KK	30 M SS		
12	1	1	1	2	1	2	1	1	1	1	1	13	1
9	2	6.5	5	6	8	4	3	2	2	2	2	42.5	2
15	3.5	3	6.5	4	6	8	10	3	5	5	9	63	3
17	5	2	12	3	5	3	6	13	6	4	6	66	4
11	7	21	9	8	3	6	9	11	3	3	4	84	5
14	3.5	4	8	1	18	13	13.5	6	15	6	11	99	6
19	19	10.5	12	19.5	13	10	4	7	4	10	3	113	7
8	10	6.5	2	13	11	7	25	4.5	19	17	5	120	8
23	26	18	16	5	2	5	8	8	20	9	8	125	9
5	28	22	3	7	7	11	5	14.5	7	21	13	140	10
22	8.5	9	19.5	16	12	1	20.5	18	11	8	15.5	138.5	11
7	27	19.5	6.5	9	9	23	2	4	10	12	18.5	141	12
10	12.5	23	11	14	4	18	19	10	17.5	14.5	7	150.5	13
24	12.5	16	25	10.5	10	12	18	12	14	11	10	151	14
18	17	28	18	19.5	14	19	13	16	8	7	12	172	15
27	6	15	10	25.5	17	14	7	25	17.5	14.5	27	178.5	16
16	12.5	14	19.5	23	21	24	11	9	9	26	17	186	17
21	18	5	21.5	12	22	17	22	18	22	16	15.5	190	18
13	23	8	15	10.5	16	26	23	17	21	19	21	199.5	19
20	8.5	13	17	29	15	21	27	22	12	13	24	201.5	20
25	12.5	12	12	22	25	9	16	29	23	20	26	207.5	21
30	20	19.5	24	17	19	15	20	24	13	18	18.5	208.5	22
26	25	17	29	25.5	20	16	15	14.5	16	22	22	222	23
1	21	10.5	21.5	15	30	25	17	28	26	24	23	241	24
31	15.5	24.5	26	27	27	19	26	18	24	25	20	253.5	25
28	15.5	26	23	19.5	26	29	24	23	27	28	14	255	26
6	31	29	4	19.5	23	27	28	21	28	23	25	259	27
4	24	27	27	24	24	22	12	26	25	27	28	266	28
29	29	24.5	30	30	29	27	30	27	29	29	29	314	29
2	22	31	31	28	28	31	29	31	30	31	30	322	30
3	30	30	28	31	31	30	31	30	31	30	31	333	31

Table 21. Spearman Rank Correlation Coefficients for Physical Fitness Tests and Rushing Rank.

Task	Spearman Rank Correlation	Sig 1-tailed	N	Scale
Sprint880	.486	.006	31	Moderate
Ammunition Can Lift	-.562	.001	31	Large
Body Fat	.470	.009	30	Moderate
Pounds Fat	.399	.029	30	Moderate
Pounds Lean	-.460	.011	30	Moderate
CurlUps	-.469	.008	31	Moderate
PullUps	-.559	.001	31	Large
VerticalJumpAve	-.741	.000	31	Very Large
VerticalJumpMin	-.734	.000	31	Very Large
VerticalJumpMax	-.738	.000	31	Very Large
HorizontalJumpAve	-.745	.000	31	Very Large
HorizontalJumpMin	-.733	.000	31	Very Large
HorizontalJumpMax	-.736	.000	31	Very Large

C. Agent Simulation

The scenarios were both run using the preliminary data and data from the Rushing Study. The probability of success based upon the chosen metric was calculated from the simulation output and used as input for logistic regression discussed in Section 4.6. The results were reviewed and graphed for analysis.

1) Helicopter Scenario Simulation Runs Using Preliminary Data: There were at least 200 runs for the Helicopter Scenario using each of the preliminary data velocity data points (2.35, 3.25, 3.8, and 4.65 m/s) at each shooting cadence (.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 shots per second) for a total of at least 5,600 Helicopter Scenario runs. For the Helicopter Scenario, success was defined as having less than or equal to 1 casualty. The results from the simulation showed a layered effect with the fastest rushing velocities having the highest probability of success (Figure 21).

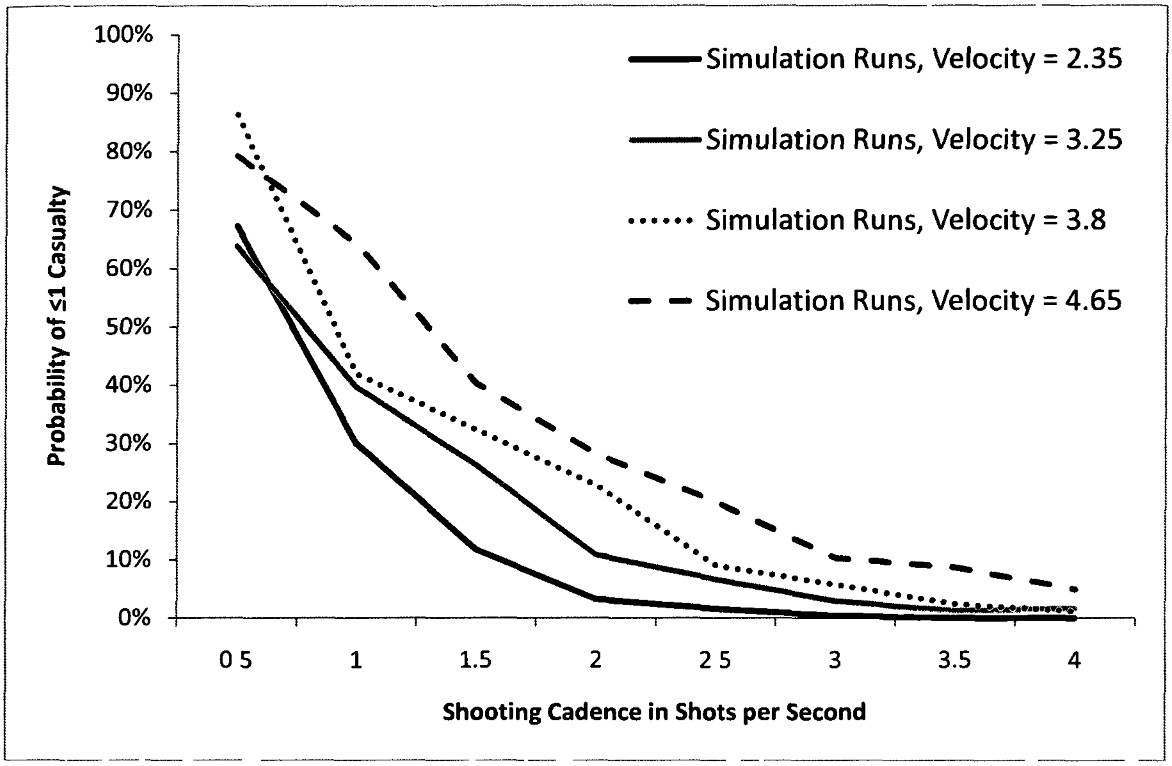


Fig. 21. Probability of Success for Helicopter Runs Using Pilot Data.

Casualty metrics of zero casualties and two or less casualties were also reviewed and showed similar results with respect to layering of plots according to rushing velocity (Fig. 22).

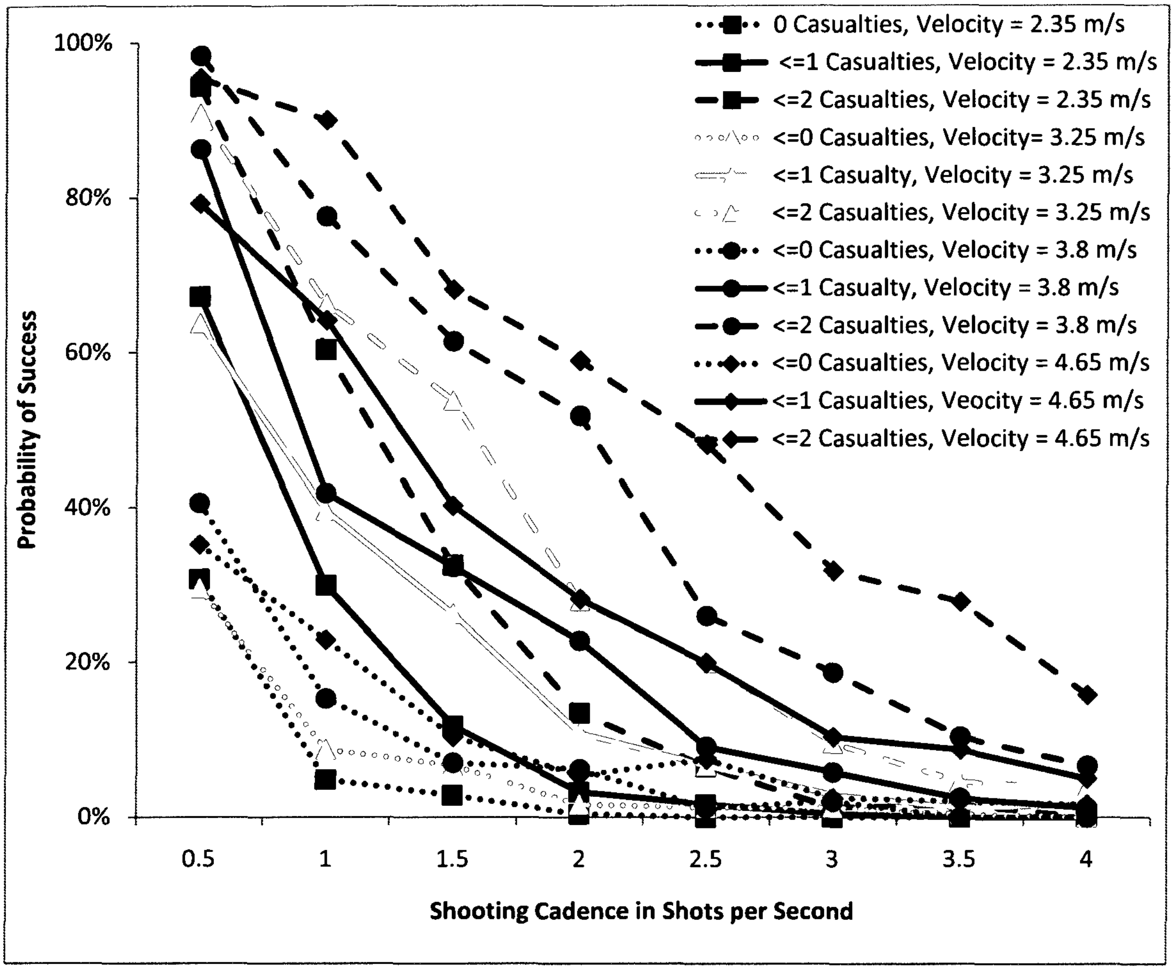


Fig. 22. Probability of Success for Helicopter Runs with Different Casualty Metrics.

2) Grenade Scenario Simulation Runs Using Preliminary Data: The Grenade Scenario was considered successful if the grenade was thrown by one of the soldiers. Again over 200 runs were performed for each velocity (2.35, 3.25, 3.8, and 4.65 m/s), and each shooting cadence (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 shots per second) at an enemy shooting accuracy of 20% and enemy reaction time of 0.5 seconds. A layering effect for probability occurs with the fastest velocities producing the highest chance for success (Figure 23).

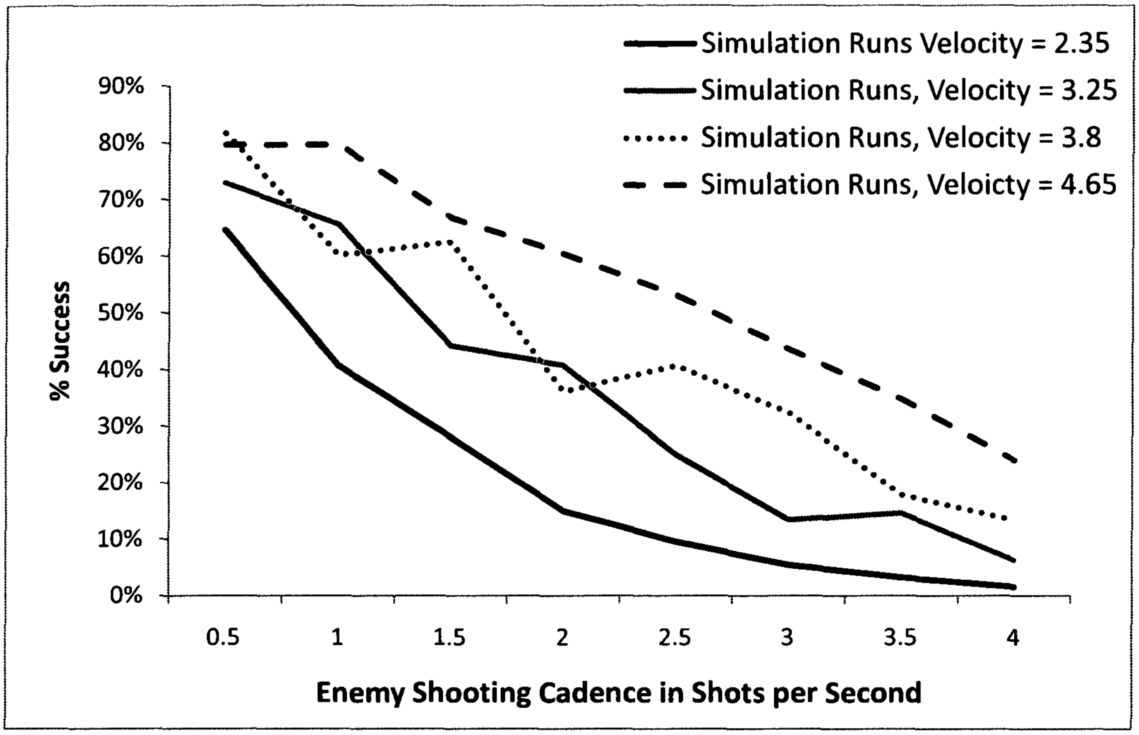


Figure 23. Probability of Success for Grenade Scenario Using Pilot Data.

There are intersection points between the simulation runs at 3.24 and 3.8 m/s. To help determine what might cause these intersections, the maximum number of shots at each of the shooting cadences and rushing velocities was examined (Table 22). These data showed that the maximum number of shots were occasionally the same for some of the shooting cadences, causing the probability of success to be the same.

Table 22. Maximum Shots in Grenade Scenario.

Enemy Shooting Cadence	Rushing Velocity (ms/)			
	2.35	3.25	3.8	4.65
.5	9	5	5	5
1.0	13	9	9	6
1.5	19	13	10	9
2.0	24	14	14	10
2.5	26	20	14	11
3.0	27	24	18	14
3.5	30	25	21	15

Upon further analysis, the maximum shots that can be taken for each scenario decreases as the velocity increases therefore causing the probability of success to increase (i.e., if you are rushing slower, more shots can be fired at you). To illustrate this concept, bubbles were plotted for the maximum possible shots for each scenario at the differing velocities and at their shots per second. The size of the bubble indicated the probability for success. The smallest bubbles indicated the lowest probability of success, and were related to slower rushing velocities at greater shooting cadences (Fig. 24). In other words, faster rushing velocities reduce the number of available shots the agent can effectively take at the soldier.

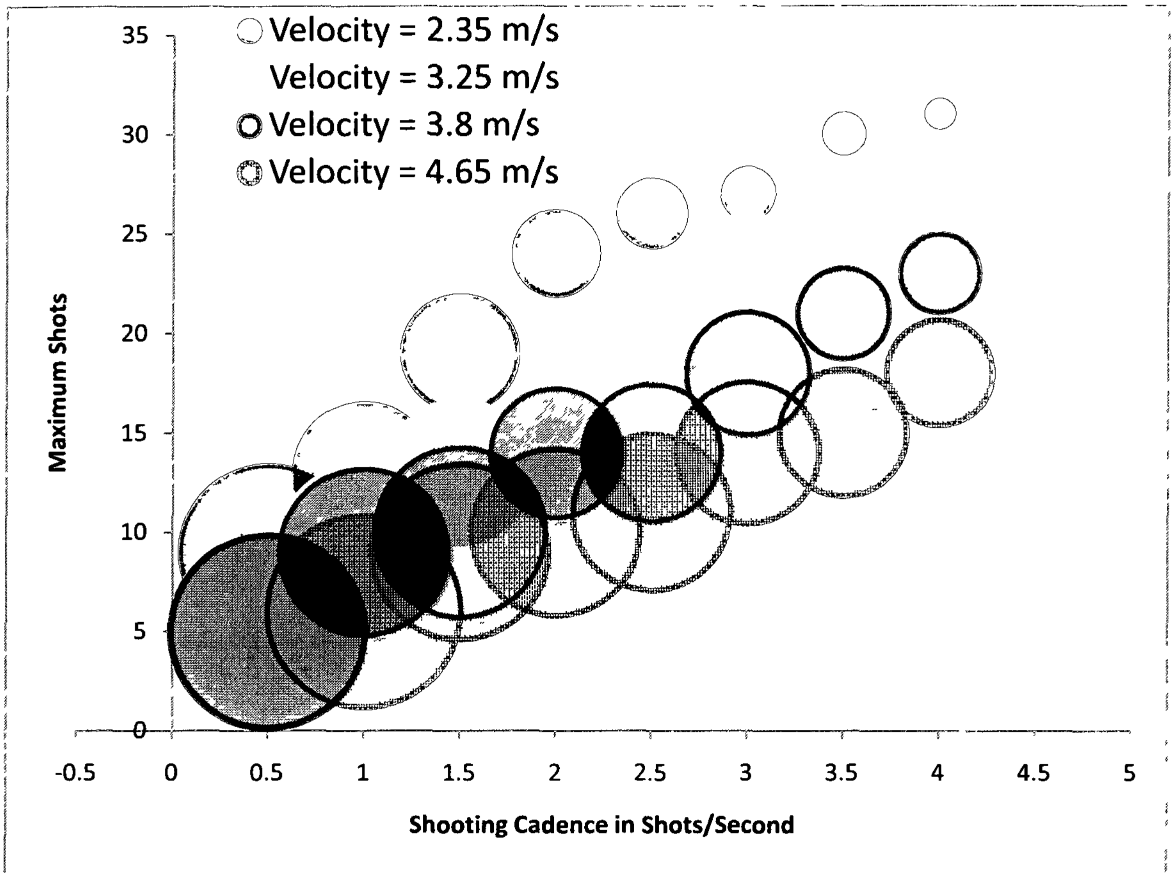


Fig. 24. Probability of Success for Number of Shots and Probability of Survival.

3) Helicopter Scenario Simulation Runs with Rushing Study Input: After data from the Rushing Study were collected, the helicopter scenario was executed 500 times for each of the rushing velocities (3.106, 3.497, 4.05, and 4.31 meters/second) with three enemy shooting accuracies (10%, 20%, 30%), and seven shooting cadences (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 shots per second). Results (Fig. 25-27) indicated that: 1) the probability for success was consistently higher for faster rushing velocities regardless of the shooting cadence and shooting accuracy and 2) the change in the plots with less accuracy had a more gradual slope than the change in plots with higher accuracy. This trend was seen even when the casualty metric was changed.

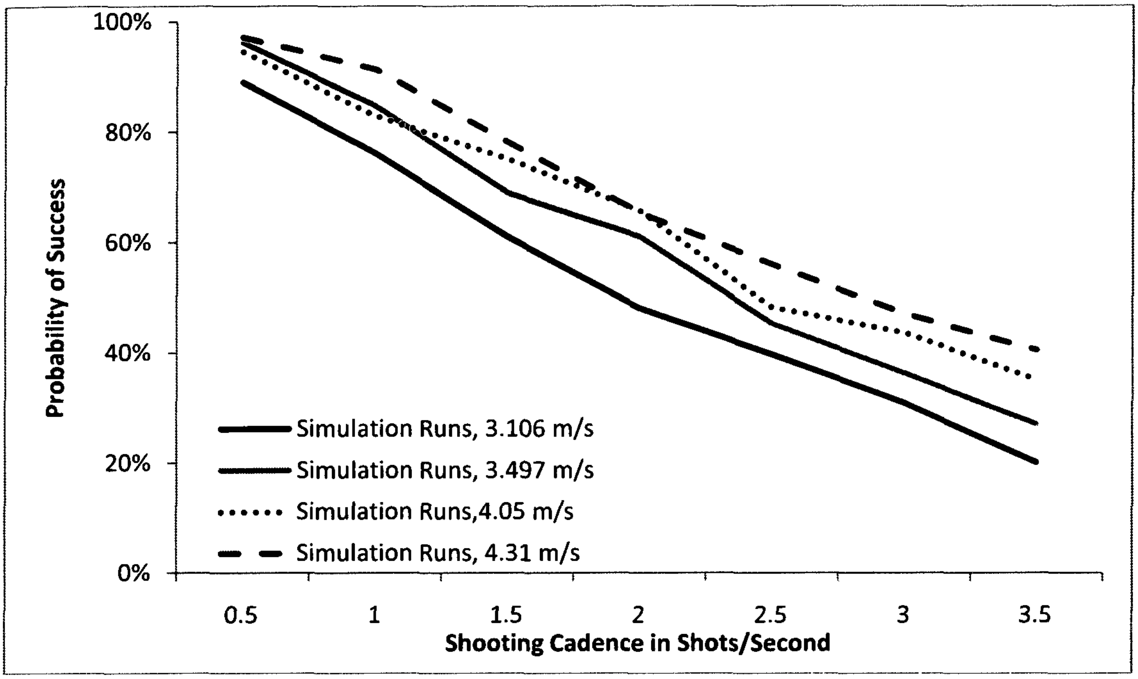


Fig. 25. Probability of Success in the Helicopter Scenario at 10% Shooting Accuracy

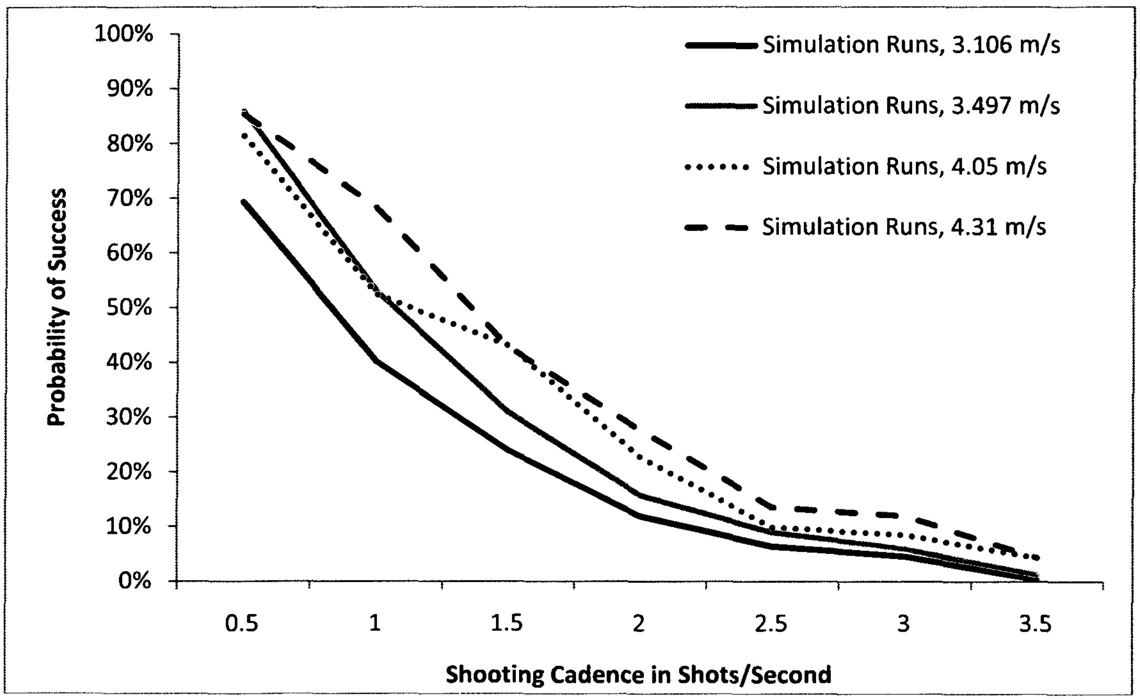


Fig. 26. Probability of Success in Helicopter Scenario at 20% Shooting Accuracy

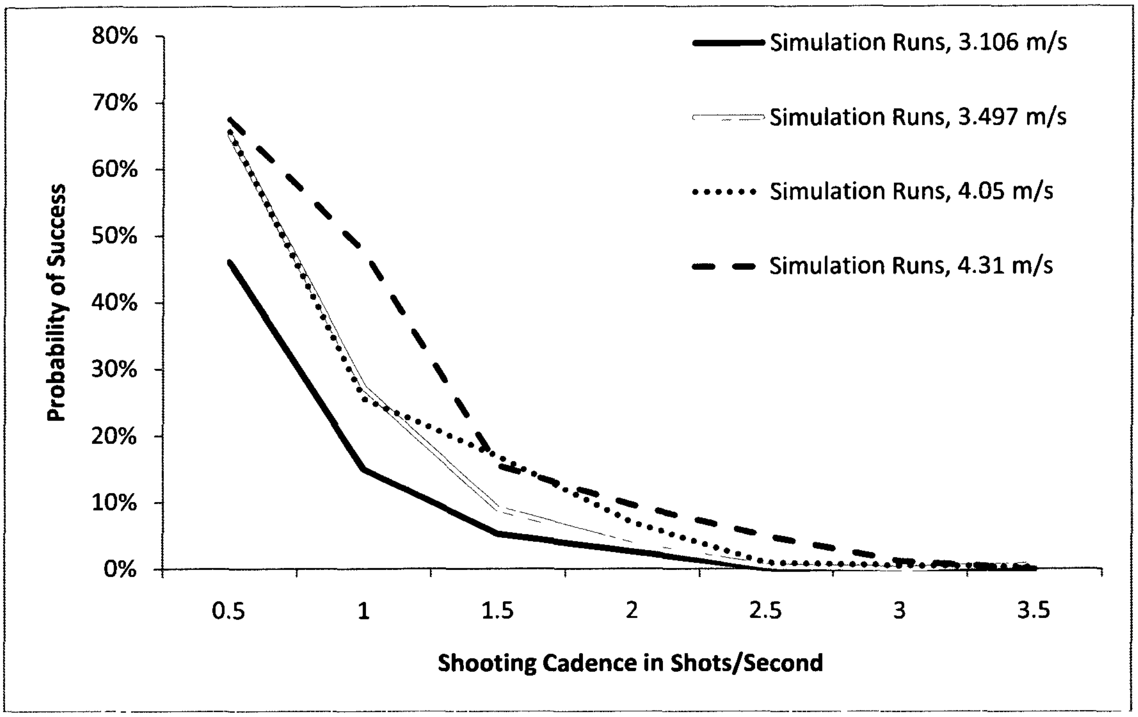


Fig. 27. Probability of Success in Helicopter Scenario at 30% Shooting Accuracy.

4) Grenade Scenario Simulation Runs for 3 and 6 Meter Rushes: As described in section 4.3, the velocities collected from the Rushing Study for the 3 and 6 meter rushes were found to be different. The Grenade Scenario incorporates one 3 meter rush and two 6 meter rushes. Rather than list each velocity separately, the values are labeled as follows: Slow = (1.224, 1.893) m/s, Medium = (1.429, 2.12) m/s, Fast = (1.639, 2.5) m/s and Very Fast = (2.307, 2.777) for velocities of the (3 meter rush, 6 meter rush). The slope for the lower accuracies had a more gradual change and as the accuracy was increased, the slope was much steeper just as in the Helicopter Scenario (Fig. 28-30). The two faster and slower lines were clustered together.

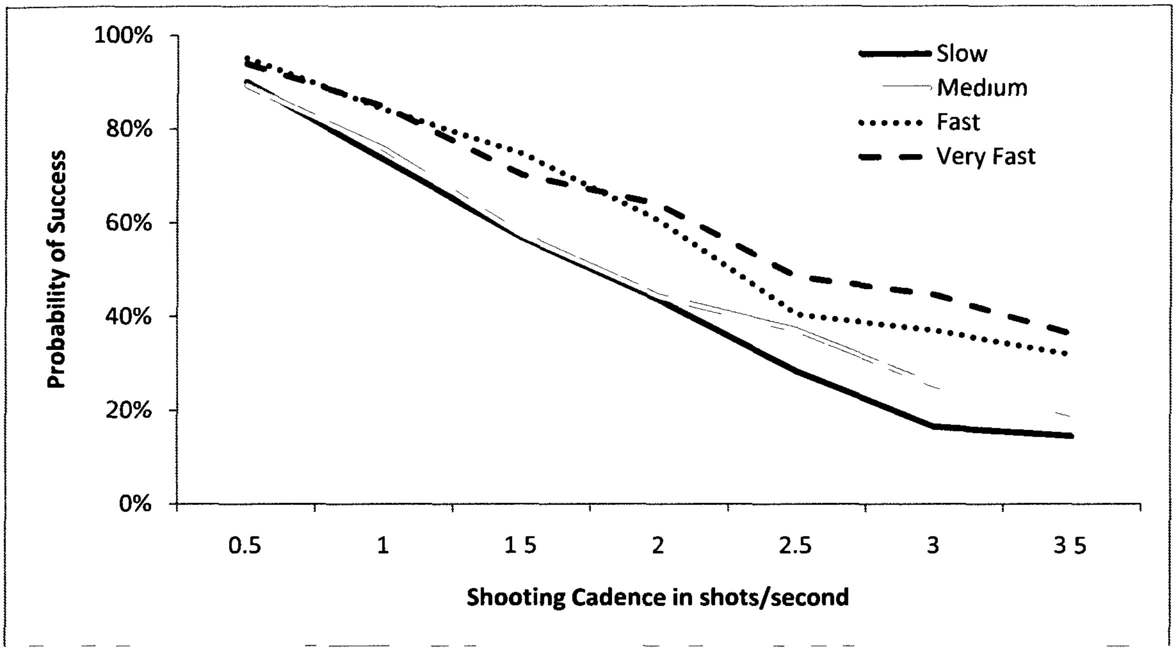


Fig. 28. Probability of Success for Grenade Scenario at 10% Shooting Accuracy.

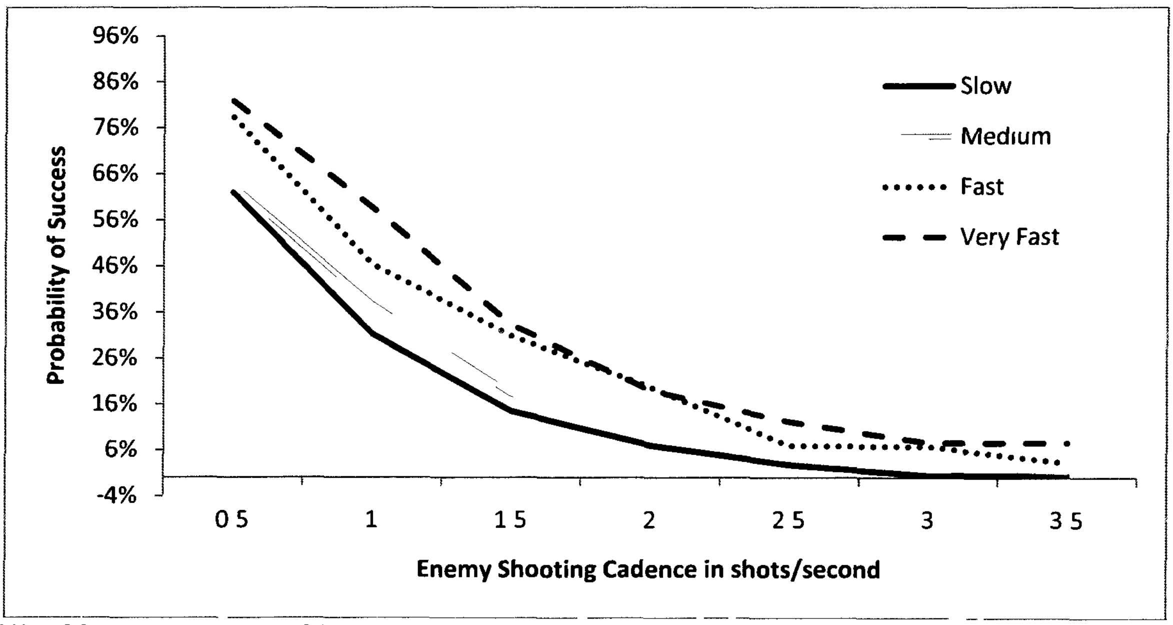


Fig. 29. Probability of Success for Grenade Scenario at 20% Shooting Accuracy.

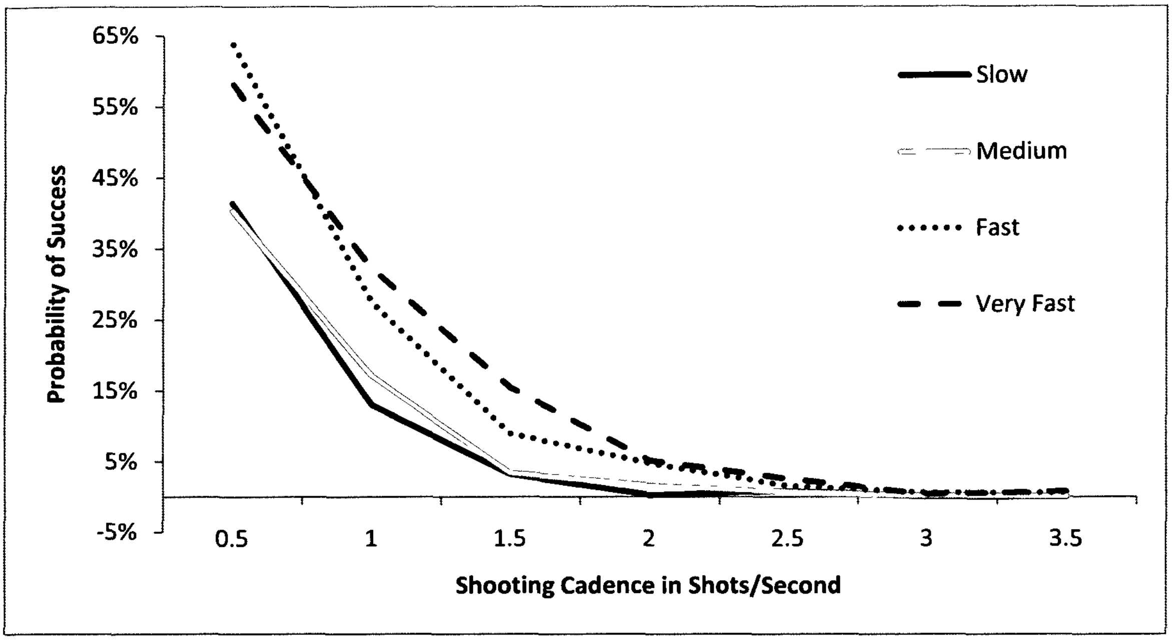


Fig. 30. Probability of Success for Grenade Scenario at 30% Shooting Accuracy.

The average number of shots for each shooting accuracy, shooting cadence, and velocity are graphed in Fig. 31-33 and given in Tables 23-25. They show that often the two fastest and slowest velocities had similar average number of shots. The average number of shots also seemed to reach a limit, which was most evident in Fig. 33. There was a relationship between when the limit for the average number of shots has been reached by all of the rushing velocities (Fig. 31-33) and when the probability of success converged for all of the velocities (Fig. 28-30). This average number of shots was the number of shots required to achieve the expected value for hits that would prevent achievement of the metric given the specific shooting accuracy of the enemy. The formula to compute the average number of shots needed to achieve the expected value for hits is Shots=Hits/Accuracy where shots is the average number of shots needed, H is the number of hits that will prevent mission success, and A is the shooting accuracy. This formula is derived from the calculation of expected value for a negative binomial probability distribution [107].

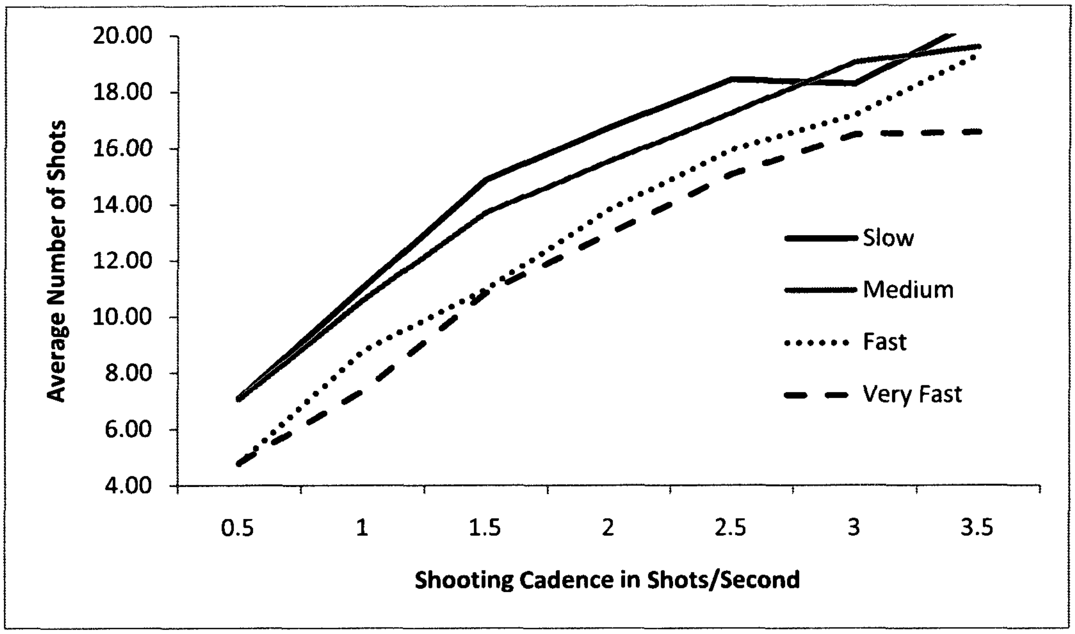


Fig. 31. Average Numbers of Shots at 10% Shooting Accuracy,

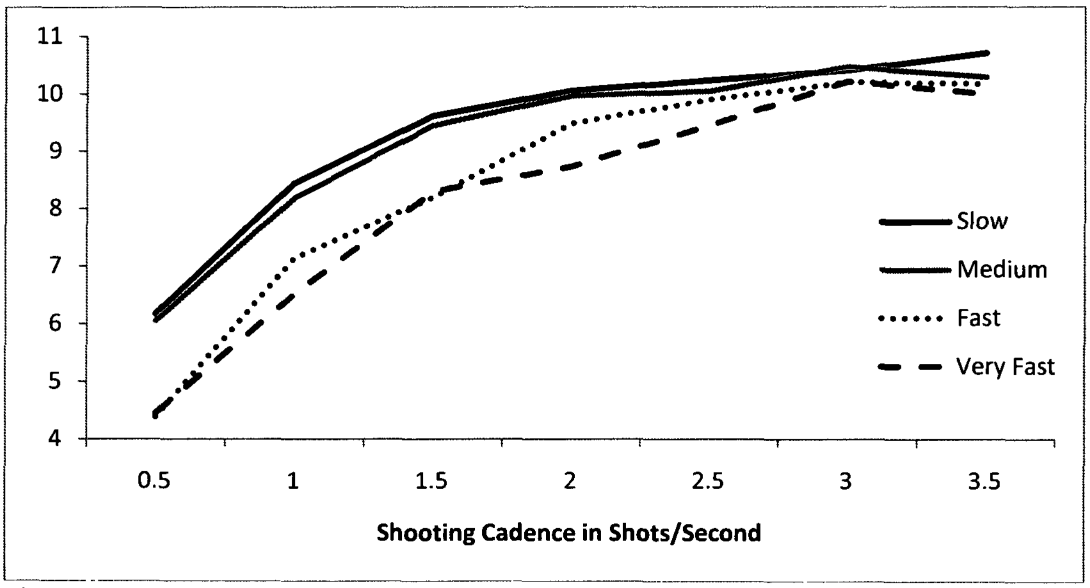


Fig. 32. Average Numbers of Shots at 20% Shooting Accuracy.

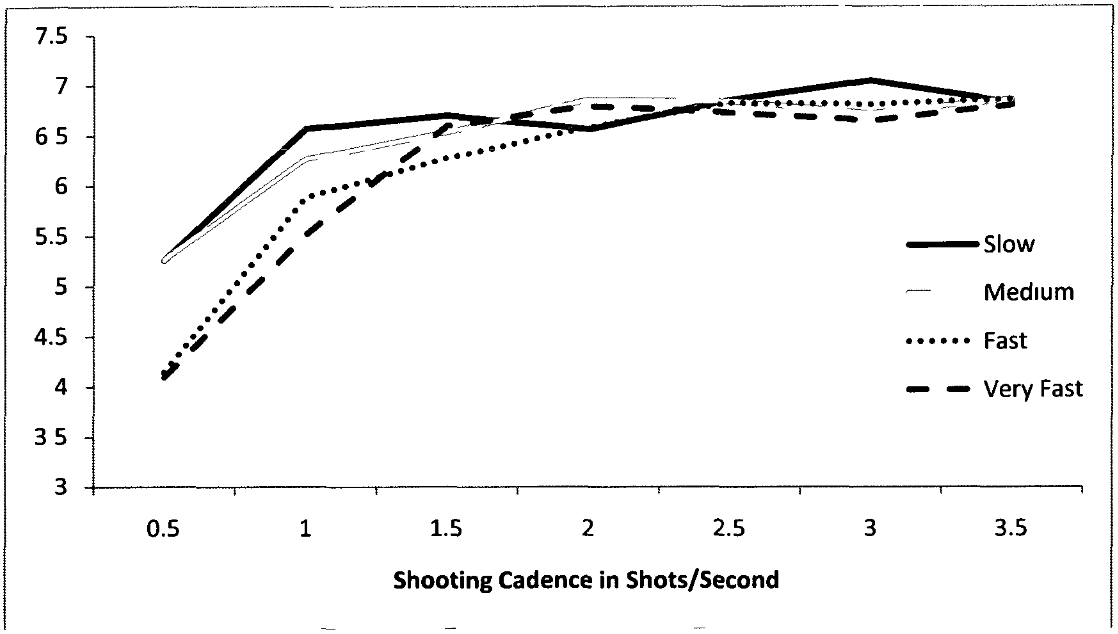


Fig. 33. Average Numbers of Shots at 30% Shooting Accuracy.

Table 23. Average shots for Grenade scenario at 10% Shooting Accuracy.

Shooting Cadence	Slow	Medium	Fast	Very Fast
.5	7.09	7.05	4.78	4.81
1.0	11.00	10.56	8.79	7.36
1.5	14.86	13.70	10.97	10.84
2.0	16.70	15.51	13.82	12.96
2.5	18.40	17.22	15.94	15.06
3.0	18.25	19.00	17.16	16.47
3.5	20.51	19.55	19.28	16.56

Table 24. Average Number of Shots Converged to 10 at Accuracy of 20%.

Shooting Cadence	Slow	Medium	Fast	Very Fast
.5	6.17	6.05	4.39	4.45
1.0	8.44	8.18	7.14	6.51
1.5	9.62	9.45	8.20	8.30
2.0	10.05	9.97	9.49	8.74
2.5	10.23	10.04	9.90	9.45
3.0	10.40	10.46	10.20	10.21
3.5	10.70	10.29	10.18	10.00

Table 25. Average Number of Shots Converged to 6.8 at Accuracy of 30%.

Shooting Cadence	Slow	Medium	Fast	Very Fast
.5	5.26	5.26	4.14	4.09
1.0	6.57	6.27	5.89	5.52
1.5	6.70	6.54	6.28	6.60
2.0	6.56	6.86	6.59	6.80
2.5	6.85	6.84	6.83	6.73
3.0	7.05	6.72	6.81	6.65
3.5	6.82	6.86	6.87	6.81

To determine the shooting cadence when the difference in the probabilities for success converge to 0 and the average number of shots converges for each of the rushing velocities, compute the maximum number of shots for each shooting cadence and rushing velocity for the scenario. Then compute the probability of the critical number of hits (2 in this case) according to the maximum number of shots using the negative binomial probability distribution P(y) = $\binom{y-1}{r-1}p^r q^{y-1}$ [107] where y is the number of shots possible, r is the number of hits required to prevent mission success, p is the probability of a hit, and q = 1-p. Compute the continuous distribution by summing the probability for all shots less than or equal to the number of shots possible. When the continuous distribution is equal to 99%, the average number of shots will have converged to ensure the expected value is equal to the number of hits, and the probability of success will have converged to near 0%. At this point, rushing velocity will not change the probability of success. The value P(y) should be approximately 50% when y=hits/accuracy as described above.

D. Logistical Regression

Logistical regression was used to analyze output from both the helicopter and grenade simulations that used data from both the Pilot Study in 2009 and the Rushing

Study from 2010. Logistical regression was used to predict success based upon the independent variables selected (rushing velocity and enemy shooting cadence) by calculating an odds ratio. Logistic regression also calculates the significance of B = ln(exp(B)) =ln(odds ratio). If the value of B is not significant with $p<.05$, then velocity does not significantly affect the probability of mission success.

1) Helicopter Scenario Using Preliminary Data and Logistical Regression: In the helicopter simulation where success was defined as less than or equal to one casualty, logistic regression showed that velocity was a significant factor for success with an odds ratio of 1.95 and $p<.000$. This meant that for each meter/second increase in velocity, the success rate would climb by a factor of 1.95. Fig. 34 showed a layering of probabilities of success both using velocity as an independent variable and not using velocity as an independent variable. The highest probabilities of success came from faster rushing velocities. The dashed black line that predicted success without using velocity was located in the middle of all of the rushing velocities. The line that does not use velocity can have the predicted probability different from the others by as much as 18%.

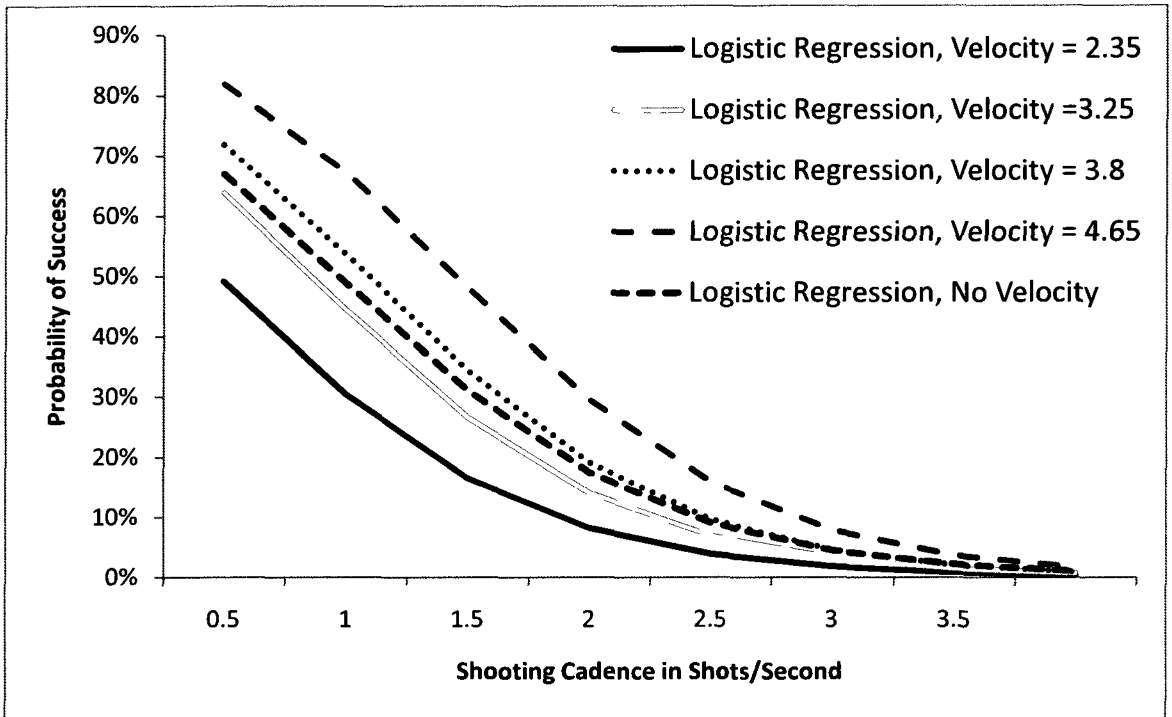


Fig. 34. Probability of Success Predicted from Logistic Regression for Helicopter Scenario.

2) Grenade Scenario Using Preliminary Data and Logistical Regression: When logistic regression was used to analyze the grenade scenario with preliminary data, velocity was significant with an odds ratio of 2.338 and $p<0.000$. A layering effect was again seen in Fig. 35, where the probability of success was consistently higher for faster velocities. Logistic regression was also run to predict success without the velocity; prediction without using velocity as an independent variable was off by as much as 22.97%.

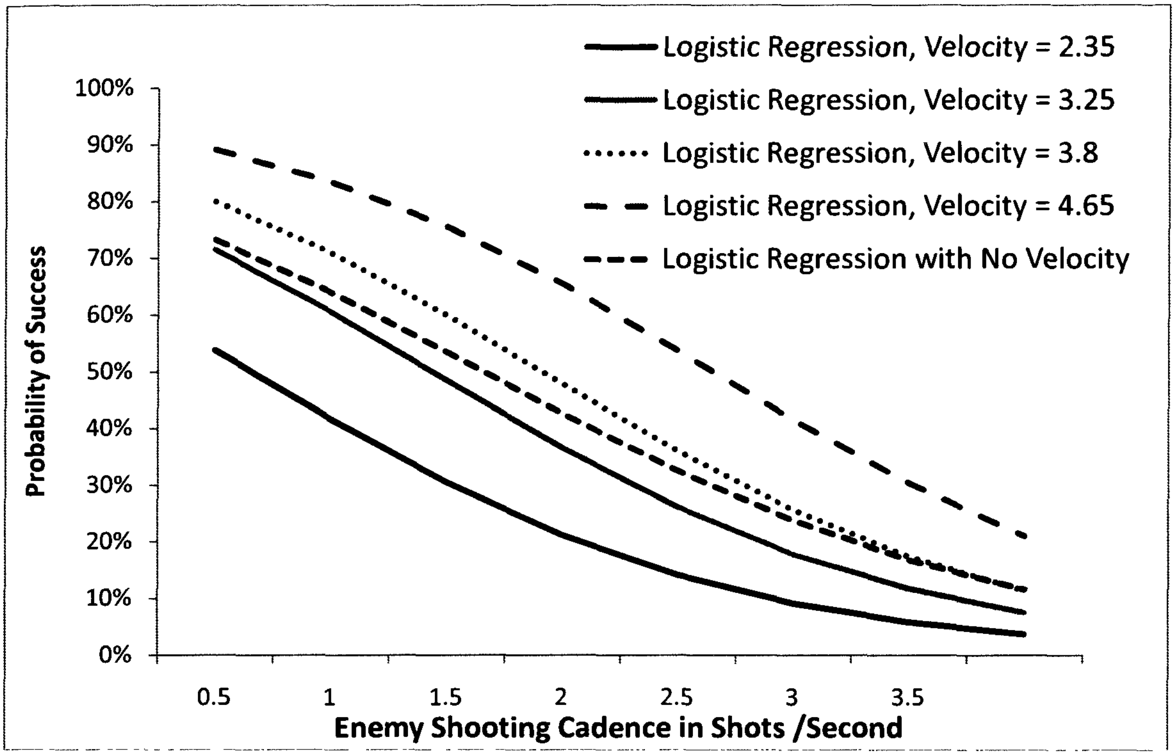


Fig. 35. Probability of Success Predicted Using Logistic Regression for Grenade Scenario.

3) Helicopter Scenario Analysis Using Logistical Regression: After the data from the Rushing Study was collected, additional simulation runs were performed to analyze the effect of changing shooting accuracy in the scenarios. Logistic regression was performed for velocity and shooting cadence together with only one type of shooting accuracy during each regression. Shooting accuracy was a selection variable and not an independent variable. The odds ratios for velocity and shooting cadence at 10%, 20%, and 30% accuracy were listed in Table 26. The significance for each of these was $p<.000$. As the odds ratio gets farther from the value 1, the dependent variable was affected more by change in the independent variable. Therefore, as the accuracy of the shooter increased, the impact of change upon survivability due to the velocity of the rusher was greater.

Table 26. Odds Ratios for Helicopter Scenario Metrics at 10%, 20%, and 30% Shooting Accuracy.

	Odds Ratios for Percentage Shooting Accuracy					
	10%		20%		30%	
Success Metric	**Velocity**	**Shooting Cadence**	**Velocity**	**Shooting Cadence**	**Velocity**	**Shooting Cadence**
0 Casualties	1.743	.359	1.868	.176	2.058	.086
1 Casualty	1.901	.343	2.135	.190	2.534	.096
2 Casualties	2.071	.297	2.732	.194	2.912	.104

Logistic regression at various shooting accuracies demonstrated that: 1) the probability for success was consistently higher for faster rushing velocities regardless of the shooting cadence and shooting accuracy and 2) the slope and descent of the plots was greater as the shooting accuracy increased (Fig. 36-38). This trend was seen even when the casualty metric was changed.

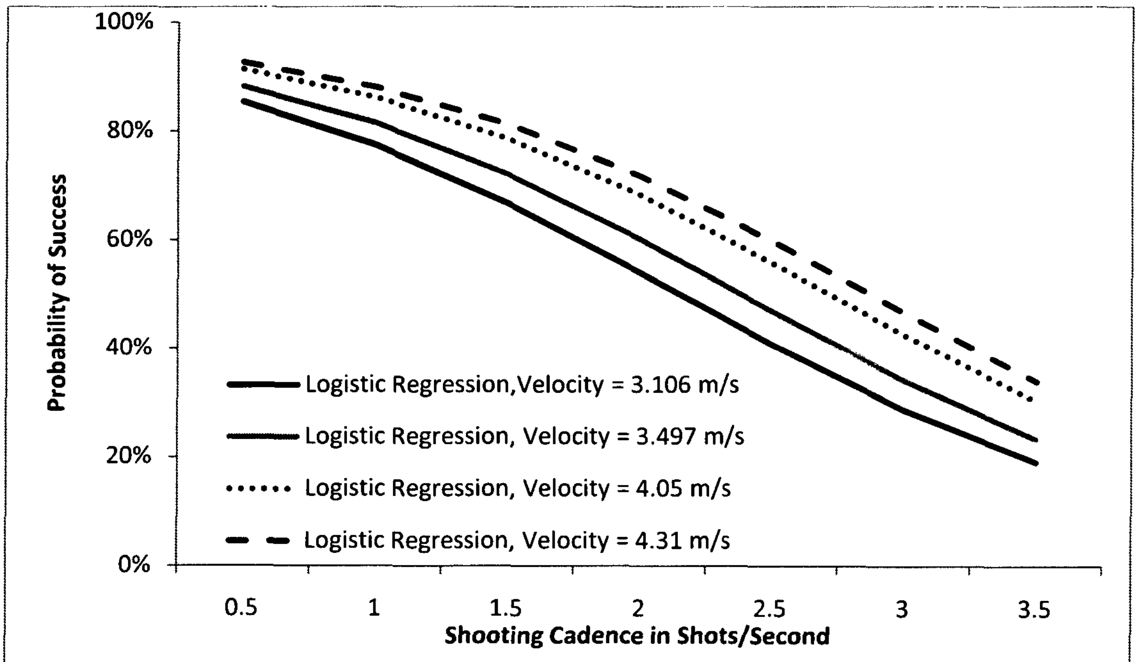


Fig. 36. Logistic Regression for ≤1 Casualty at 10% Accuracy for Helicopter Runs.

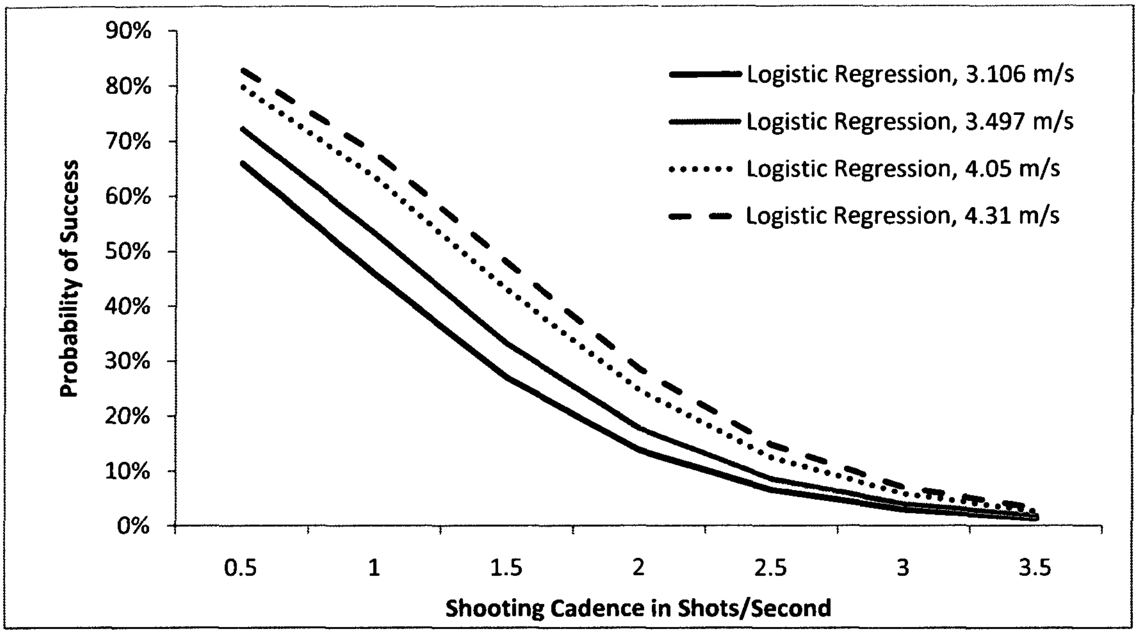


Fig. 37. Logistic Regression for ≤1 Casualty at 20% Accuracy for Helicopter Runs.

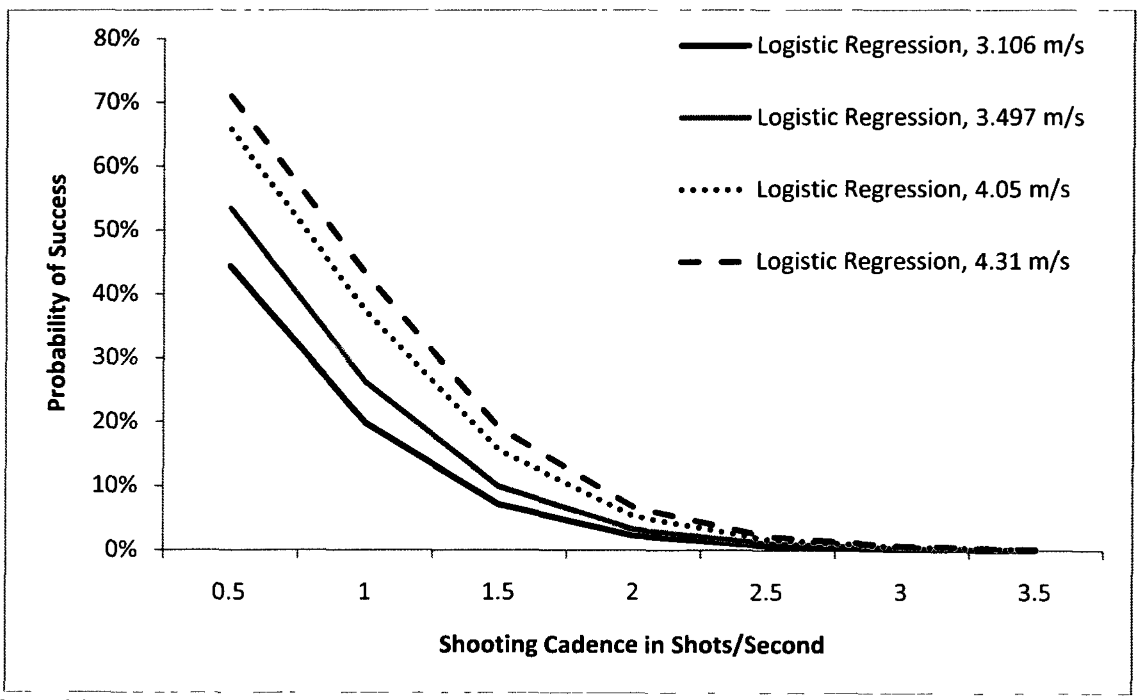


Fig. 38. Logistic Regression for ≤ 1 Casualty at 30% Accuracy for Helicopter Runs.

As the accuracy increased, the difference in survivability based upon the velocity was maximized at slower cadences or in fewer shots. The difference between the logistic regression predicted probability of survival at a rushing velocity of 3.106 m/s and the probability of survival at a rushing velocity of 3.497 m/s, 4.50 m/s, and 4.31 m/s, respectively, were graphed to illustrate this (Fig. 39-41). This was performed for each shooting accuracy (10%, 20%, 30%) and each shooting cadence. The maximum difference was at a shooting cadence of 2.5 shots per second when shooting accuracy was 10%, 1 shot per second when shooting accuracy was 20 %, and .5 shots per second when shooting accuracy was 30%.

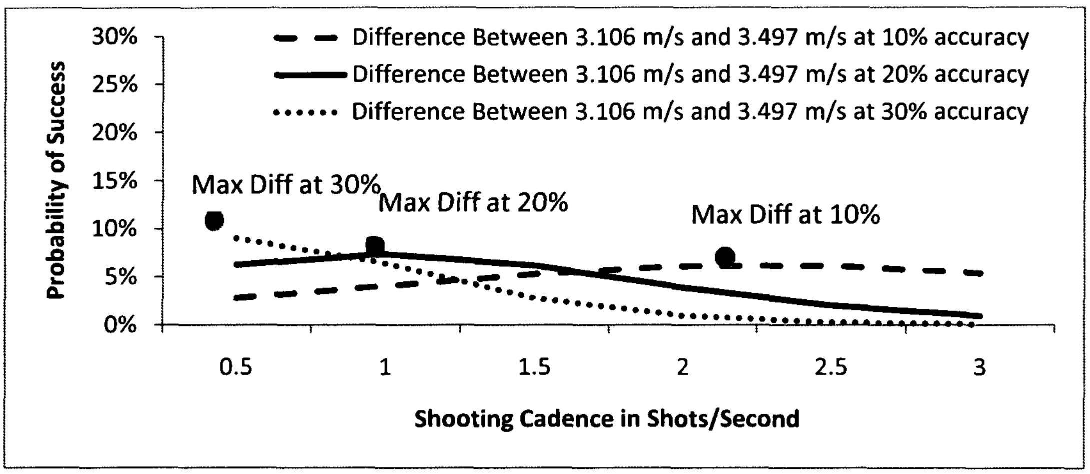


Fig. 39. Difference in Probability of Success Between Slowest Velocities at 10%, 20%, and 30% Shooting Accuracy.

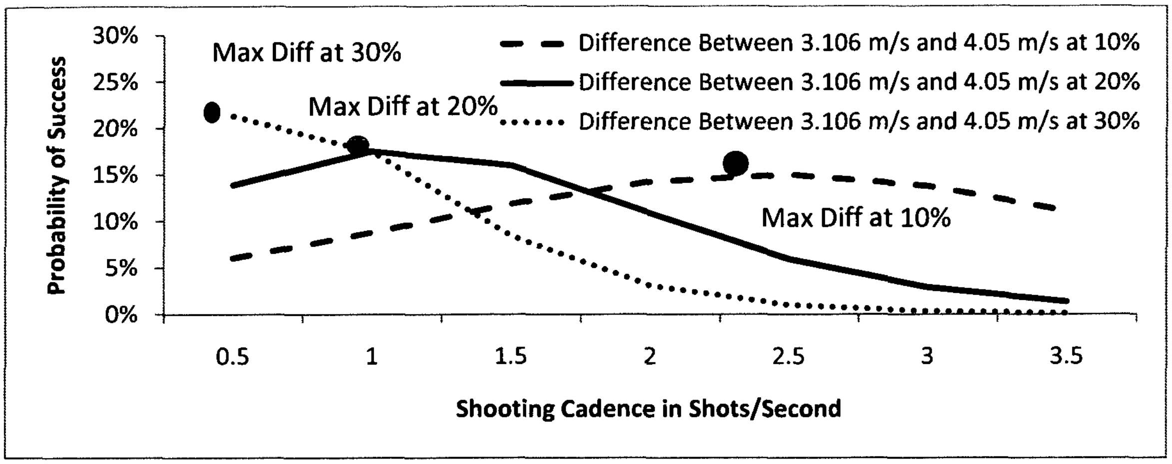


Fig. 40. Difference in Probability of Success between Medium & Slowest Velocities at 10%, 20%, and 30% Shooting Accuracy.

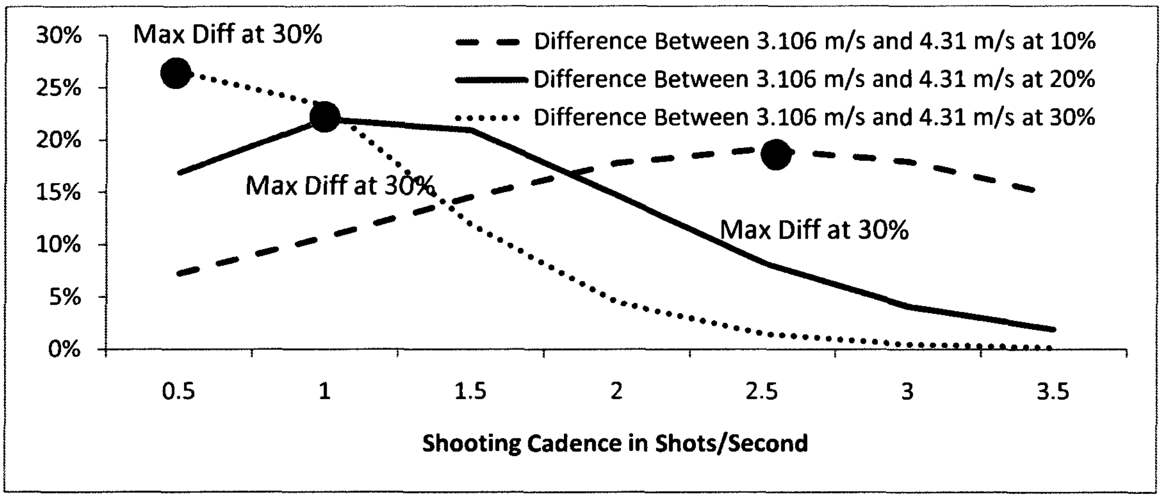


Fig. 41. Difference in Probability of Success between Fastest and Slowest Velocities for 10%, 20%, and 30% Shooting Accuracy.

The difference in probability of success decreased much more quickly as the shooting cadence increased (Figures 39-41) for higher shooting accuracies. The odds ratios were calculated for only the rushing velocity while keeping the shooting cadence constant, which showed 2 trends. First, as the cadence increases, the odds ratio consistently moves farther away from the value 1.0, indicating that a higher cadence increases the effect of a faster rushing ratio. However, when the accuracy was higher (30%), a point was reached where the odds ratio was no longer significant (Tables 27-29). Regardless of how fast the soldiers all rush, they are unlikely to be more successful than a group of slower rushers when the enemy shooting accuracy was above 30% and the enemy shooting cadence was above 2 shots per second for a success metric of 0 casualties (Table 27). Table 28 corresponds with the ratios for Fig. 39-41 with a metric of 1 casualty. This does not mean that the number of casualties was not affected by rushing velocity, but that keeping casualties under a specific limit is no longer obtainable.

There was an exception to the increase in the odds ratio as the shooting cadence increased. After the significance started to increase above 0, the odds ratio dips. This is seen in Tables 27-29 at 30% accuracy for of (shooting cadence =1.5, significance=.028, Table 27), (shooting cadence =3.5, significance=.914, Table 28) and (shooting cadence=3.5, significance=.02, Table 29).

Table 27. Odds Ratios for 0 Casualties with Increase in Shooting Accuracy and Cadence.

Success Metric of 0 Casualties						
	Odds Ratio			Significance (P < ?)		
Shooting Cadence	10%	20%	30%	10%	20%	30%
.5	1.640	1.546	1.799	.000	.000	.000
1.0	1.522	1.945	2.636	.000	.000	.000
1.5	1.855	2.074	2.217	.000	.000	.028
2.0	1.706	2.867	2.981	.000	.000	.136
2.5	1.573	2.877	7.612	.000	.000	.103
3.0	2.548	2.508	173.158	.000	.000	.147
3.5	2.275	25.01	***	.000	.000	***
*** Indicates that there were no successes preventing logistic regression from being used. There must be a binary result: two values.						

Table 28. Odds Ratios for 1 Casualty with Increase in Shooting Accuracy and Cadence.

Success Metric of 1 Casualty						
	Odds Ratio			Significance (P < ?)		
Shooting Cadence	10%	20%	30%	10%	20%	30%
.5	2.700	1.891	1.928	.000	.000	.000
1.0	2.074	2.162	2.997	.000	.000	.000
1.5	1.964	2.141	2.762	.000	.000	.000
2.0	1.789	2.396	3.284	.000	.000	.000
2.5	1.627	1.844	65.447	.000	.000	.000
3.0	1.769	2.352	72.282	.000	.000	.026
3.5	2.225	6.259	.903	.000	.000	.914

Table 29. Odds Ratios for 2 Casualties with Increase in Shooting Accuracy and Cadence.

Success Metric of 2 Casualties						
	Odds Ratio			Significance (P < ?)		
Shooting Cadence	10%	20%	30%	10%	20%	30%
.5	4.429	3.303	3.451	.000	.000	.000
1.0	3.165	2.239	2.52	.000	.000	.000
1.5	2.588	2.665	2.761	.000	.000	.000
2.0	2.014	2.806	3.176	.000	.000	.000
2.5	1.748	2.675	4.656	.000	.000	.000
3.0	1.674	2.905	5.971	.000	.000	.000
3.5	2.499	3.942	3.058	.000	.000	.020

4) Grenade Scenario Analysis for 3 and 6 Meter Rushes: After collecting the data from the Rushing Study, the velocities for the 3 and 6 meter rushes were different. A paired t-test was performed on the rushing results for the 3 and 6 meter rushes which showed that these were indeed two separate groups with $p<.000$. This did not cause a problem for the simulation runs, but it did cause issues for logistic regression and would make the odds ratios invalid. To enable analysis of the 3 meter and 6 meter variables, an additional 42,000 runs were executed where the 3 meter velocity varied while the 6 meter velocity remained constant at the median of 2.12 m/s. Then 42,000 runs were performed where the 3 meter velocity remained constant at the median of 1.428 m/s while the 6 meter velocity was varied. This enabled logistic regression to be performed with valid results. Each rushing velocity was present in at least 1000 runs for each shooting accuracy and shooting cadence where the 3 and 6 meter rushing velocities did not always both go up at the same time.

Table 30. Grenade Scenario Parameters and Number of Runs for Each.

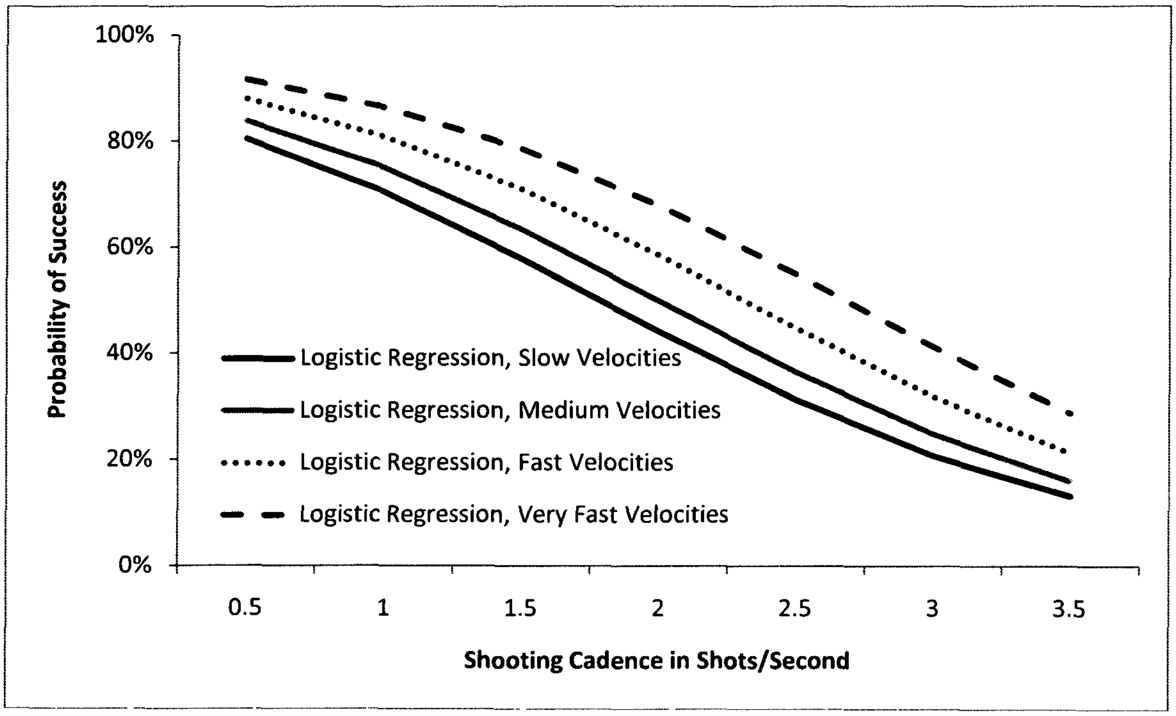
Shooting Accuracy	Shooting Cadence	3 M Velocity m/s	6 Meter Velocity m/s	Number of Runs
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	1.224	1.893	3*7*500=10500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	1.224	2.12	3*7*500=10500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	1.429	1.893	3*7*500=10500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	1.429	2.12	3*7*1500=31500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	1.429	2.5	3*7*500=10500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	1.429	2.777	3*7*500=10500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	1.639	2.12	3*7*500=10500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	1.639	2.5	3*7*500=10500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	2.307	2.12	3*7*500=10500
10%, 20%, 30%	.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5	2.307	2.777	3*7*500=10500

Logistic regression was run with the shooting cadence, 3 meter velocity, and 6 meter velocity as independent variables for probability of success and the odds ratios were given in Table 31. Significance for the 3 meter and 6 meter velocity odds ratios were all $p<.000$. A plot for the probability of success given the velocities and the shooting cadence for a shooting accuracy of 10% was presented in Fig. 42. The slopes for the Grenade Scenario became steeper as the accuracies increased as with the Helicopter Scenario.

Table 31. Odds Ratios for 3 and 6 Meter Velocities in Grenade Scenario.

	Odds Ratios			
Accuracy	3 Meter Velocity	6 Meter Velocity	Shooting Cadence	Constant
10%	1.344	2.117	.332	1.209
20%	1.342	2.587	.183	.318
30%	1.222	2.964	.082	.195

Fig. 42. Logistic Regression Prediction of Success at 10 % Shooting Accuracy in Grenade Scenario.



When a rusher was faster, he was probably faster in both the 3 and 6 meter rushes, so they would normally increase together. A plot was made using the information from changing the 3 meter and 6 meter rushes separately. Fig. 43-45 show the predicted differences in the slowest speeds verses each of the faster speeds for survivability when only the 3 meter velocity was changed, the 6 meter velocity was changed, and when both are changed together.

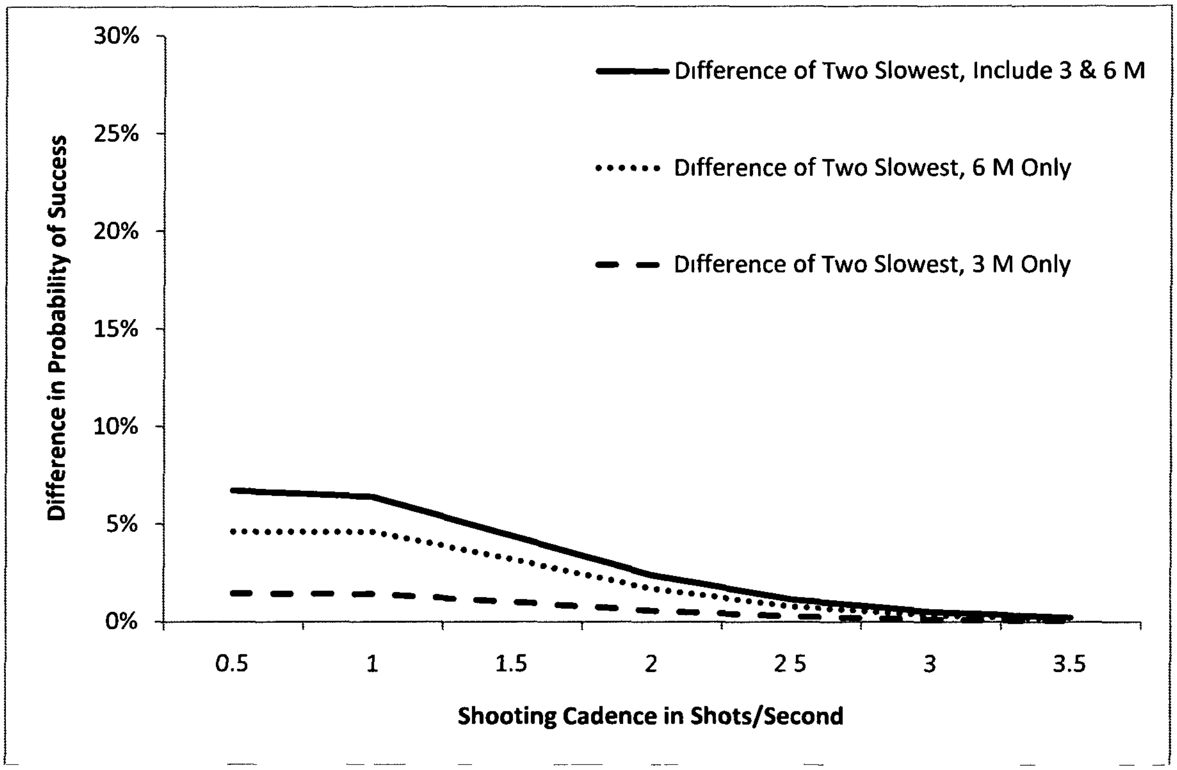


Fig. 43. Predicted Difference Between Two Slowest Rushing Velocities for 3 and 6 Meter Rushes.

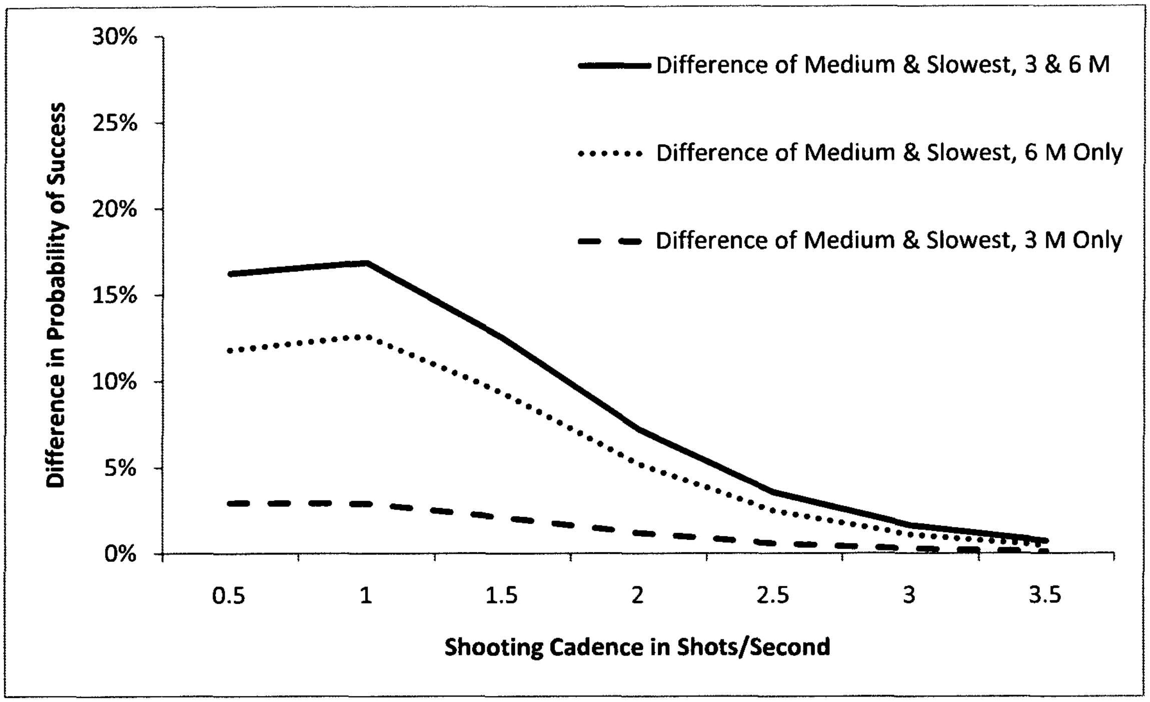


Fig. 44 - Predicted Difference between Slowest and Medium Rushing Velocities for 3 and 6 meter Rushes.

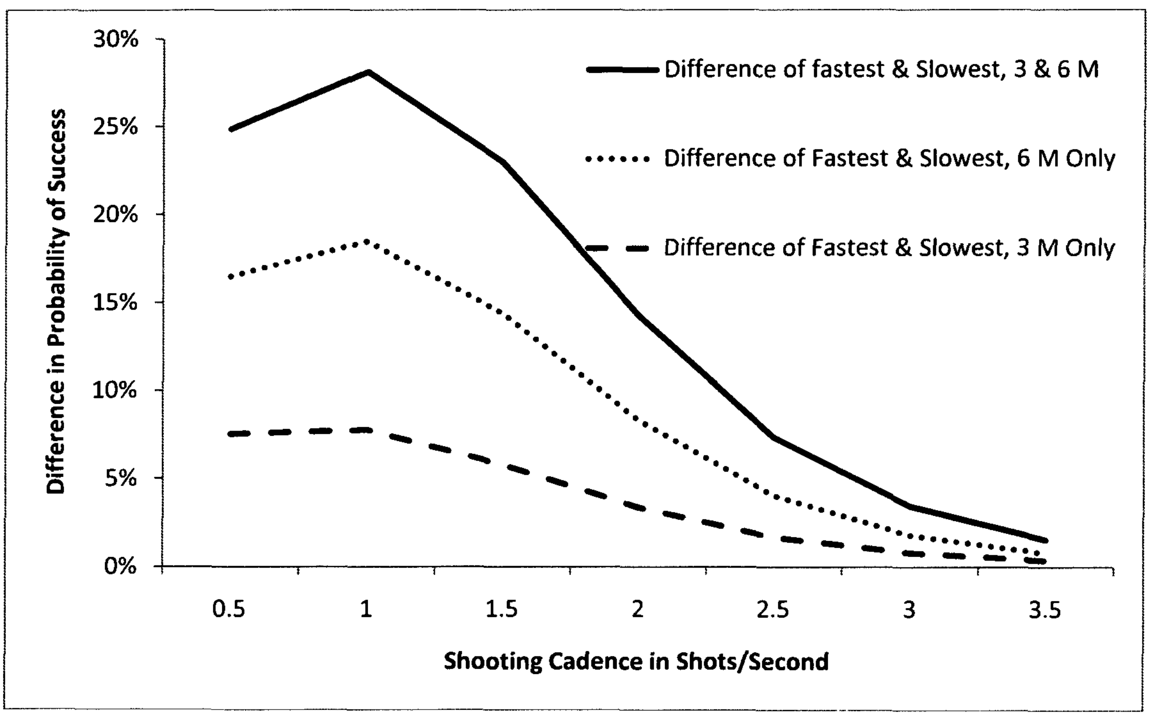


Fig. 45. Predicted Difference between Slowest and Fastest Rushing Velocities for 3 and 6 meter Rushes.

V Discussion

This purpose of this study was to determine if including a physical capability (rushing velocity) has a significant impact upon the results of a tactical infantry simulation. Rushing was selected as a physical task performed on the battlefield that could vary due to physical fitness and capabilities and be successfully implemented in a tactical simulation. Data collection confirmed that physical fitness impacts rushing velocity and also showed that rushing performance relative to others is consistent across rushing distances, shorter distances were rushed with slower velocity, and that the starting and stopping positions affect rushing velocity. A preliminary spreadsheet model found that rushing impacted survivability except for long distances based enemy shooting cadence, enemy shooting accuracy, and enemy reaction time. Two agent based models were developed to investigate the impact of survivability upon a tactical infantry scenario. The simulations found that the rushing velocity affected probability of success, as defined by a minimum number of casualties, given enemy shooting cadence, enemy shooting accuracy, and enemy reaction time and the success metric itself. Two extreme battlefield scenarios were reviewed to determine the types of parameters and chances of survivability that existed for the soldiers involved. These battlefield scenarios suggest that the conclusions in this dissertation are plausible. In addition to using the results of this research effort in tactical infantry scenarios, this data could be used to support training decisions for missions. Although the studies were limited to the influence of rushing, it is reasonable to conclude in general that modeling physical fitness will contribute not only to the accuracy of the simulation, but can aid in decisions relating to physical fitness.

A. Data Collection

Data were collected for two main purposes 1) to ensure the rushing data used as input for the simulation would be valid and 2) to determine if there were any correlations between physical fitness and rushing performance. In addition to fulfilling the purpose of data collection there were four additional findings from the data collected: 1) rushing performance was consistent across the various distances tested 2) shorter distances had a slower rushing velocity 3) the starting and stopping positions affected rushing velocity and 4) soldiers can train to increase those physical fitness attributes that were found to be correlated with increased rushing performance

Performance on the physical fitness tests and overall rank on rushing were tested for Spearman rank correlations to preliminarily determine what fitness parameters were most related to rushing performance (Table 21). The highest correlations were found with respect to rushing rank and the horizontal and vertical jumps, which indicate a leg power component to rushing. This finding was similar to another published study which found the vertical and horizontal jump correlated with better performance in the 400 m run and in 30 m rushes [26]. Body composition was also correlated with better rushing performance. Other studies have found that body size and composition were associated with load carriage ability and running performance [42]. The Spearman rank coefficients indicated that physical fitness attributes measured by the 880 yard sprint, ammunition can lift, body fat percentage, curl-ups, pull-ups, vertical jump, and horizontal jump are attributes that may affect rushing performance. Of these parameters, two are included in the US Marine Corps Combat fitness test (880 yard sprint and ammunition can lift) and two are part of the physical fitness test (curl ups and pull ups). Additionally, percent body fat, while not measured using the caliper method, is part of the fitness screening in all branches of the military. This means that there is a relationship between physical fitness and rushing, and that measures that are already being obtained could be used as model input parameters in a future study, assuming that more data are collected on a larger sample size to define a stronger relationship between the fitness parameters and rushing velocity. It can also be concluded that if a person is more physically fit than others, specifically with regard to horizontal and vertical jumps, 880 yard sprint, ammunition can lift, body fat percentage, curl-ups, and pull-ups, he will have faster rushing performance. Rushing performance was shown to be consistent across rushes as demonstrated in Table 20 where a visual assessment of consistency was given for the rushers relative to each other. This means that if a soldier trains to perform rushing better at 30 meters, he will likely increase performance at 3 meters.

An extra benefit to this research is that since specific physical fitness attributes predict better rushing performance, a subject can increase rushing performance by increasing the specific physical fitness values measured by the tasks that are correlated with rushing performance. For example, the vertical and horizontal jumps measure leg power. Thus, increasing leg power should increase the vertical and horizontal jump, and also rushing performance. This is useful both in the development of training programs as well as using data from simple assessments to input into future models.

For the input data in the simulation to be valid, it needed to represent performance of infantry soldiers. Data concerning these physical fitness attribute measurements and active infantry soldiers was not found. Data regarding US Marine Corps recruits has been published and was reviewed [108]. The participants scored slightly better in pull-ups and crunches than the average Marine recruit [108]. The average number of pull-ups was 12.06±6.9 compared to 8.6±4.2 and the number of crunches was 77.3±23.8 compared to 53.8±12 [108]. The participants were 21±5.157 years of age compared to the age of the average recruit of 19.9±2.0 years. The aerobic fitness endurance component cannot be compared, as Marine recruits only ran 1.5 miles in the published study [108].

The participants performed the Marine Corps PFT and CFT, and were scored as if they were Marines to determine if they met the passing standards for both fitness tests. The assumption was that if they passed, then their rushing times would be comparable to infantry fit for deployment. The lower scores that were from participants who did not pass these tests were not used as input into the scenarios. The velocities 3.106, 3.497, 4.5, 4.31 m/s; 1.893, 2.12, 2.5, 2.777 m/s; and 1.224, 1.429, 1.639, and 2.307 m/s were used for the 15, 6, and 3 meter rushes respectively. Based upon the comparison of performance in pull-ups and crunches with Marine recruits and only data from participants who passed the Marine Corps PFT were used, the data should be representative performance by a U.S. Marine.

Three additional items were learned during the data collection phase: 1) higher performing rushers tended to perform better on the Marine Corps PFT and CFT than the lower performing rushers, indicating that poor performance on these tests may correlate to poor rushing performance (Tables 17 and 19). 2) The rushing velocity for shorter distances was much slower than for the longer distances. 3) The starting and ending position of the rush affects the timing of the rush. The participants had much less distance to accelerate during the shorter rushes of 3 and 6 meters than for the 15 or 30 meter rushes. Thus, the same person in a simulation will not rush at the same velocity for different distances, which could change the results in tactical infantry scenarios due to more time spent rushing shorter distances than before. Rushes where the soldier must start and stop prone, kneeling, or standing will each have different average rushing velocities due to the change in position which could again affect the results of a tactical simulation. Therefore, careful selection of the appropriate motions must be considered as input data are selected for a given scenario.

B. Preliminary Spreadsheet

The pilot data were used in a rushing survivability spreadsheet. It was hypothesized that velocity would not affect survivability in short or long distances, where the soldier would survive or perish regardless of the velocity, respectively. This was confirmed only in the preliminary data. Specifically, in a short rush of less than 3 meters, it did not matter very much if the rusher was slow, he would survive. In long distances of greater than 130 meters, it did not matter if the rusher was fast, he would generally not survive. But, rushing velocity mattered for the distances between 3 and 130 meters given shooting accuracy of 20%, shooting cadence of 0.5 shots/second, and a reaction time of 0.5 seconds. After the rushing data were collected, the 3 meter velocities in particular showed a difference in even short rushes of less than 3 meters (Fig 16-20). The slower rushers did not clear the distance before the reaction shot. An important point here is that neither velocity nor acceleration is linear. If a person rushed 30 meters, he did not immediately achieve the peak velocity. The average velocity was calculated based upon the time it took for the subject to travel the entire distance. The rush can be broken into an acceleration phase, a velocity maintenance phase, and a deceleration phase. During the acceleration phase, the soldier is increasing his rushing velocity. Thus, peak velocity will not generally be achieved at 3 meters; a much slower velocity just above the 3 meter average rushing velocity will be achieved at that point. After the rusher has reached maximum velocity, it will be maintained until the rusher approaches the ending point of the rush. At that time, the rusher will start a deceleration phase to slow down and stop behind cover. Thus, based upon the 3 meter rushing velocities all but the single fastest of the rushers may not clear a reaction shot at 0.5 seconds for a 3 meter rush. So, even in short distances, rushing velocity could affect the outcome of a rush.

Data were not collected for distances above 30 meters. Human beings are physically limited in how fast they can rush. Thus, there will be long distances where no matter how fast a soldier rushes, he will probably be hit.

Consecutive rushes illustrate even further the differences in survivability due to rushing velocity (Figure 14). The top of this figure is dominated by lines from the faster velocities. After each rush (rush 1, rush 2, rush 3), the probability of survival for a rush of 7 meters three times is (79%, 63%, 50%) for a slower rusher of 2.35 m/s and (90%, 81%, and 73%) for a faster rusher of 3.8 meters per second (Figure 14). To get the same probability of survival as the faster rusher, the slower rusher can only rush 4.33 meters 3 times consecutively given the same shooting accuracy of 20%, reaction time of 0.5 seconds, and enemy shooting cadence of 0.5 shots per second.

As a result of this effort, data hit tables were created for use in lookup tables for computer software using the preliminary spreadsheet model and data collected during the Rushing Study (Appendix E). The dependent variables were the number of shots taken and the number hits that occur during the time it takes for the rusher to cross the distance.

The independent variables in these tables were the distance to be rushed, starting and ending posture, rushing velocity, shooting accuracy, and shooting cadence. The distances given in the tables were 3, 6, 12, 15, and 30 meters. A standard lookup can be used with interpolation. The data should not be interpolated beyond 30 meters, as the velocity will have a human limit and may not continue to increase. Data needs to be collected for greater distances as well as for different loads. The starting and ending postures were standing to standing (SS), kneeling to kneeling (KK), and prone to prone (PP). The user could look up the number of hits or shots using any rushing velocity and the other independent variables (rushing distance, shooting cadence, shooting accuracy, starting/stopping position) and then interpolate to get the answers. Shooting accuracies are 10% and the shooting cadence ranges from 0.5 to 5.0 shots per second. The column "Position Measured" indicates if the data were directly measured, or calculated. The average difference in rushing time for the 12 and 30 meter rushes was calculated between the three positions: standing to standing, kneeling to kneeling, and prone to prone. A linear regression was created based upon that number and the "Spearman" total rank (Section 4.3, Table 20). The significance was found to be $p<0$ for prone to kneeling, and prone to standing but $p=.075$ for the conversion of kneeling to standing. An "N" in the "Position Measured" indicates that the data was calculated using these regression equations and was not measured directly.

C. Agent Based Simulations

Two tactical infantry scenarios were created: one incorporates 13 soldiers rushing to a helicopter extraction point, and the other models two soldiers alternating rushing to get to a point where one can throw a grenade. These scenarios were created after reviewing photographs posted on military websites such as MilitaryPhotos.net, watching videos posted by infantry men in Iraq and Afghanistan infantry battles, reading books about battles [21, 25, 85, 109], and reading Army field manuals [83-84]. The significance of the two different types of scenarios is that one involves a group of soldiers rushing at one time, and the other involves one person rushing at a time to achieve a particular task. Whether rushing to a helicopter or across a street, rushing is an important component if infantry battles.

The success metric used to calculate the probability of success in the Helicopter Scenario was based upon minimizing casualties, which is a common tactical success metric [110-112]. When the success metric for this scenario was varied from 0-2 casualties, the same layering of probability of success lines occurred based upon the rushing velocity, indicating that rushing velocity affects probability of success for each of the three casualty metrics (Fig. 22), although the probability increased as the metric became easier to meet (i.e., the more casualties allowed, the easier it is to define success). The lines for each velocity had greater distance between them as the metric became more lax indicating that the impact of rushing velocity initially increased. As the metric becomes even more lax, at some point the trend will reverse and rushing velocity will have less effect on meeting the metric. However, since the ideal situation would be zero casualties in a war, a success metric that is so lax that rushing velocity does not make a difference is not desirable.

The success metric in the Grenade Scenario was based upon task completion. The Grenade Scenario has 2 soldiers, and if there are two casualties, the grenade is not thrown. This could arguably be a casualty metric as well, however many military tasks are based upon the number of soldiers: the number of soldiers needed to defend a position, clear a building, clear a street, patrol an area, or attack an enemy. Without the soldiers to perform the tasks, the tasks are not completed, and the mission unsuccessful. Therefore, the success metric here was based solely upon the ability to perform the task.

Logistic regression was performed on the output from the simulation runs and showed that the rushing velocity was a significant predictor for success. When rushing velocity was not used; the prediction was off by as much as 18% in the Helicopter Scenario and 22% in the Grenade Scenario. A difference of this much could change decisions made based upon the results of a tactical infantry simulation because the decision maker could believe that there would be minimal casualties, when in fact the success metric would not be met. Therefore, it is important to include rushing velocity which is affected by physical fitness or incorrect decisions could be made based upon invalid simulation results.

The Grenade Scenario was initially run using the Pilot Study data, and the same layering of success based upon rushing velocity as seen in the Helicopter Scenario was present (Fig. 23). There were intersections between the two middle velocities at some of the shooting cadences because at those velocities the number of possible shots in the time it took to complete a rush is the same (Table 22). The rushing velocity determined the time interval during which the enemy can shoot and potentially injure the soldier. A slower rusher takes more time to cross a distance, increasing the number of shots the enemy can take. The number of shots directly affects the probability of success and decreases when the velocity increases and when the shooting cadence decreases (Fig. 24).

One reason physical fitness can make a difference in battle is because it affects rushing velocity which decreases the number of shots the enemy can take.

The new data from the 2010 Rushing Study were used for the helicopter and Grenade Scenarios. Additional simulations were run for both scenarios using 10%, 20%, and 30% shooting accuracy. The probability of survival dropped more rapidly as shooting accuracy increased, and the layering effect based upon the rushing velocities was still present (Figures 25-30). The odds ratios and significance calculated for rushing velocity for each of the three casualty metrics in the Helicopter Scenario and calculated for the grenade throw confirmed that the rushing velocity affected the probability of success for each of the three shooting accuracies (Tables 26 & 31). When success was based upon a specific limit for casualties, there was a shooting cadence when the velocity no longer affected the probability of success (Tables 27-29). This occurred earliest when the casualty metric was at its strictest of zero. This indicates a unique operational envelope beyond which there is almost no chance of reaching a metric of success regardless of rushing velocity. However, this does not mean that rushing velocity does not affect the possible number of casualties. If there were an infinite number of casualties possible, rushing velocity would always affect the number of casualties. There are not an infinite number of soldiers in battles, and a finite minimum number of casualties may be reached in specific scenarios, regardless of rushing velocity and depending upon the number of potential shots available to the enemy.

The average numbers of shots for the scenarios were reviewed for each enemy shooting cadence and enemy shooting accuracy in the Grenade Scenario. At 20% accuracy, the average number of shots approached a limit of approximately 10 shots during the time of rushing as the shooting cadence increased. The average number of shots deceased as the accuracy increased, and was approximately 6.7 shots when the shooting accuracy is 30%. The equation **shots = hits / accuracy** was given in Section 4.5.4 to predict what the average number of shots will be for the mission to be in peril without running the simulation. Hits are the number of successful hits or casualties the enemy needs to make to prevent mission success and accuracy is the expected accuracy of the enemy given past encounters. The number of shots can be estimated from the average distances between cover, expected enemy shooting cadences, expected number of enemies, and average velocity of soldiers in the battle. If the number of estimated shots is less than the number calculated using the equation, the mission should be successful. This method does not take into account enemy soldier attrition as time moves forward. Situations where rushing velocity will no longer impact success will occur when the shooting accuracy and the shooting cadence are both high and the probability of success of the mission is near zero. Achieving the number of shots from the equation could mean that the mission will be in peril. However, that does not mean that the rushing velocity will not impact the probability of success. To determine whether rushing velocity will impact success of the mission, the continuous probability should be calculated for negative binomial probability distribution given the number of shots expected and the shooting accuracy. When this value is 99%, then the probability of success for the differing rushing velocities will be virtually the same and close to zero.

When the differences between the slowest velocity and the medium, fast, and very fast velocities were examined (Fig. 43-45), the velocity increases for 3 meter change probability of survival by 1% with the increase to the second slowest velocity, but at the fastest velocity the success of the mission is 8% higher than the slowest rushing velocity due only to the 3 m rush velocity difference. The single three meter rush still showed significance with $p < 0.000$ although the odds ratio was close to 1, varying from 1.22 to 1.34. The 6 meter rush odds ratio was higher, at 2.1-2.9 with $p < 0.000$. As an odds ratio approaches 1, it causes less change to the dependent variable (probability of survival) when the independent variable (rushing velocity) varies. If the single 3 meter rush increases in velocity by 1 m/s, the probability of success increases by a factor of 1.3, compared to a factor of 2.0 for the six meter rush. This is a scenario dependent result. If this scenario had more 3 meter rushes, the odds ratio should increase. The effect from increasing the 3 meter rushing velocity is significant, and should increase survivability of any soldier in any 3 meter rush in any simulation. The amount of increase is dependent upon the number of times 3 meters are rushed by soldiers. When physical fitness is implemented within a simulation, the impact of the implementation will change depending upon the importance and use of the physical fitness attribute. In this case, the 6 meter rush velocity had more impact upon the final outcome than the 3 meter rush velocity. But, the rushing velocity has an impact upon survivability, even for distances as short as 3 meters.

Logistical regression required additional runs for the Grenade Scenario using the data from the Rushing Study because the 3 meter and 6 meter rushes were different velocities which increased the number of independent variables. The velocities were both increased in the same manner creating codependent variables. To enable logistic regression, two new sets of runs were performed: the 3 meter velocities were held constant at their median speed while the 6 meter rushes were varied and vice versa. This is an important feature to note with future research when there is more than one task to be implemented that has a correlation with the same physical fitness task. To assess the impact of the physical tasks, they must be implemented separately, or the dependence upon the same attribute will affect the calculation of the odds ratio and analysis of the implementation.

D. Comparison of Parameters with Battlefield Episodes

Section 5.3 discussed that rushing velocity will always impact the possible number of casualties where infinite soldiers are available. But, real battles have a finite number of soldiers, and so there are missions where given the shooting cadence and shooting accuracy, the rushing velocity will not affect the outcome. This occurs when the number of hits for the number of shots possible at soldiers that are not under cover is equal to the number of soldiers critical to the mission or metric. It is important to compare the data values used in the simulation to actual battlefield conditions to understand when rushing velocity will affect mission success.

Shooting cadence was given as a parameter that affects when rushing velocity impacts success in the battlefield. Shooting cadence used in the scenarios needs to be compared to that in the field. Shooting cadence in this dissertation is measured in shots per second, but it is a metric related to the rate of fire in rounds per minute. A rate of fire of 60 rounds per minute is the same as 1 shot per second. Sustained or effective rate of fire for a weapon is the rate of fire that can be maintained without the weapon failing [113]. It is the actual rate in rounds per minute the weapon would typically be fired in combat [113]. Rapid rate of fire consists of longer bursts of shots than the sustained rate [113]. A rapid rate of fire is not sustainable through battle because it uses too much ammunition too quickly [113]. A typical infantry soldier carries about 300 rounds or 10 magazines of 30 or a double load of 600 rounds for an M16. Three 200 round boxes are carried for a SAW (machine gun) with a double load being six 200 round boxes [114]. Many insurgent enemies carry versions of the AK-47 which has a practical rate of fire of 40-100 rounds per minute or 0.7 to 1.7 shots per second [115]. A common machine gun used by insurgents is the RPK which has a practical rate of fire of 150 rounds per minute or 2.5 shots per second [115]. An M16 has a practical rate of fire at 40-150 rounds per mine or .7 to 2.5 shots per second [115]. Given this, a rate of fire from a single shooter above 2.5 shots per second is unreasonable in battle [115]. In addition, it is not desirable to sustain a continuous shooting rate of 2.5 shots per second as multiple shots can decrease accuracy and 600 rounds could be used in 6 minutes: much shorter than many firefights. More than one enemy shooting at the same time within a battle can achieve greater than 2.5 shots per second, but this is a waste of ammunition and bunch shooting decreases accuracy as described in section 3.6.2. Several videos from combat were reviewed as research for shooting cadence in battle (Table 32). After reviewing these and many other videos, the shooting is often by one person at a time from either side. When more than one person is shooting it is difficult to determine if they are aiming at the same target. If there is more than one soldier then more than one target may be selected by the enemies at the same time.

Table 32. Shooting Cadence Calculated from Battle Videos

Title/Website	Time Period	Number of Shots and Rate
U. S. Army Soldiers From 5/20 Inf Battle Insurgents http://www.liveleak.com/view?i=054_1178361961	:28 - :34	5 shots, .83 shots per second Soldier on far right
Combat Footage – Korengal valley Afghanistan Firefight http://www.youtube.com/watch?v=YXKOCSefF5o&feature=related	:41 – 47	15 shots, 2.5 shots per second
Combat Footage – Korengal valley Afghanistan Firefight http://www.youtube.com/watch?v=YXKOCSefF5o&feature=related	2:27-2:33	4 shots, .8 shots per second
Kicking Taliban Ass – First-Person View – Firefight in Afghanistan – Korengal Valley http://www.youtube.com/watch?v=MBd8Fl6gGdI	1:34-1:39	7 shots 1.4 shots per second
Kicking Taliban Ass – First-Person View – Firefight in Afghanistan – Korengal Valley http://www.youtube.com/watch?v=MBd8Fl6gGdI	1:43 – 1:47	4 shots 1 shot per second (Started to run out of ammo)
27 Marines in a Firefight with the Taliban in Farah Afghanistan http://www.youtube.com/watch?v=i8AxDbuPOMU&feature=related	:05-:08	7 shots 2.5 shots per second Soldier in Front
U.S. Army soldiers Ambushed in Afghanistan http://www.youtube.com/watch?v=4YSVFJjvNDU	:09-:20	15 shots 1.36 shots per second
U.S. Army soldiers Ambushed in Afghanistan http://www.youtube.com/watch?v=4YSVFJjvNDU	1:24-1:30	12 shots 2 shots per second
U.S. Army soldiers Ambushed in Afghanistan http://www.youtube.com/watch?v=4YSVFJjvNDU	3:11-3:15	5 shots 1.25 shots per second
U.S. Army soldiers Ambushed in Afghanistan http://www.youtube.com/watch?v=4YSVFJjvNDU	3:40-3:47	11 shots 1.57 shots per second
Front Line Footage of US Marines in Afghanistan 2010 http://www.youtube.com/watch?v=-I-1RotjwPM&feature=related	3:54-3:57	3 shots 1 shot per second

Shooting is generally required for three reasons: 1) to provide cover fire 2) to prevent enemy movement and 3) to injure an enemy. The goal of the first two requires very little shooting accuracy with respect to hitting a target. The last is performed when the enemy is in the open and reachable by gunfire. The shooter may be shooting at the same target as others, or may be shooting at a separate target from others. When one shooter is aiming at the target, the shooting cadence is calculated as above (total shots/time). When one shooter is aiming at the same target as others, the accuracy will go down due to bunch shooting as described in section 3.6.2, but the shooting cadence against the target will increase. Knowing the exact shooting cadence at each individual in a battle is not possible, but we can extrapolate based upon indications of fire described by combatants, the number of people injured in battle on both sides, and the number of people involved in the battle. From this, we can try to determine how the characteristics from the battle relate to the shooting cadence, shooting accuracy, and reaction velocity discussed in this dissertation. A synopsis of 2 battles or battle action is given followed by discussion relating the battle to parameters of shooting accuracy and shooting cadence with respect to the impact of rushing velocity.

1) Mogadishu, Somalia 1993: The raid in Mogadishu, Somalia of 1993 is cited as an example where physical fitness contributed towards success on the battlefield [17, 22]. In this raid, key subordinates of General Mohammed Farah Aideed were to be captured in an effort to reduce his power and his ability to hinder peacekeeping operations by the U.N. in Somalia [116]. Sixteen Rangers each in Chalk 1, Chalk 2, Chalk 3, and Chalk 4 were to isolate the target area and provide security through suppressive fire while Delta Force teams assaulted and surrounded the building containing the targets to be captured [25, 116-117]. Enemy fire upon Delta and Ranger groups increased quickly and Rangers were being hit by fire [116]. Sergeant Matt Eversman, leader of Chalk 4, describes fire as not accurate at first, but the Somalis were aiming and not spraying their weapons [117]. He states that the "heavens opened up with small arms fire" [117] and describes that when a Somali gunman was hit, another took his place [117]. Berendsen, a grenadier from Chalk 4 was hit in the arm and crossed the street to get it bandaged [118], and Sergeant Scott Galentine was shot in the hand and did the same. A Black Hawk (MH-60) that was attempting to provide fire support to the Rangers crashed three blocks from the ground objective [116]. A ground convoy arrived to take the prisoners, and then went towards the crash site supported by Chalk 4 to evacuate wounded [116]. The convoy, consisting of sixty-five men, was continually ambushed and suffered three dead and forty-five wounded. It did not make it to the crash site, but instead left to go back to base [116]. Rangers from Chalk 1 and Chalk 2 went to the crash site on foot [116]. One Ranger was killed and one was wounded while dodging bullets to get to the crash and set up a perimeter [116]. Chalk 3 helped Chalk 4 load the prisoners and wounded into the convoy to go back towards base, and then proceeded towards the crash site [117]. Mike Kurth from Chalk 3 describes a small part of their track to the first crash site after Chalk 1 & 2 "The fiercest part of the battle was taking place there. The volume of fire had grown so intense that it had been a little while since anyone had crossed the street." [117] A CSAR (casualty and rescue) team fast-roped into the crash site from an MH-6 Helicopter [116]. Two of the four CSAR medics were shot [116]. The rangers and CSAR team expanded their perimeter around the site and gave suppressive fire towards the increasing swarm of attacking Somalis [116]. Half the force was hit, and fire was too intense for casualty evacuation [116]. Captain Mike Steel led remaining raiders from the objective fighting on foot to the crash site [116]. Helicopters provided fire support, and dropped medical supplies and ammunition throughout the battle, but could not evacuate casualties due to the intense fighting [116]. A second helicopter (MH-60) was hit by an RPG-7 and went down 2 km away [116]. Two rescuers fast-roped down to the second site, but the crash site and its rescuers were eventually overrun by the Somalis [116]. QRF en route to the second crash site was ambushed and pinned down, requiring dismounted assaults to clear the Somalis' attacks [116]. After hearing the second crash site was over-run, they returned to their base but it took an hour to break contact with the Somalis [116].

It took five hours before the next QRF was sent to rescue the stranded operation [116]. The QRF divided into A and C companies [116]. A company was ambushed and engaged an estimated 1,500 Somalis shooting from trees and inside and on top of buildings, according to SPC Ralph Scott [116]. C Company reached the second crash site, empty of wounded or survivors, and destroyed the remaining equipment and helicopter [116]. C company fought through Somalis using dismounted fire and movement tactics to return to A company [116]. C Company then returned to base, while A company fought to get to the first crash site against heavy fire, dismounting to move through roadblocks in vicinity of the Olympic Hotel [116]. Upon reaching the first crash site, wounded and prisoners were loaded into vehicles while healthy soldiers had to run the "Mogadishu Mile" back to base while under fire [116]. 1LT Ferry states the intensity of weapons fire increased as they started moving. Somalis seemed to know that they were leaving and were attacking with all they could [116]. Depending upon the source, there were 18-19 US soldiers killed, one taken prisoner, and eighty-three wounded [116]. The Somali casualties, not counting civilians, were estimated to be anywhere from 200-1000 of Aideed's fighting men, and two to three times that many were wounded [116]. Despite the intense fighting and unexpected casualties, the mission crippled Aideed's power and he agreed to a cease-fire [116].

The description above indicates an extremely intense battle with virtually unlimited enemies compared to the number of soldiers. Technically, the mission was successful. But, it failed with respect to the number of casualties expected [116]. There are parts of the mission that were in the envelope where rushing velocity can affect survivability of the individual soldier, and parts where rushing velocity had no impact. Eversman describes the fire as not accurate, but the enemy was aiming, and that the "heavens opened up with small arms fire". This indicates that not all bursts of bullets were machine guns or it would be described as a spray without aiming, and the shooting cadence was extremely high due to the number of Somali attackers which should be above 2.5 shots per second. Neither Berendsen and nor Galentine were hit while crossing the street during fire to receive first aid for a previous gunshot injury. This indicates that the enemy shooting accuracy was poor, as there were so many bullets described. This indicates bunch shooting as described in section 3.6.2. As they were willing to cross the street to seek aid, they must have considered a better than even chance that they would have survived the crossing or in their best interest to cross the street. There were so many enemies, one can assume that at least two people were shooting at them with a combined shooting cadence of 3.0 shots per second, reaction time of .5 seconds, and shooting accuracy of only 5% due to bunch shooting described above in section 3.6.2. The street was approximately 30 ft or 9.144 meters wide according to Fig. 46 from Google Earth. Using the spreadsheet prediction model and the rushing velocities for 12 meters standing to standing, a slow rusher would have a 62% chance of not getting hit while the fastest rusher would have a 72% chance of not getting hit. Thus, physical fitness impacted the probability of success for these men to cross the street. Table 33 shows the probability of success for this maneuver with different values for the shooting accuracy and shooting cadence given a reaction time of 0.5 seconds. Each of the numbers below is a valid guess and indicates differences in probability of success from 3-15% for not getting hit while crossing the street due to rushing velocity. It is that chance that could have cost another injury that might have prevented the group from surviving as time moved forward from this early part of the battle.

Two of the thirty-two Rangers from Chalk 1 & 2 were hit on the way to the crash site about three blocks away. This was a long way to move under heavy fire. Every move in the open mattered just as crossing the street above did. The time periods that Kurth described as having no movement in the street would have occurred when rushing velocity would not have mattered or the soldiers felt it was unlikely that they would make it across the street. Assuming similar accuracy, a shooting cadence of 4.0 gives a probability of 54% for a slow rusher or 66% for a fast rusher (Table 33). This is a range where rushing velocity will impact survivability, but given the consequences the odds are not conducive for rushing across the street except in extreme circumstances.

When the shooting cadence is extremely high or the soldiers cannot move due to wounded, the smaller force risks being pinned down as in crash site 2. These men were unable to rush from the crash site, and two received Medals of Honor for sacrificing their lives. This also iterates the importance of avoiding casualties. Excessive casualties risk the entire group, not just by endangering the mission, but also because wounded cannot be left behind or basic principles of fighting and unit cohesion are undermined.

Table 33 - Probability of Surviving Street Crossing of 9.144 Meters.

Velocities (m/s)	Shooting Accuracy	Shooting Cadence (shots/sec)	Shots	Probability of Not Getting Hit
2.81	2%	2.0	6.51	88%
3.175			5.76	89%
3.67			4.98	90%
4.013			4.56	91%
2.81	2%	3.0	9.26	83%
3.175			8.14	85%
3.67			6.97	87%
4.013			6.34	88%
2.81	2%	4.0	12.02	78%
3.175			10.52	81%
3.67			8.97	83%
4.013			8.11	85%
2.81	5%	2.0	6.51	72%
3.175			5.76	74%
3.67			4.98	77%
4.013			4.56	79%
2.81	5%	3.0	9.26	62%
3.175			8.14	66%
3.67			6.97	70%
4.013			6.34	72%
2.81	5%	4.0	12.02	54%
3.175			10.52	58%
3.67			8.97	63%
4.013			8.11	66%
2.81	10%	2.0	6.51	50%
3.175			5.76	55%
3.67			4.98	59%
4.013			4.56	62%
2.81	10%	3.0	9.26	38%
3.175			8.14	42%
3.67			6.97	48%
4.013			6.34	51%
2.81	10%	4.0	12.02	28%
3.175			10.52	33%
3.67			8.97	39%
4.013			8.11	43%

A QRF force of nine 2.5 trucks and twelve HMMWVs were sent to bring back the entrapped soldiers. Estimating approximately 100 people, they were engaged with 1500 Somalis. The soldiers had to dismount to engage the enemy effectively. It took an hour to disengage to return to base without rescuing the entrapped soldiers. In a dismounted attack, the soldiers would have had to stay behind cover until the gunfire subsides enough for a reasonable chance to re-embark the vehicle to leave the location. In the instances where soldiers did not move outside of cover, they perceived that the odds of traveling outside of cover were not in their favor. Table 29 above shows this for a high shooting cadence of 4 shots per second at 5% and 10% shooting accuracy, but even still, the faster rushing velocities have a higher probability of success. Only when the men were pinned down at the crash site and could not leave was there no chance of rushing velocity making a difference. The helicopters provided fire support to the trapped soldiers at crash site 1 which aided them to make it through the night without being overrun.

There were about 100 soldiers killed or wounded and from 800-3000 Somalis killed or wounded as a result of this campaign. The soldiers were vastly outnumbered. Given the odds, the shooting cadence against each soldier should have been easily above 4.0 for each movement outside of cover with more than one Somali shooting at a single target: there were 100 soldiers hit after 14 hours of gun fighting and the number of Somalis that were hit was ten times greater. This indicates that while shooting cadence and shooting accuracies may have been high enough for rushing velocity to not make a difference at specific points in time, there were many points in time (crossing the street, moving to/from the vehicles, etc.), where rushing velocity made a difference in the survival of individual soldiers, and potentially the whole group. While casualties were unexpectedly high on both sides and the mission publicly deemed a failure, it was in fact a success with respect to prisoners taken and the weakening of General Aideed's grip on power.

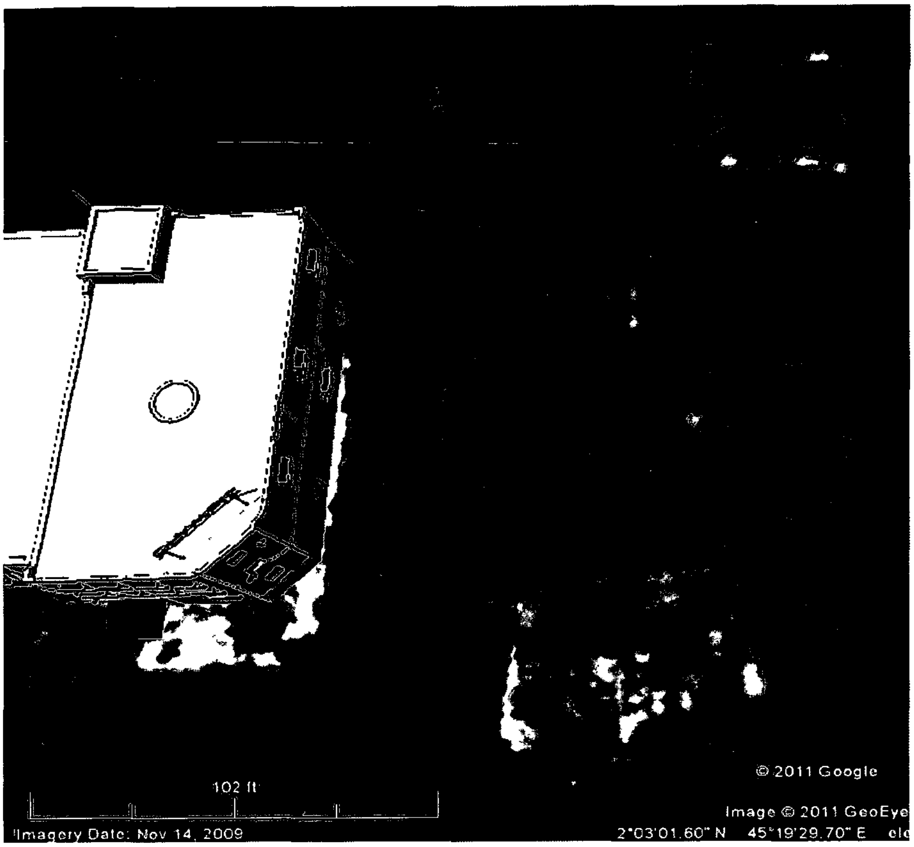


Fig. 46. Satellite Image of Area Around the Olympic Hotel.

Output from the agent simulation scenarios indicate that there are points in time where velocity does not make a difference in mission success. Relating these to an intense battle of well trained soldiers helps to define the envelope where rushing velocity has an impact on results with respect to a real battle. In this battle, there were a few instances where rushing velocity did not affect survival and they resulted in the soldiers being pinned into specific areas. Despite this, there were also many instances where during an extremely intense battle of greater than 2.5 shots per second, rushing velocity still made a difference. Rushing velocity should make a difference during most rushing situations where the probability of survival is greater than 1%. As the probability of survival increases, the impact of rushing velocity upon the outcome also increases, to a certain point. As seen above, the results are very sensitive to accuracy and shooting cadence as well as rushing velocity. An accurate assessment of the situation will lead to the most valid of simulation results and analysis of alternatives to ensure a successful outcome. Knowing that rushing velocity almost always makes a difference, even extreme situations like in Mogadishu will encourage accurate parameters to achieve valid results from a tactical infantry simulation for decision making.

2) Enemy Ambush March 20, 2005: The MP (Military Police) Raven 42 squad consisting of 8 men and 2 women was escorting a 30-truck supply convoy from the rear [119-121]. The convoy was ambushed by approximately 50 insurgents in a short range "L" shaped ambush [119-121]. Three up-armored Humvees raced to the front of the convoy, turned immediately right at the intersection, and then disembarked to attack by flanking the insurgents [119-121]. One Humvee was hit by an RPG injuring the occupants [117-118]. Two of the MP's, rushed 20 meters to enter the trenches from which the insurgents were attacking, while attacking the insurgents using grenades, a grenade launcher, and shooting. The remaining soldiers ensured the insurgent cars were emptied and attacked the insurgents from the road [121]. Depending upon the source, the battle lasted 25-40 minutes [119, 122]. There were 10 MP's and over 40 insurgents in the battle. Twenty-seven insurgents were killed, five wounded, and one captured [121]. Three MP's were wounded [121].

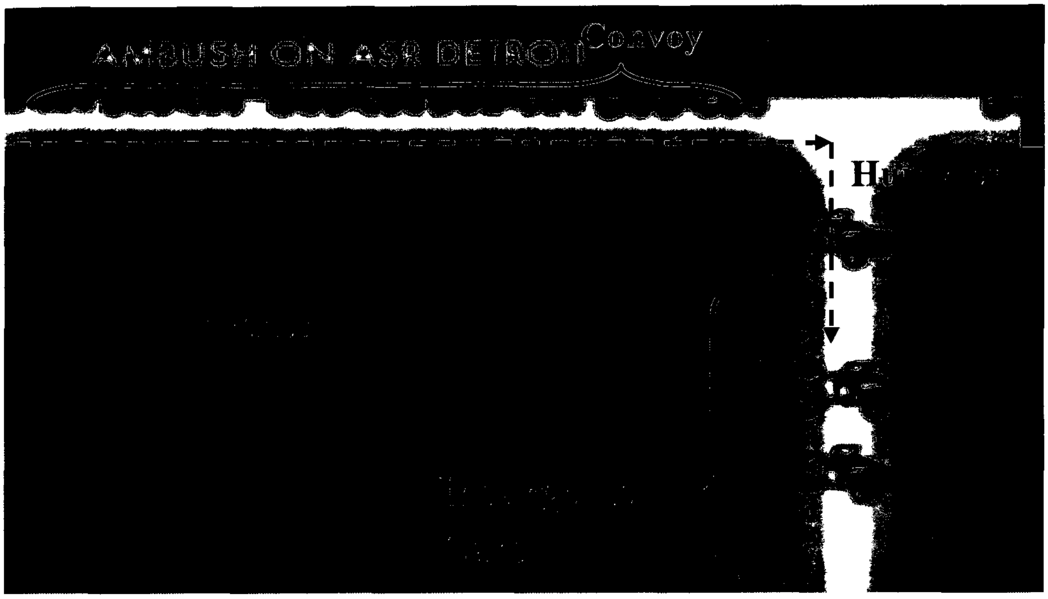


Fig. 47. Map of the battle engaged by MP Raven 42. [121]. The field is filled with insurgents. Along the top is the stopped convoy. To the right are cars the insurgents used and Humvees driven by the MPs after stopping [121].

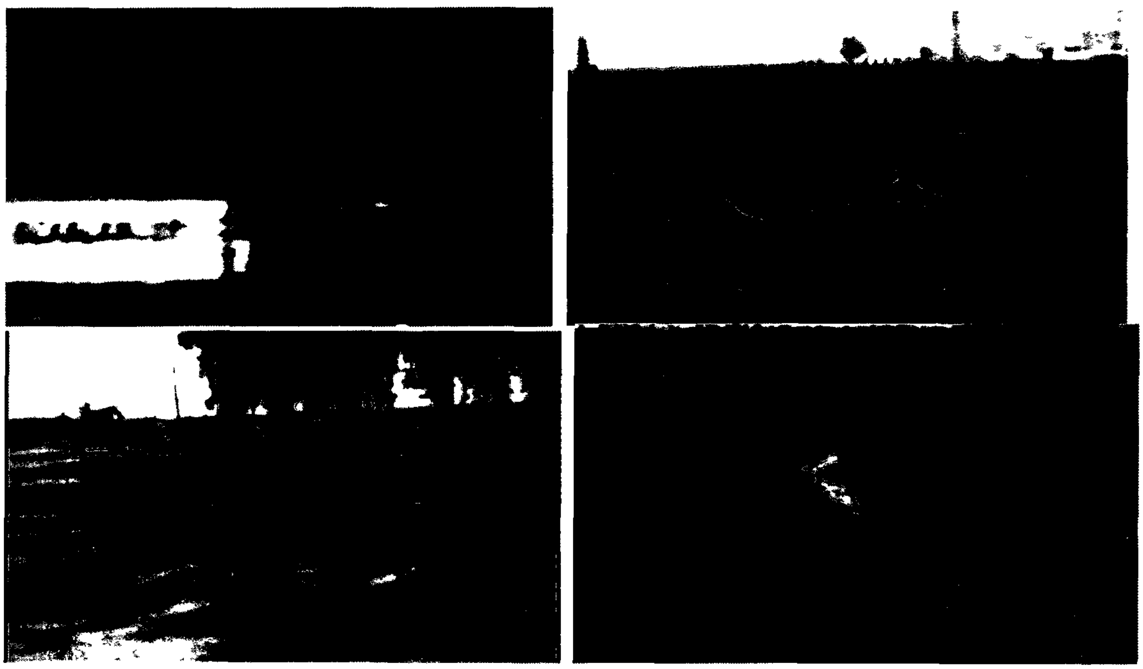


Fig. 48. Pictures from Battle with Raven 42 Squad. 1) A shot taken by an attacking terrorist facing the convoy. 2) Field that was filled with ~40 terrorists, convoy is on right along the road. 3) Road with terrorists' cars and Raven humvees. 4) A picture of trench used for cover by the terrorists [121].

The key to the success in this battle are two soldiers that flanked the enemy after rushing 20 meters. Sgt Leigh Ann Hester actually rushed the 20 meters two more times when she ran out of ammunition and ran back to the vehicle to get ammunition and returned to the trenches. The properties described in this battle are similar to Mogadishu in that there was the intense gun fire needed to reach the envelope where rushing velocity may not make a difference. The velocities for 15 meters standing to standing were used in Table 34 to compute probabilities of success for rushes. The velocities may have been a bit faster as they were not wearing fighting gear, but the terrain was uneven. A reaction time of 2.0 seconds was used, as it may have taken longer for the enemy to switch from their target to the new adversaries coming from the side of the road. The enemy would have been using point shooting techniques and would have low accuracy and bunch shooting characteristics. Table 34 has the percentage chance for each of them to survive the first rush. This does not cover how quickly they moved through the trench. An additional column is given to show the probability of survival for three consecutive rushes and all four rushes together given the same parameters. With the exception of the fastest rushing velocities at 2% shooting accuracy and 2 shots per second, none of the probabilities for both of them not getting hit is above 50%. The lowest difference in probability of survival is for one rush at 6%, and for all four rushes is 15%. A hit in just the first rush would have increased the shooting cadence upon the remaining solder and decreased the chance of success. Rushing velocity would influence the probability of survival in this situation, and would influence success in a simulated version of this scenario.

While the probability of surviving the two rushes is calculated, they were moving through the trench towards the enemy and accessible to enemy fire when they were not rushing. This is not even discussed in this section, but is as dangerous as rushing under fire. Three of the eight MP's had already been wounded and were being tended to by a fourth member. Two of the eight MP's were firing towards enemy combatants situated at their flank and searching the cars. Sgt Niles describes opening his door to disembark to move towards the enemy trench and receiving many bullets that amazingly did not ricochet towards him. This indicates the heavy fire and graveness of the situation, and the importance that these two soldiers were able to perform as required to fix twenty-seven enemy combatants.

Table 34 - Probability of Surviving 20 Meter Rush.

Velocities (m/s)	Shooting Accuracy	Shooting Cadence (shots/sec)	Shots	Probability Not Getting Hit (1 Rush)	Probability Not Getting Hit (3 Rushes)	Probability Not Getting Hit (ALL Rushes)
3.106	2%	2.0	9.88	82%	55%	45%
3.497			8.44	84%	59%	50%
4.05			6.88	87%	66%	57%
4.31			6.28	88%	68%	60%
3.106	2%	3.0	14.32	75%	42%	32%
3.497			12.16	78%	47%	37%
4.05			9.81	82%	55%	45%
4.31			8.92	84%	59%	50%
3.106	2%	4.0	18.76	68%	31%	21%
3.497			15.88	73%	39%	28%
4.05			12.75	77%	46%	35%
4.31			11.56	79%	49%	39%
3.106	5%	2.0	9.88	60%	22%	13%
3.497			8.44	65%	27%	18%
4.05			6.88	70%	34%	24%
4.31			6.28	72%	37%	27%
3.106	5%	3.0	14.32	48%	11%	5%
3.497			12.16	54%	16%	9%
4.05			9.81	60%	22%	13%
4.31			8.92	63%	25%	16%
3.106	5%	4.0	18.76	38%	5%	2%
3.497			15.88	44%	9%	4%
4.05			12.75	52%	14%	7%
4.31			11.56	55%	17%	9%

This scenario is a relatively short gunfight between four soldiers and fifty enemies. All fifty enemies were not aiming at the four soldiers, but were initially concentrating on the convoy potentially slowing reaction their reaction time. Once the enemies realized the soldiers were approaching, the shooting cadence against them would have been very high and the probability of their survival less than 50% with a potential range of 2%-50% for heavy gunfire above 2.5 shots per second. This highlights the importance of determining the actual parameters and sensitivity within a simulation. Rushing velocity alone accounts for a variation of 7% to 18% in survivability which would impact the results of a simulation and the real life scenario.

E. Use of Data for Physical Training

Rushing velocity can be used as a tool to determine if soldiers are physically fit for specific scenarios. If a mission is planned in an area where typical cover is spaced 10 meters, and the number enemy soldiers and their general shooting accuracy are known, a minimum rushing velocity can be determined. For instance a particular city block has streets that are 10 meters apart. A maneuver is planned and expected resistance is 0.5 enemies for each soldier. Shooting cadence is expected to be 0.5 shots per second when moving outside of cover. Shooting accuracy is expected to be 5% given training and past experience with the enemy. The average soldier is expected to rush under fire 1-2 times during the maneuver. A reaction time of 2 seconds is expected from the enemy during the course of the scenario. Soldiers would like a 90% success rate during the course of battle. Using the velocities for 12 meters standing to standing, the probability of success is given in Table 35. There is a greater than 90% probability that the soldier will survive one rush, but surviving both rushes is less than 90%. This does not mean that the second rush has less chance of survival than the first. But, there should be a greater percentage of faster soldiers that survive two rushes than that survive one rush. The soldier should easily achieve 90% for one rush, but he would be just shy of 90% for two rushes even at the fastest velocities. He should still aim to get his rushing velocity as close to 4 meters per second as possible, as the difference in survivability between the slowest and fastest two rushing velocities after two rushes is 5%.

Table 35 – Probability of Surviving 10 Meter Rushes

Velocity	Probability of Survival 10 Meter Rush	Probability of Survival Two 10 Meter Rushes
2.81	91%	83%
3.175	92%	85%
3.67	94%	88%
4.013	94%	88%

Currently, many of the soldiers in Afghanistan are experiencing ambushes. The conditions of past ambushes could be modeled along with the terrain. The scenario could be simulated to determine the rushing velocities that would have led to better or worse success. The soldiers could train to increase attributes that contribute towards better rushing times until they achieve rushing performance desired to promote success according to these simulated ambush situations.

F. Limitations and Future Work

This was the first study that looked at implementing physical fitness models within tactical infantry simulations. It started with preliminary investigation using a spreadsheet to look at rushing velocity and probability of survival for single and consecutive rushes. Then two scenarios were created: one that is unlikely to end based upon shots from the enemy and has many soldiers rushing at one time and a second where only one soldier rushes at a time with a potentially limited number of shots due to the more limited number of targets. Neither a published military shooting accuracy nor published shooting cadence was used. However, police shooting accuracies were used to help determine realism in the field. Uploaded military videos and weapon performance standards were used to compare with the shooting cadences used. To accommodate the epistemic uncertainty surrounding these two variables, the accuracy and shooting cadence were varied to determine the properties of the impact of rushing with respect to shooting accuracy and shooting cadence. It is impossible to know every military scenario that can exist: the number of rushes in a battle, distance of the rushes, heavy fire or light fire, shooting accuracy of the enemy, etc. All of these features change from one situation to the next. Shorter distances that should have less impact upon a rushing situation were used, so a conservative number would be predicted rather than an inflated one. Rushing velocity was found to significantly affect the results of the simulation runs.

There is much more that can be done to further research in this area. All of the velocities were homogeneous. The next step in this research is to change the rushing velocities in the scenarios to be heterogeneous to see how fast or slow rushing of one soldier impacts the group. The selection of the target was random for the Helicopter Scenario. Research could be performed to determine if an enemy would target a faster rusher in the front or a slower rusher towards the back.

Casualty evacuation was not included. Whenever a person is injured, he may need help to continue moving towards cover. This would slow down an additional soldier, exposing him to fire. Where changing rushing velocity might affect the results by 18%, adding casualty evacuation will change the result even more as other soldiers will be exposed longer every time they need to rescue a fellow soldier.

Several shooting attributes will also change the model. The shooting cadence was performed at a strict pace. A pause between shots based upon a statistical distribution should smooth out the results of the simulation rather than relying on shots taken only at specific times. These scenarios do not include decreased enemy shooting accuracy for increased rushing velocity, decreased enemy shooting accuracy during response with friendly cover fire, or return fire with decreased accuracy due to fatigue. These could each increase the impact of rushing velocity in an infantry simulation. The simulation has an unlimited supply of ammunition, but in real life, soldiers are limited in how much ammunition they can carry which can in turn affect the shooting cadence and maximum number of shots. Each of these efforts is a new study that could make infantry simulations more accurate and provide simulated results that could aid in training and policy making that would aid infantry.

G. Summary

In real life, physical fitness impacts success in battle (sections 1.2 and 2.2). Currently, tactical infantry simulations do not differentiate fitness levels for the soldiers and no information has been found concerning physical fitness models included in tactical infantry simulations. Rushing velocity was affected by physical fitness as shown by the Spearman rank coefficients (Table 21) using data collected from 31 test participants. Knowing which attributes contribute towards rushing success can increase training success by training to increase those attributes.

Rushing velocity has been implemented in two tactical infantry scenarios and shown to significantly affect the probability of success using eight different velocities for each scenario, while changing the enemy shooting cadence and the enemy shooting accuracy. This finding has additional attributes. When the rushing distance is extremely long and when the interaction of the enemy shooting cadence and enemy shooting accuracy become too high, rushing velocity does not have a significant impact. However an analysis of two extreme battles where soldiers were outnumbered show that this envelope is rarely reached, and only reached when soldiers are outnumbered. Methods are given to determine when rushing velocity will not impact the results using the negative binomial probability distribution in Sections 4.5.4 and 5.3 The differences in probability of mission success were as high as 22% due to the difference in rushing velocities, a very compelling reason to implement physical fitness through rushing velocities in tactical scenarios. Tactical infantry scenarios that do not include physical fitness models may give inaccurate results that may lead to poor decision choices. Physical Fitness attributes need to be implemented into tactical infantry simulations to aid in quality decision making, and training.

VI Conclusions and Follow-On Work

This dissertation showed that implementing rushing velocity can have a significant impact upon tactical simulation. As a review, this effort's main contribution and side contributions are the following:

1) Rushing velocity can affect the results of an infantry tactical simulation. (main hypothesis)
2) Rushing velocity has a strong positive correlation with horizontal and vertical jump which are physical fitness measures. It also has correlations with the 880 sprint, ammunition can lift, body fat composition, curl-ups test, and push-ups test.
3) Rushing performance is consistent for fast and slow rushers for the data collected. If a person rushes 3 meters fast, he should rush 15 and 30 meters fast.
4) Enemy shooting accuracy and enemy shooting cadence (light versus heavy fire) influences when the maximum benefits occur from implementing rushing velocity. The negative binomial probability distribution can be used to determine at what point rushing velocity no longer affects the outcome.
5) When measuring the effect of implementing physical fitness modeling in tasks, it is important to determine if some of the physical fitness characteristics could be used in both. In this project the 3 meter and 6 meter rushing velocities should both increase with increases in leg power. However, they must each be implemented separately if separate measurements are required to determine the significance.

This effort's primary goal is to determine if modeling physical fitness can change results of tactical infantry simulation. Once a statistical model is developed, it can be used for implementing physical fitness with respect to rushing in many simulations based upon physical fitness parameters. Look-up tables could be created to determine the rushing velocity with respect to physical fitness parameters just as tables have been created here to look up the number of shots or the number of hits based upon enemy reaction time, distance to be rushed, and a known rushing velocity.

This effort can also aid other research benefiting the military community as new questions can be asked in different ways. Information beneficial to infantry include 1) knowing how far a soldier should be willing to rush given type of fire (light, medium, heavy) and perceived accuracy of the enemy 2) equations could be developed and incorporated into mathematically based simulations that might affect attrition and 3) physical fitness could be incorporated into training simulations so the avatar has the same physical fitness characteristics as the soldiers using the software yielding more realistic results. It is the hope of the author that this research can continue towards the benefit of the infantry.

References

[1] H. V. D. Parunak, *"MAS Combat Simulation", AAMAS Technology for Military and Security Applications*. New York: Springer, 2007.

[2] G. L. Boylan, E. S. Tollefson, J. M. J. Kwinn, and P. G. Martin, "Determining Simulation Requirements and Identifying a Course of Action to More efficiently support Acquisition Decision-making for the Current and Future Force Infantry Warrior," Operations Research Center of Excellence, Department of Systems Engineering, United States Military Academy West Point, NY ADM001736, December 2004.

[3] R. Schleper, C. Gaughan, M. O. Kierzewski, C. Dunmire, L. Salvi, J. Fann, and B. Kellihan, "Individual Warfighter Effectiveness and survivability in a CBRN Threat Environment," in *Modeling and Simulation for Defense Systems and Applications*, San Francisco, CA, 2010.

[4] E. S. Tollefson, M. J. Kwinn, P. G. Martin, G. L. Boylan, and B. I. Foote, "Simulation Modeling Requirements for Determining Soldier Tactical Mission System Effectiveness," in *2004 Winter Simulation Conference*, Washington, D. C. , 2004.

[5] J. N. Templeman, L. E. Sibert, R. C. Page, and P. S. Denbrook, "Pointman - A New Control for Simulating Tactical Infantry Movements," IEEE Virtual Reality Conference, Charlotte, North Carolina, 2007.

[6] J. D. Smith and J. Steel, "The Use of Virtual Simulation for Dismounted Infantry Training," RTO NMSG Conference on "The Second NATO Modelling and Simulation Conference, Shrivenham, UK, 2000.

[7] M. Hilburn. (2008, May 2008) 'Ramp up the Chaos' Marine Corps simulation systems allow tactical mission rehearsals. *Seapower*. 36-38.

[8] K. Nemire, "Individual Combatant Simulator for Tactics Training and Mission Rehearsal," in *Proceedings of SPI--International Sciety for Optical Engineering*, San Jose, California, 1998, pp. 435-441.

[9] E. S. Tollefson, G. L. Boylan, J. Michael J. Kwinn, B. L. Foote, and P. D. West, "Simulation Roadmap for Program Executive Office (PEO) Soldier," Operations Research Center, Department of Systems Engineering, US Military AcademyMay 31, 2004 2004.

[10] T. Ghazal, R. Morley, E. Terry, and R. Kllingaman, "Soldier Tactical Mission System Combat Effectiveness," in *Proceedings of 2003 Systems and Information Engineering Design Symposium*, Charlottesville, VA, 2003.

[11] *FM 21-20 Physical Fitness Training,* D. o. t. A. Headquarters Military, 1992.

[12] P. F. Gorman, "The Future of Tactical Engagement Simulation," in *1991 Summer Computer Simulation Conference*, Baltimore, MD, 1991, pp. 1181-6.

[13] D. Wright, "A Low Cost Dismounted Infantry Trainer Derived from Gaming Technology," Future Modelling and Simulation Challenges, Breda, Netherlands, 2001.

[14] D. R. Lampton, J. V. Cohn, M. R. Endsley, J. Freeman, M. T. Gately, and G. A. Martin, "Measuring Situation Awareness for Dismounted Infantry Squads," Interservice/Industry Training, simulation, and Education Conference (I/ITSEC), Orlando, FL, 2005.

[15] M. T. Gately, S. M. Watts, J. W. Jaxtheimer, and R. J. Pleban, "Dismounted Infantry Decision Skills Assessment in the Virtual Training Environment," United States Army Research Institute, Final program element number 665502, March 2005 2005.

[16] A. Heller and F. Shimamoto, "Simulating Warfare Is No Video Game," *Science and Technology Review,* pp. 4-11, January/February 2000 2000.

[17] F. M. O'Donnell, "Physical Training Programs in Light Infantry Units: Are They Preparing Soldiers for the Rigors of Combat?," M. S. BS, Military Art and Science, U. S. Military Academy, West Point, NY, 1990.

[18] A. J. Thompson, "Physical Fitness in the United States Marine Corps: History, Current Practices, and Implications for mission accomplishment and human performance," Naval Postgraduate School, Naval Postgraduate School, Monterey, California, 2005.

[19] C. Commanders. (2006, January 2006) Company Command, Building Combat-Ready Teams. *ARMY*. 51-54.

[20] D. A. Williamson, G. P. Bathalon, L. D. Sigrist, H. R. Allen, K. E. Friedl, A. J. Young, C. K. Martin, T. M. Stewart, L. Burrell, H. Han, V. S. Hubbard, and D. Ryan, "Military Services Fitness Database: Development of a Computerized Physical Fitness and Weight Management Database for the U.S. Army," *Military Medicine,* vol. 174, pp. 1-8, January 2009 2009.

[21] P. P. Colonel John Antal, Ed., *Attack the Enemy's Strategy Lessons from Counterinsurgency Operations*. Elbit Systems of America, Historical Explorations, 2009, p.^pp. Pages.

[22] M. R. Forman, "Too Fat to Fight - Too Weak to Win, Soldier Fitness in the Future?," School of Advanced Military Studies, Command & General Staf College,1997.

[23] J. J. Knapik, "The Army Physical Fitness Test (APFT); A Review of the Literature," *Military Medicine,* vol. 154, pp. 326-329, 1989.

[24] J. E. Batchelor, "The Applicability of the Army Physical Fitness Test in the Contemporary Operating Environment," US Army Command and General Staff College, Fort Leavenworth KS, 2008.

[25] R. Connaughton, *Modern Warfare, The True Story of Conflict From the Falklands to Afghanistan*: Constable & Robinson Ltd, 2008.

[26] E. A. Harman, D. J. Gutekunst, P. N. Frykman, M. A. Sharp, B. C. Nindl, J. A. Alemany, and R. P. Mello, "Prediction of Simulated Battlefield Physical Performance from Field-Expedient Tests," *Military Medicine,* vol. 173, pp. 36-41, 2008.

[27] Z. Griffiths, S. Sanert, M. Snodgrass, and S. Snook, "Identification of Critical Factor Sets for Close Range Engagements in Urban Operations," Systems and Information Engineering Design Symposium, SIEDS, Charlottesville, VA, 2006.

[28] D. Muscietta and R. Auer. (2005, April 20, 2010). *The Infantry Warrior Simulation(IWARS) Advances Technology*. Available: http://www.rdecom.army.mil/rdemagazine/200510/itf_IWARS.html

[29] B. A. Walters, S. Huber, J. French, and M. J. Barnes, "Using Simulation Models to Analyze the Effects of Crew Size and Crew Fatigue on the Control of Tactical Unmanned Aerial Vehicles (TUAVs)," Army Research LaboratoryJuly 2002 2002.

[30] J. P. Stenbit, I. Linton Wells, and D. S. Alberts, Eds., *Code of Best Practice Experimentation* (Information Age Transformation Series. DoD Command and Control Research Program 2002, p.^pp. Pages.

[31] T. I. Oren, Ed., *Modeling and Simulation: A Comprehensive and Integrative View* (Agent-Directed Simulation and Systems Engineering. Wiley-Berlin, Germany: Wiley Series in Systems Engineering and Management, 2009, p.^pp. Pages.

[32] J. P. Stenbit, I. Linton Wells, and D. S. Alberts, Eds., *NATO COBP Code Of Best Practice for C2 Assessment*. DoD Command and Control Research Program, 2002, p.^pp. Pages.

[33] T. M. Cioppa, T. W. Lucas, and S. M. Sanchez, "Military Applications of Agent-Based Simulations," in *2004 Winter Simulation Conference*, Washington D.C., 2004.

[34] E. J. Bitinas, Z. A. Henscheid, and L. V. Truong, "Pythagoras: A New Agent-based Simulation System," *Technology Review Journal,* pp. 45-58, 2003.

[35] R. M. Hernandez, "Defining a Simulation Capability Hierarchy for the Modeling of a Seabase Enabler," M. S. , Modeling, Virtual Environments, and Simulation Naval Post Graduate School, Monterey, CA, 2010.

[36] E. S. Tollefson, J. Michael J. Kwinn, G. Boylan, B. Foote, and P. West, "A Needs-based Analysis of Analytical, High-Resolution Infantry Simulations,"?

[37] H. T. Minners and D. C. Mackey, "Conceptual Linking of FCS C4ISR Systems Performance to Information Quality and Force Effectiveness Using the CASTFOREM High Resolution Combat Model," in *2006 Winter Simulation Conference*, Monterey, CA, 2006.

[38] J. L. Weeks, L. B. McDonald, and J. Hughes, "Development of Computer-Generated Forces for Air Force Security Forces Distributed Mission Training," Air Force Research Laboratory Warfighter Training Research Division, Mesa, AZ AFRL-HE-AZ-TP-2002-0004, October 2002.

[39] E. S. Tollefson, J. B. Schamburg, and H. M. Yamauchi, "A Methodology for Conducting Composite Behavior Model Verification in a Combat Simulation," in *2006 Winter Simulation Conference*, Monterey, CA, 2006.

[40] J. N. Templeman, L. E. Sibert, R. C. Page, and P. S. Denbrook, "A Novel User Interface Controller for Dismounted Infantry Traininb," *Naval Research Laboratory Review,* pp. 59-65, 2009.

[41] B. W. Knerr, D. R. Lampton, I. Harrison P. Crowell, M. A. Thomas, B. D. Comer, J. R. Grosse, J. H. Centric, K. A. Garfield, G. A. Martin, and D. A. Washburn, "Virtual Environments for Dismounted Soldier Simulation, Training, and Mission Rehearsal: Results of the FY 2001 Culminating Event," U. S. Army Research Institute for the Behavioral and Social Sciences2001.

[42] F. a. N. B. Committee on Military Nutrition Research, Institute of Medicine, *Body Composition and Physical Performance, Applications for the Military Services*: National Academy Press, 1992.

[43] J. J. Knapik, W. Rieger, F. Palkoska, S. V. Camp, and S. Darakjy, "United States Army Physical Readiness Training: Rationale and evaluation of the Physical Training Doctrine," *Journal of Strength and Conditioning Research,* vol. 23, pp. 1353-1362, 2009.

[44] D. C. Myers, D. L. Gebhardt, C. E. Curmp, and E. A. Fleishman, "The Dimensions of Human Physical Performance: Factor Analyses of Srength, Stamina, Flexibility, and Body Composition Measures," *Human Performance,* vol. 6, pp. 309-344, 1993 1993.

[45] B. C. Nindl, B. R. Barnes, J. A. Alemany, P. N. Frykman, R. L. Shippee, and K. E. Friedl, "Physiological consequences of U.S. Army Ranger Training," *Medicine and Science in Sports Exercise,* vol. 39, pp. 1380-1387, 2007.

[46] R. P. Mello, M. M. Murphy, and J. A. Vogel, "Relationship Between a Two Mile Run for Time and Maximal Oxygen Uptake," *Journal of Applied Sport Science Research,* vol. 2, pp. 9-12, 1988.

[47] P. Schenk, A. Klipstein, S. Spillmann, J. Stroyer, and T. Laubli, "The Role of Back Muscle Endurance, Maximum Force, Balance and Trunk Rotation Control Regarding Lifting Capacity.," *Eur J Appl Physiology,* vol. 96, pp. 146-156, 2006 2006.

[48] R. R. K. Yu. S.Vanyushin, "Physical Work capacity of Athletes with Different Types of Adaptation of the Cardiorespiratory System," *Human Physiology,* vol. 34, pp. 771-773, 2008 2008.

[49] T. W. Calvert and E. W. Banister, "A systems model of the human response to training," in *Proceedings of the annual Conference on Engineering in Medicine and Biology*, 1973, p. 189.

[50] ACSM, "ACSM Position Stand: The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardio respiratory and Muscular Fitness, and Flexibility in Healthy Adults," *Medicine & Science in Sports & Exercise*, vol. 30, pp. 975-991, June 1998 1998.

[51] A. Kozma, M. J. Stones, and T. E. Hannah, "Age, Activity, and Physical Performance: An evaluation of Performance Models," *Psychology and Aging*, vol. 6, pp. 43-49, 1991.

[52] D. Gottesman, "The New (OLD) Fit test," *Woman's Day*, vol. 71, p. 88, October 7, 2008 2008.

[53] H. P. Busso T. K Hakkinen, C. Carsso, J. R. Lacour, P. V. Komi, H. Kauhanan, "A systems model of training responses and its relsationship to mornonal responses in elite weight lefiters," *European Journal of Applied Physiology and Occupational Physiology*, vol. 61, pp. 48-54, 1990 1990.

[54] A. C. Clement DB, Taunton C, Taunton JE, Ridley D, Banister EW, "The sprts scientist's role in identification of performance critera for dista," *Canadian journal of applied sprt sciences* vol. 4, pp. 143-148, June 1979 1979.

[55] R. Silvestre, W. J. Kraemer, C. West, D. A. Judelson, B. A. Spiering, J. L. Vingren, D. L. Hatfield, J. M. Andersion, and C. M. Maresh, "Body Composition and Physical Performance During a National Collegiate athletic Association Division I Men's Soccer Season," *Journal of Strength and Conditioning Research*, vol. 20, pp. 962-970, 2006.

[56] B. T. Vescovi JD, Murray TM, "Positional Charactersitcs of Physical Performance in Division I College Female Soccer Players," *Journal Of Sports Medicine and Physical Fitness*, vol. 46, pp. 221-226, 2006.

[57] E. M. Olson, "The Marine Corps Physical Fitness Test: The Need to Replace it with a Combat Fitness Test," United States Marine Corps, Command and Staff College, Marine Corps Combat Development CommandFebruary 19, 2008 2008.

[58] P. A. Bishop, L. R. Fielitz, T. A. Crowder, C. L. Anderson, J. H. Smith, and K. R. Derrick, "Physiological determinants of Performance on an Indoor Military Obstacle Course Test," *Military Medicine*, vol. 164, pp. 891-896, 1999.

[59] T. D. Wright, "Combat Conditioning: The Need for Stronger Marines," United States Marine Corps, Command and Staff CollegeFebruary 18, 2008 2008.

[60] L. R. F. P.A. Bishop, T. A. Crowder, C.L. Anderson, J. H. Smith, K. R. Derrick, "Physiological determinants of Performance on an Indoor Military Obstacle Course Test," *Military Medicine*, vol. 164, pp. 891-896, 1999.

[61] T. W. Calvert, E. W. Banister, and M. V. Savage, "The Prescription of Exercise Therapy with Computer Models," in *Canadian Medical and Biological engineering Conference*, Montreal, Canada, 1976, pp. 18a-18b.

[62] R. H. Morton, J. R. Fitz-Clarke, and E. Q. Banister, "Modeling Human Performance in Running," *J. Applied Physiology*, vol. 69, pp. 1171-1177, July-Sept 1990 1990.

[63] P. C. Zarkadas, J. B. Carter, and E. W. Banister, "Modeling the Effect of Taper on Perfomance, Maximal Oxygen Uptake, and the Anaerobic Threshold in Endurance," *Modeling and Control of Ventilation*, pp. 179-86, 1995 1995.

[64] E. W. Banister, J. B. Carter, and P. C. Zarkadas, "Training Theory and Taper: Validation in Triathlon Athletes," *European Journal Applied Physiology*, vol. 79, pp. 182-191, 1999 1999.

[65] M. R. Fitz-Clarke JR, Banister EW, "Optimizing athletic performance by influence curves," *J Applied Physiology,* vol. 71, pp. 1151-1158, 1991.

[66] T. W. Calvert, "A Systems Model of the Effects of Training on Physical Performance," *IEE Transactions on Systems, Man and Cybernetics,* vol. SMC-6, pp. 94-102, Feb 1976 1976.

[67] M. Avalos, P. Hellard, and J.-C. Chatard, "Modeling the Training-Performance Relationship Using a Mixed Model in Elite Swimmers," *Medicine & Science in Sports & Exercise,* pp. 838-846, December 2002 2003.

[68] P. Hellard, M. Avalos, L. Lacoste, F. Barale, J.-C. Chatard, and G. P. Millet, "Assessing the Limitations of the Banister Model in Monitoring Training," *Journal of Sports Sciences,* vol. 24, pp. 509-520, May 2006 2006.

[69] M. Kumar, R. Stoll, and N. Stoll, "Robust Adaptive Fuzzy Identification of Time-varying Processes with Uncertain Data. Handling Uncertainties in the Physical Fitness Fuzzy Approximation with Real World Medical Data: An Application," *Fuzzy Optimization and Decision makeing,* vol. 2, pp. 243-259, September 2003 2003.

[70] JurgenEdelmann-Nusser, A. Hohmann, and BerndHenneberg, "Modeling and Prediction of Competitive Performance in Swimming Upon Neural Networks," *Europen Journal of Sport Science,* vol. 2, pp. 1-11, 2002.

[71] J. Perl, P. Dausher, and M. Hawlitzky, "On the Long Term Behavior of the Performance-Potential Metamodel PerPot," *International Journal of Computer Science in Sport,* 2003 2003.

[72] J. Perl, "Modelling Dynamic Systems - Basic Aspects and application to Performance Analysis. ," *International Journal of Computer Science in Sport,* vol. 3, pp. 19-28, 2004 2004.

[73] W. C. M. v. Beers and J. P. C. Kleijnen, "Kriging Interpolation in Simulation: A Survey," Proceedings of the 2004 Winter Simulation Conference, Washington, D. C., 2004.

[74] R. Laughery, "Using Discrete-Event Simulation to Model Human Performance in Complex systems," 1999 Winter simulation Conference, 1999.

[75] G. V. Kondraske, "Performance Theory: Implications for Performance Measurement, Task Analysis, and Performance Prediction," 22nd Annual EMBS International C onference, Chicago, IL, 2000.

[76] G. V. Kondraske, "Experimental evaluation of an elemental resource model," IEE Engineering in Medicine & Biology Society 10th annual conference, 1988.

[77] A. G. Williams and M. Wilkinson, "Simple Anthropometric and Physical Performance tests to Predict Maximal Box-Lifting Ability," *Journal of Strength and Conditioning Research,* vol. 21, pp. 638-642, 2007.

[78] A. C. Clement DB, Taunton C, Taunton JE, Ridley D, Banister EW, "The sprts scientist's role in identification of performance critera for dista," *Canadian journal of applied sprt sciences,* vol. 4, pp. 143-148, June 1979 1979.

[79] Z. N. Sekulic D, Markovic G, "Non Linear relationships between anthropometric and motor-endurance variables," *Collegium antropologicum,* vol. 29, pp. 723-730, December 2005 2005.

[80] P. N. Frykman, E. A. Harman, and C. E. Pandorf, "Correlates of Obstacle Course Performance Among Female Soldiers Carrying Two Different Loads," ADP010994, 2000.

[81] J. Ross R. Vickers, "Generalizability Test of a Physical Ability-job Performance Model," Naval Health Research Center1996.

[82] I. Park and R. W. Schutz, "An Introduction to Latent Growth Models: Analysis of Repeated Measures Physical Performance Data," *Research Quarterly for Exercise and Sport,* vol. 76, pp. 176-192, June 2005 2005.

[83] H. D. o. t. Army, *Combat Skills of the Soldier*, 1984.

[84] H. D. o. t. Army, *The Infantry Rifle Platoon and Squad*: Headquarters Department of the Army, 2007.

[85] C. E. Larsen, *Light Infantry Tactics For Small Teams*. Bloomington Indiana: Author House 3/16/05, 2005.

[86] M. A. Ito, M. A. Sharp, R. F. Johnson, D. J. Merullo, and R. P. Mello, "Rifle Shooting Accuracy During Exercise Recovery From Fatiguing Exercise," 2000 ASC Proceedings, 22 Army Science Conference, 11-13 December 2000, Baltimore MD, 2000.

[87] C. R. S. Rachel K Evans, Max A Ito, Robert P. Mello, "Upper Body Fatiguing Exercise and Shooting Performance," *Military Medicine,* vol. 168, pp. 451-456, 2003.

[88] M. Barnekow-Bergkvist, U. Aasa, K.-A. Angquist, and H. Johansson, "Prediction of Development of Fatigue During a Simulated Ambulance Work Task from Physical Performance Tests," *Ergonomics,* vol. 47, pp. 1238-1250, September 2004 2004.

[89] R. A. Kady and J. Davis, "The Impact of Exit Route Designs on Evacuation Time for Crawling Occupants," *Journal of Fire Sciences,* vol. 27, pp. 481-493, June 11, 2009 2009.

[90] E. M. Blount, A. Tolk, and S. Ringleb, "Physical Fitness for Tactical Success," VMASC Student Capstone Conference, Suffolk, VA, 2010.

[91] E. Blount, S. Ringleb, A. Tolk, M. Bailey, and J. Onate, "Incorporation of Physical Fitness in a Tactical Infantry Simulation," Huntsville Simulation Conference, Huntsville, Alabama, 2010.

[92] T. F. Devil, "The Modern Warrior's Combat Load," U. S. Army Center for Army Lessons Learned2003.

[93] D. K. Pace, "Modeling and Simulation Verification and Validation Challenges," *Johns Hopkings APL Technical Digest,* vol. 25, pp. 163-172, 2004 2004.

[94] R. G. Sargent, "Verification and Validation of Simulation Models," Proceedings of the 2008 Winter Simulation Conference, Miami, FL, 2008.

[95] R. B. Whitner and O. Balci, "Guidelines for Selecting and Using Simulation Model Verification Techniques," in *Proceeedings of the 1989 WInter Simulation Conference,* 1989, pp. 559-568.

[96] S. Y. Harmon and S. M. Youngblood, "A Proposed Model for Simulation Validation Process Maturity," *JDMS: The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology,* vol. 2, October 2005 2005.

[97] O. Balci, "How to Assess the Acceptability and Credibility of Simulation results," Proceedings of the 1989 Winter Simulation Conference, 1989.

[98] M. Ishihara, K. Imanaka, and S. Mori, "Lateralized Effects of Target Location on Reaction Times When Preparing for Manual Aiming at a Visual Target," *Human Movement Science,* vol. 21, pp. 563-582, 2002.

[99] M. R. R. Khan and S. A. Naqvi, "Simulation Study of Reaction Times at varying Visual Angles," *Computers in Engng,* vol. 28, pp. 467-472, 1994.

[100] R. Zajdel and D. Nowak, "Simple and Complex Reaction Time Measurement. A Preliminary Evaluation of New Approach and Diagnostic Tool," *Computers in Biology and Medicine,* vol. 37, pp. 1724-1730, 2007.

[101] S. Thorpe, D. Fize, and C. Marlot, "Speed of Processing in the Human Visual System," *Nature,* vol. 381, pp. 520-522, 1996.

[102] B. Lewinski. (2002, November/December 2002) Biomechanics of Lethal Force Encounters - Officer Movements. *The Police Marksman*. 19-23.

[103] T. J. Aveni, "Officer-Involved Shootings:What We Didn't Know Has Hurt Us," The Police Policy Studies Council2003 2003.

[104] F. C. Pampel, *Logistic Regression: A Primer*. Thousand Oaks, CA: Sage Publications, 2000.

[105] F. Y. Hsieh, D. A. Bloch, and M. D. Larsen, "A simple Method of sample Size Calculation for Linear and Logistic Regression," *Statistics in Medicine*, vol. 17, pp. 1623-1634, 1998 1998.

[106] W. G. Hopkins. (2002, March 15, 2011). *A New View of Statistics: A Scale of Magnitutdes for Effect*. Available: http://sportsci.org/resource/stats/

[107] W. Mendenhall and T. Sincich, *Statistics for Engineering and the Sciences*, Fourth ed. Upper Saddle River, NJ: Prentice Hall, 1994.

[108] R. F. Wallace, D. Kriebel, L. Punnett, D. H. Wegman, C. B. Wenger, J. W. Gardner, and J. A. Kark, "Risk Factors for Recruit Exertional heat Illness by Gender and Training Period," *Aviation, Space, and Environmental Medicine*, vol. 77, pp. 415-421, April 2006 2006.

[109] D. Bellavia and J. R. Bruning, *House to House A Soldier's Memoir*. New York: Free Press, 2007.

[110] U. S. M. C. C. Chief of Naval Operations; Commandant, United States Coast Guard, *Universal Naval Task List (UNTL) version 3.0*, 2007.

[111] W. Joint Staff, D.C. 20318, *Universal Joint Task List (UJTL)* vol. CJCSM 3500.04C, 2002.

[112] D. o. t. A. Headquarters, *The Army Universal Task List (FM 7-15)*, 2009.

[113] Wikipedia. (2010, March 10, 2011). *Rate of Fire*. Available: http://en.wikipedia.org/wiki/Rate_of_fire

[114] K. Felts. (2006, March 20, 2011). *www.survivalistsboards.com*. Available: http://www.survivalistboards.com/showthread.php?t=81379

[115] E. Forces. (2011, 3/10/2011). *Enemy Forces*. Available: http://www.enemyforces.net/firearms.htm

[116] D. C. Isby, *Leave No Man Behind Liberation and Capture Missions*, 2005 ed. Great Britain: Weidenfeld & Nicolson, 2005.

[117] R. R. Lawrence, *The Mammoth Book of Special OPS*. Philadelphia, PA: Running Press Book Publishers, 2006.

[118] R. W. Logan, C. K. Nitta, and S. K. Chidesta, "Risk reduction as the Product of Model Assessed Reliability, Confidence, and Consequence," *JDMS: The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology*, vol. 2, October 2005 2005.

[119] A. S. Tyson, "Soldier Earns Silver Star for Her Role in Defeating Ambush," in *Washington Post*, ed. Washington D.C., 2005.

[120] U. Sgt Sara Wood. (2005, June 16, 2005) Woman Soldier Receives Silver Star for Valor in Iraq. *American Forces Press Service, U. S. Department of Defense*.

[121] L. A. Hester, T. Nein, and J. Mike. (2011, March 11, 2011). *Consipicuous Courage Under Fire, Part 4*. Available: http://www.usa-patriotism.com/videos/hp/heroes_stories.htm , http://www.youtube.com/watch?v=0GzhEte-7rg

[122] Wikipedia. (2011, March 11). *Leigh Ann Hester*. Available: http://en.wikipedia.org/wiki/Leigh_Ann_Hester

Appendices

Appendix A - IRB#09-105 – Pilot Study

A.1 Internal Review Board Application and Exercise Questionnaire

IRB Identifier:

APPENDIX C
OLD DOMINION UNIVERSITY
HUMAN SUBJECT RESEARCH REVIEW APPLICATION FORM

Responsible Project Investigator (RPI)		
***Responsible Project Investigator:* The RPI must be a member of ODU faculty or staff who will serve as the project supervisor and be held accountable for all aspects of the project. Students cannot be listed as RPIs.**		
First Name: Stacie	**Middle Initial: I**	**Last Name: Ringleb**
Telephone: (757) 683-5934	**Fax Number: 683-5344**	**E-mail: sringleb@odu.edu**
Office Address: Mechanical Engineering, Kafuman Hall 238 C		
City: Norfolk	**State: VA**	**Zip: 23529**
Department: Mechanical Engineering	**College: Batten College of Engineering and Technology**	
Complete Title of Research Project: Effect of Physical Fitness on Military Performance	**Code Name (one word): Performance**	
Investigators If more investigators exist than lines provide, please attach a separate list.		
Investigator(s): Individuals who are directly responsible for any of the following: the project's design, implementation, consent process, data collection, and/or data analysis.		
First Name: Elaine	**Middle Initial: M**	**Last Name: Blount**
Telephone: 898-3259	**Fax Number:**	**Email: eblou002@odu.edu**
Office Address: VMASC, 1030 University Blvd		
City: Suffolk	**State: VA**	**Zip: 23435**
Department: *Modeling and Simulation*	**College: Batten *College of Engineering and Technology***	
Affiliation: __Faculty _X_Graduate Student __ Undergraduate Student __Staff __Other________________		
First Name: James	**Middle Initial:**	**Last Name: Onate**
Telephone: 683-4351	**Fax Number:**	**Email: jonate@odu.edu**
Office Address: Student Recreation Center		
City:	**State:**	**Zip:**
Department: Human Movement Sciences	**College: Education**	
Affiliation: _X_Faculty __Graduate Student __ Undergraduate Student __Staff __Other________________		
List all information for additional investigators on attachment and check here: _X_		

IRB Identifier:
To Be Assigned by the IRB

First Name: David	Middle Initial: P	Last Name: Swain
Telephone: 683-6028	Fax Number: 683-4270	Email: dswain@odu.edu
Office Address: Student Recreation Center 2026		
City: Norfolk	State: VA	Zip: 23529
Department: Human Movement Sciences	College: Education	
Affiliation: _X_Faculty __Graduate Student __Undergraduate Student __Staff __Other________________		
First Name: Marlene	Middle Initial:	Last Name: DeMaio
Telephone:	Fax Number:	Email:
Office Address:		
City:	State:	Zip:
Department: Portsmouth Naval Medical Center	College:	
Affiliation: __Faculty __Graduate Student __Undergraduate Student __Staff _X_Other_Navy physician____________		
First Name: Courtney	Middle Initial:	Last Name: Butowicz
Telephone:	Fax Number:	Email:
Office Address:		
City:	State:	Zip:
Department: HMS	College: Education	
Affiliation: __Faculty _X_Graduate Student __Undergraduate Student __Staff __Other________________		
First Name: Corbet	Middle Initial:	Last Name: Weller
Telephone:	Fax Number:	Email:
Office Address:		
City:	State:	Zip:
Department: HMS	College: Education	
Affiliation: __Faculty __Graduate Student _X_ Undergraduate Student __Staff __Other________________		

IRB Identifier: ____
(To Be Assigned by the IRB)

First Name: Christopher	Middle Initial:	Last Name: Vause
Telephone:	Fax Number:	Email:
Office Address:		
City:	State:	Zip:
Department: HMS	College: Education	
Affiliation: __Faculty __Graduate Student _X_ Undergraduate Student __Staff __Other________		

Type of Research

1. This study is being conducted as part of (check all that apply):

_XFaculty Research
_XDoctoral Dissertation
__Masters Thesis
__Non-Thesis Graduate Student Research
__Honors or Individual Problems Project
__Other__________

Funding

2. How is the research project funded?

__Research is **not funded (go to 3)**
_XResearch is **funded (go to 2a)**
__**Funding decision is pending** (funding decision has not been made) **(go to 2a)**

2a. What is the type of funding source? (Check all that apply)

_XFederal Grant or Contract
Agency Proposal Number Office of Naval Research: ONR W911QY0710002
Grant Start Date (MM/DD/YY) 07/01/07 Grant End Date (MM/DD/YY) 12/31/09
__State or Municipal Grant or Contract
__Private Foundation
__Corporate contract
__Other (specify):______________

2b. Who is the point of contact at the funding source?
Name: Roy Stripling
Mailing Address:
Office of Naval Research
One Liberty Center
875 North Randolph Street - Suite 1425
Arlington, VA 2203-1995
703-696-0942
Fax: 703-696-0066
roy.stripling@navy.mil

Research Dates

3a. Date you wish to start research (MM/DD/YY): ____09_/__17__/____09
3b. Date you plan to end research (MM/DD/YY): ____09_/__17__/___10 (End date for data collection and analysis)
Note: Protocols are approved for a maximum of 1 year. If a proposed project is intended to last beyond the approval period, continuing review and reapproval are necessary.

IRB Identifier: ___________
(To Be Assigned by the IRB)

Research Location
4. Where will the experiment be conducted? (Check all that apply) _X_ On Campus (Building and Room Number) Student Recreation Center 2003 (Human Performance Laboratory) __ Off-Campus (Street Address)
5. Has this project been reviewed by any other committee (university, governmental, private sector) for the protection of human research subjects? __Yes _XNo **(If no, go to 6)** **5a. If yes, is ODU conducting the "primary" review?** __Yes __No **(If no, go to 5b)** **5b. Who is conducting the primary review?**
Study Purpose

IRB Identifier: To Be Assigned by the IRB

6. Describe the rationale for the research project.

The various military service branches currently perform physical fitness and assessment tests on a regular basis as shown in the table below: (http://www.military.com/military-fitness/)

Event	Air Force	Army	Coast Guard	Marines	Navy
Push-ups	1 minute	2 minutes	1 minute		2 minutes
Sit-Ups	1 minute	2 minutes	1 minute	2 minutes	2 minutes
Timed 2 Mile Run		X			
Timed 1.5 Mile Run	X		X		X
Sit & Reach			Distance		
Tread water 5 minutes			X		
Jump off 5 m platform, swim 100 meters					
Timed 3.0 Mile run				X	
"Dead Hang" Pull-ups				Number Until Failure (Males)	
"Flex Arm Hang"				Time Until Failure (Females)	
Body Composition or Weight	X	X	X	X	X

From the Field manuals published by the army, the most important tasks for battle are as follows:

1) **Shooting Ability**
   a. *FM3-21.8 The Infantry Rifle Platoon and Squad*, 1-45, 1-46, 2-38
   b. *FM21-75 Combat Skills of the Soldier*, pages G-2, 1-2
2) **Low Crawl**
   a. *FM3-21.8 The Infantry Rifle Platoon and Squad*, 1-47, 3-65, 3-83, 7-190, 7-208, 7-224, 7-228, F-68
   b. *FM21-75 Combat Skills of the Soldier* 2-24, 2-30, 3-2, 3-3, 3-4, 3-10
3) **High Crawl**
   a. FM3-21.8 The Infantry Rifle Platoon and Squad paragraphs 1-47, 3-65, 3-83, 7-190, 7-208, 7-224, 7-228, F-68
   b. FM21-75 Combat Skills of the Soldier 2-24, 2-30, 3-2, 3-3, 3-4, 3-10
4) **3-5 second rush**
   a. FM3-21.8 The Infantry Rifle Platoon and Squad paragraphs 1-47, 3-65, 3-83, 7-190, 7-220, 7-224, 7-228
   b. FM21-75 Combat Skills of the Soldier 3-2, 3-3, 3-4, 3-10,

The Marines also recognize these tasks as among the most important as they have created a new combat fitness test which incorporates crawling and short bursts of running similar to the 3-5 second rush.(http://www.military.com/military-report/marine-fitness-test-changes)

In addition to the above skills, the ability to **assault a building** properly is also required, see FM 3-21.8 *The Infantry Rifle Platoon and Squad*, paragraphs 7-184 through 7-207. Ascending stairways is a dangerous part of clearing a building as it creates a fatal funnel. A soldier could find themselves in a potentially lethal situation if he/she cannot keep pace with fellow soldiers. Thus, a fifth element is being added to this study to determine the speed of movement through a stairwell.

The goal of this study is to collect data relevant to physical fitness assessment performed by the various military organizations, and the ability to perform the low crawl, high crawl, 3-5 second rush, shoot targets and travel through stairways. The data from the four tasks will be compared and analyzed with respect to the performance on the physical assessment tasks to assess correlations. The data from the battlefield skills will be used for an agent based simulation that will look at tactical scenario performance and its relationship to the ability to perform the battlefield tasks. This study hopes to assess the liability of unfit soldiers and determine the level of fitness needed for successful task performance on the battlefield.

IRB Identifier:

Subjects

7. What will be the maximum number of subjects in the study? _____100___

7a. Indicate the approximate number of: Males ______75_____ Females___25_____

7b. What is the age of subjects? (Check all that apply)

__Children (1-17 years old)
_X_Adults (18-65 years old)
__Elderly (64-years and older)

7c. Will students be enrolled in the study? (Check all that apply)

_X__Undergraduate students(dept)* _campus-wide__
___Advanced students (dept)campus-wide

If students are under 18 years old, parental consent must be obtained

7d. Provide rationale for the choice of subjects. Enumerate any additional defining characteristics, including age, of the subject population. (e.g., symptomatology, history, socio-economic status).

Target participants will be primarily male and female ROTC students ranging in age from 18-44 years as well as healthy individuals who. More men will be recruited to reflect the difference in the gender distribution in the military. Subjects shall be at low risk for cardiovascular discease according to ACSM's Guidelines ofr Exercise Testing and Prescription, 8th edition. They will not have any signs or symptoms of cardiovascular discease, and will not have any known cardiovascular, pulmonary or metabolic disease and will not have more than one major coronary heart disease risk factor. Exclusionary criteria will include any subject classified at moderate or high risk for cardiovascular disease according to the ACSM, anyone taking medications that influence heart rate, and anyone who is pregnant. A screening questionnaire is attached.

Vulnerable Subjects

8. Are research subjects being used whose ability to give informed voluntary consent may be in question? (e.g., children, persons with AIDS, mentally disabled, psychiatric patients, prisoners.)

__Yes (If yes, explain the procedures to be employed to enroll them and to ensure their protection).
_X_No

8b. What type of vulnerable subjects are being enrolled? (check all that apply)

__Critically Ill Patients
__Mentally Disabled or Cognitively Impaired Individuals
__Prisoners
__Physically Handicapped
__Pregnant Women
__Children
__Other________________

Recruitment

9. How will participants be recruited? (Please submit a copy of the sign-up sheet, newspaper advertisement, or any other protocol or procedure which will be used to recruit subjects.)

__Internet
__Newspaper/radio/television advertising
_X_Posters/brochures/letters
_X_Other____

Comments:

Subjects will be primarily recruited by making announcements through the ROTC program. If required number of subjects are not recruited, local military groups or gyms will be asked for help with recruitment.

Inclusion and Exclusion Criteria

IRB Identifier:
To Be Assigned by the IRB

10. Are subjects equitably chosen for participation in the study? (no one group is excluded without justification)

_X_Yes
__No (If no, specify criteria and justify in detail below.)

10a. Does the study require special evaluation and screening of potential subjects to determine their *appropriateness for inclusion in the study?*

_X_Yes (If yes, briefly elaborate on the screening process and attach the screening questionnaire.)
__No

A health screening questionnaire will be used to evaluate potential subjects. Anyone not meeting the age requirement or having knowledge of a cardiopulmonary or metabolic disease, or knowledge of a symptom of such diseases, or knowledge of two or more heart disease risk factors will be excluded. Potential subjects must also not be taking any blood pressure medications and female subject must believe they are not pregnant. If participants have had a knee or back injury, they *must be pain free for six months before participation and if they have had surgery, they must be at least 1 year post* surgery or have a doctors note stating that they can resume activity at the pre-surgery level. Finally, participants must exercise vigorously for 75 minutes per week or 150 minutes per week of moderate exercise to ensure the proper fitness level.

Experimental Procedures

IRB Identifier: ____________
To Be Assigned by the IRB

11. Describe the experimental procedures that will be followed. (Include a succinct, but comprehensive statement of the methodology relating to the human subjects. You are encouraged to include a discussion of statistical procedures used to determine the sample size.)

An informed consent document will be reviewed and signed by those agreeing to participate. Participating subjects will be required to wear adequate running shoes. The subject will have his/her age, height, and mass measured on a balance scale, and a bodpod and skin fold test with calipers will be used to measure body fat percentage using three sites (chest, abdomen, and thigh for males; triceps, suprailiac. And thigh for females.

The subjects will put on a vest and helmet with a combined mass of 10kg. Subjects will perform a shooting task using an indoor Simulated Marksmanship Trainer or other simulated shooting target system. The subject will perform a low crawl and high crawl with the height and velocity of the crawl measured using a visual system while carrying a realistic simulation of an M16. The subject will perform a 3-5 second rush originating from and ending in prone position while carrying a realistic simulation of an M16. The subject will ascend a flight of stairs for time to complete. The subject will rest until comfortable, and then descend a flight of stairs for time. Each of these tasks will be performed 3 times to get an average performance. Ample water will be available during completion of these battle tasks. After completing the above, the subject will take off the helmet, vest, and relinquish the simulated gun. The subject will then be asked to perform a marine combat fitness test which consists of three events: 1) an 880 yard run, ammo can lifts (lift 30 lb weight from the ground over head as many times as possible in two minutes), and maneuver under fire portion which will include a combat crawl, ammunition resupply, body drag, casualty carry, and a grenade throw (22 meters to target circle, grenade weighs about from 14 to 32 oz, http://www.armystudyguide.com/content/army_board_study_guide_topics/hand_grenades/hand-grenades-study-guide.shtml) Lap times will be taken when possible. For more information on Marine Combat Fitness test see http://www.military.com/military-fitness/marine-corps-fitness-requirements/marine-corps-combat-fitness-test and http://www.tecom.usmc.mil/cft/cft.htm .

The subject will be asked to return on a separate day to complete tasks from military fitness tests by testing the number of push-ups and curl-ups he/she can perform in two minutes, perform a sit & reach as a flexibility measurement and will perform either "dead hang" pull-ups or the flex arm hang. As a measurement of explosive power, the subject will perform a vertical jump and a horizontal broad jump. and finally the subject will run 3 miles for time. Ample water will be available throughout testing. After completion of these tasks, the subject will have completed this study.

11a. Will any aversive or painful procedures be employed (e.g., shock, the threat of shock or punishment, experimentally induced stress?)

__Yes *(If yes, specify and justify in detail below.)*

X No

11b. Will the deliberate deception of research participants be involved as part of the experimental procedure?

__Yes (If yes, explain the nature of the deception, why it is necessary, any possible risks that may result from the deception, and the nature of the debriefing with specific reference to the deception.)

X No

Attach copies of the following items:

___Research Protocol(s)
___Questionnaire
___Copies of any instructions or debriefings given
___If the research is part of a research proposal submitted for federal, state or external funding, submit a copy of the FULL proposal

Compensation

IRB Identifier: ____________
To Be Assigned by the IRB

12. How much time will be required of each subject?

The time required of each subject will be approximately 2-3 hours over two separate days.

12a. Will research subjects receive course credit for participating in the study?
__Yes (If yes, please explain in comments section.)
_X_No
Comments:

12b. Are there any other forms of compensation that may be used? (e.g. Money)
__Yes (If yes, please explain in comments section.)
_X_No
Comments:

12c. Are there any penalties for subjects who do not show up for a research session?
__Yes (If yes, please explain in comments section.)
_X_No
Comments:

Informed Consent

13. Do you intend to obtain informed consent from subjects?
_X_Yes (please answer question 13a)
__No (please complete Appendix F: Request for Waiver of Consent Form)

13a. Describe the procedures that will be used to obtain Informed Consent and attach the Informed Consent Document (follow the guidelines for preparation of the University Informed Consent Form).
Note. Subjects MUST be given a description of the procedures and rationale for the study to the extent possible. The benefits and ANY risks associated with participating in the study MUST be enumerated. The subjects MUST be informed of their right to terminate the experiment at any time. If there is no risk associated with the study and participants' signature on the informed consent sheet is the only identifying information about the name of the subject, then the subjects' signature may not be necessary.

Individuals who are interested in the study and pass the screening questionnaire will be scheduled for testing. The screening questionnaire will be formally reviewed and the subject will have the procedures and risks of the study verbally explained to them and given opportunity to read the informed consent document and ask questions before deciding to consent to the study. If the subject consents to the study, they will be asked to sign and date the form.

Risks

IRB Identifier: ____________
To Be Assigned by the IRB

14. What are potential risks of the research? (Check all that apply)

X physical harm
__psychological harm
__Release of confidential information
__Other ______________________________

14a. *Describe any potential risks to subjects for the activities proposed and describe the steps that will be taken to minimize the risks.* Include any risks to the subject's physical well being, privacy, dignity, emotions, employability, and criminal and legal status. A detailed, comparative statement of the risk (harm or likelihood) must also be described in the consent form.

Subjects could experience muscle or joint injury, inappropriate changes in blood pressure or heart rhythm, a heart attack, stroke or death during testing. The risk of these events is extremely low in individuals who are physically active and apparently healthy, as are these subjects. Phone access to EMS will be maintained during all testing.

The confidentiality of collected data will be protected by keeping hard copies in locked cabinets and electronic data in secured computer work stations. Only aggregate data will be used in research reports.

Please attach the following (if you have developed them)
__The script by the experimenter to disclose potential harm and likelihood (risk) prior to the subject's choice to participate.

Benefits

15. Assess the potential benefits that may accrue to the individual subject as well as to others as a result of the proposed study. Do the potential benefits justify the possible risks involved? Although you may mention general benefits to society, *such speculative benefits should not be presented to a subject as a direct benefit for informed consent.*

The subjects will be able to take a practice physical fitness test to help determine readiness for military physical test already necessary at least every year. The subjects will learn the height and speed of their crawl and speed of their rush. The knowledge could help them within a battlefield situation The risks of injury to the subjects are low, and the benefits for the subjects outweigh the risks.

Protection of Anonymity

16. Describe in detail the procedures for protecting the anonymity (meaning that no one will ever be able to know the names) of the research subjects. If anonymity is impossible, then describe in detail the procedures for safeguarding data and confidential records. These procedures relate to how well you reduce the risk that a subject may be exposed or associated with the data.

Subjects will not be anonymous. The confidentiality of the collected data will be protected by keeping hard copies in locked file cabinets and electronic data in secured computer work stations. Only aggregate data will be used in research reports.

Drugs or Devices

17. Will any drugs, devices, or chemical biological agents be used with the subjects?

__Yes (If yes, please attach Appendix G: Drugs, Agents, and Devices Form)
X No

Biological Materials

18. Will this research involve the collection, analysis, or banking of human biological materials (cells, tissues, fluids, DNA?)

__Yes (If yes, please attach Appendix H: Biological Materials Form)
X No

Training

IRB Identifier: ____
(To Be Assigned by the IRB)

19. Briefly explain the nature of the training and supervision of anyone who is involved in the actual data collection, research design, or in conducting the research. This information should be sufficient for the IRB to determine that the RPI and investigators possess the necessary skills or qualifications to conduct the study. Dr. Ringleb is an expert in biomechanics, mechanical engineering and modeling and simulation. Dr. Swain has extensive experience in performing physiological testing and is a military veteran with shooting experience. Dr. Onate has extensive experience in performing biomechanical testing. Dr. De Maio is a physician with expertise in military medicine. Elaine has a BS and MS in computer science and MBA. She taught aerobics from 1995-1999. Elaine will be CPR certified and first aid trained. Student workers who may assist with testing will be trained by by Drs' Swain and Onate, and will be identified to the IRB prior to testing.
Human Subjects and HIPPA Training
20. A. The RPI must document completion of NIH Training. (Attach a copy of the RPI's NIH Certificate for Human Participants Protections Education for Research Teams.) Date RPI completed NIH Training: ____ B. RPI's who propose studies with patient populations must document HIPPA training by accessing the NIH booklet entitled "Protecting Personal Health Information in Research: Understanding the HIPPA Privacy Rule" at: http://privacyruleandresearch.nih.gov/pr_02.asp. and must submit an attachment to the review application stating that the material has been read and will be adhered to in the proposed research. The attachment must include the date the material was read, which must be within the 12 months prior to the application. (If you are submitting this attachment with your application the RPI must initial here: ____
PLEASE NOTE:
• You may begin research when the University Human Subjects Review Board gives you final WRITTEN notice of its approval. • You MUST inform the committee of ANY adverse event, changes in the method, personnel, funding, or procedure. • At any time the committee reserves the right to re-review a research project, to request additional information, to monitor the research for compliance, to inspect the data and consent forms, to interview subjects that have participated in the research, and if necessary to terminate a research investigation.
Responsible Project Investigator (Must be original signature) Date

EXERCISE TEST SCREENING QUESTIONNAIRE

Read the questions to potential subjects and interpret the responses. Do not have the person fill out the questionnaire on his/her own.

Name ____________ Sex ____ Date ______

Phone ____________ email ____________

I. Risk Factors

___1. Do you have a family history of heart disease? [heart attack, bypass surgery, angioplasty or sudden death prior to the age of 55 (father or brother) or 65 (mother or sister)]

___2. Have you smoked cigarettes in the past 6 months?

___3. Do you know if your blood pressure is typically 140/90 or more? Do you take blood pressure medication?

___4. Do you know if your LDL cholesterol is more than 130, or if your HDL cholesterol is less than 40? If you don't

IRB Identifier: ________
To Be Assigned by the IRB

know your LDL, do you know if you total cholesterol is more than 200?

___5. Do you know if your fasting glucose is more than 100?
___6. What is your height and weight? [determine if BMI is > 30]
___7. Over the past three months, how much physical activity have you typically gotten each week? Consider moderate intensity activities, such as walking, slow bicycling, and gardening, and also consider vigorous intensity activities such as jogging, fast bicycling, and competitive sports. [physically active is at least 150 min/wk of moderate intensity, or at least 75 min/wk of vigorous, or a combination of the two, in which time spent in vigorous activities is doubled and added to time spent in moderate activities; less than this is considered sedentary, and a risk factor]

II. Symptoms

___1. Do you ever have pain or discomfort in your chest or surrounding areas? (i.e. ischemia)
___2. Do you ever feel faint or dizzy? (Other than when sitting up rapidly)
___3. Do you find it difficult to breathe when you are lying down or sleeping?
___4. Do your ankles ever become swollen? (Other than after a long period of standing)
___5. Do you ever have heart palpitations, or an unusual period of rapid heart rate?
___6. Do you ever experience pain in your legs? (i.e. intermittent claudication)
___7. Has a physician ever said you have a heart murmur? (Has he/she said it is OK, and safe for you to exercise?)
___8. Do you feel unusually fatigued or find it difficult to breathe with usual activities?

III. Other

___1. Do you have any of the following diseases? Heart disease, peripheral vascular disease, cerebrovascular disease, chronic obstructive pulmonary disease (emphysema or chronic bronchitis) asthma (chronic), interstitial lung disease, cystic fibrosis, diabetes mellitus, thyroid disorder, renal disease, or liver disease
___2. Are you younger than 18 or older than 44 years of age?
___3. (For women) Do you think you may be pregnant?
___4. Are you taking any medications, such as blood pressure medication, that would affect your heart rate?
___6. Do you have any problem that might make it difficult for you to do strenuous exercise?

Eligible for study if: Has no more than 1 risk factor from section I, has none of the symptoms in section II, answers "No" to all questions in section III, AND the person must be considered physically active (see question 7 in section I).

Note: For individuals who do not know their blood glucose or blood lipid values, the ACSM assumes they have those risk factors if they are males over 44 years of age or females over 54 years of age, and assumes they do not have those risk factors if they are younger. Since all subjects in the current study will be 44 years old or less, if they do not know their blood values they will be assumed to not have those risk factors.

A.2 Approved Informed Consent Form

No: 09-105

OLD DOMINION UNIVERSITY
HUMAN SUBJECTS INSTITUTIONAL REVIEW BOARD
RESEARCH PROPOSAL REVIEW NOTIFICATION FORM

TO: Stacie I Ringleb — *Responsible Project Investigator*

DATE: September 17, 2009 — *IRB Decision Date*

RE: Effect of Physical Fitness on Military Performance
Name of Project

Please be informed that your research protocol has received approval by the Institutional Review Board. Your research protocol is:

___ Approved
___ Tabled/Disapproved
_X_ Approved, contingent on making the changes below*

George C Maihafer
IRB Chairperson's Signature

September 17, 2009
date

Contact the IRB for clarification of the terms of your research, or if you wish to make ANY change to your research protocol.

The approval expires one year from the IRB decision date. You must submit a Progress Report and seek re-approval if you wish to continue data collection or analysis beyond that date, or a Close-out report. You must report adverse events experienced by subjects to the IRB chair in a timely manner (see university policy).

---

* Approval of your research is CONTINGENT upon the satisfactory completion of the following changes and attestation to those changes by the chairperson of the Institutional Review Board. Research may not begin until after this attestation.

  * In the Application
    Under # 20, the date of the NIH training certificate needs to be entered and the certificate needs to be included/sent to George Maihafer

Attestation

As directed by the Institutional Review Board, the Responsible Project Investigator made the above changes. Research may begin.

George C. Maihafer
IRB Chairperson's Signature

January 5, 2010
date

INFORMED CONSENT DOCUMENT
OLD DOMINION UNIVERSITY

PROJECT TITLE: Effect of Physical Fitness on Military Performance

INTRODUCTION
The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES The research project will take place in the Human Performance Laboratory, room 2003 of the Student Recreation Center

RESEARCHERS
Stacie I Ringleb, Ph D Responsible Project Investigator
Elaine M Blount
David P Swain, PhD
Jimmy A Onate, ATC PhD
Marlene DeMaio, MD
Courtney Butowicz
Corbet Weller
Christopher Vause

DESCRIPTION OF RESEARCH STUDY

The goal of this study is to collect data relevant to physical fitness assessment performed by the various military organizations, and the ability to perform the low crawl, high crawl, 3-5 second rush, shoot targets and travel through stairways The data from the simulated battlefield skills will be used as input for a computer model that aims to assess the liability of unfit soldiers and determine the level of fitness needed for successful task performance on the battlefield

If you decide to participate, you will come to the exercise science laboratory facilities at Old Dominion University for one visit for preliminary assessment and information visit for a total of 2-3 hours of testing over one day You should already have filled out a questionnaire to assess your current level of physical activity and your health risks Additionally, we require that you currently exercise moderately for a minimum of 150 minutes per week or vigorously for 75 minutes per week If you are eligible for the study and agree to participate, you will be asked to return for physical testing

Body composition Your height and mass while wearing shorts and a t-shirt will be measured on a balance scale Then the thickness of your skin and underlying fat will be measured with calipers at three sites

You will put on a body armor vest and helmet with an approximate combined mass of 10kg You will ascend two flights of stairs for time to complete After resting until comfortable you will then descend two flights of stairs for time to complete Simulated battlefield tasks will be tested by having you perform a low crawl and high crawl with the height and velocity of the crawl measured using a visual system while carrying a realistic simulation of a M16 rifle Afterwards a 3-5 second rush originating from and ending in prone position while carrying a realistic simulation of a M16 will be measured for time You will then be asked to ascend and descend a flight of stairs for time Each of these tasks will be performed 3 times to obtain an average Ample water will be available throughout completion of these simulated battle tasks After these four battlefield tasks have been completed the helmet, vest and simulated M16 will be relinquished

After completing the above you will be asked to perform a marine combat fitness test which consists of three events 1) an 880 yard run, ammo can lifts (lift 30 lb weight from the ground over head as many times as possible in two minutes), and maneuver under fire portion which will include a combat crawl, ammunition resupply, body drag, casualty carry, and a grenade throw (22 meters to target circle grenade weighs about from 14 to 32 oz) Lap times will be taken when possible For more information on Marine Combat Fitness test, see http //www military com/military-fitness/marine-corps-fitness-requirements/marine-corps-combat-fitness-test and http //www tecom usmc mil/cft/cft htm

At this point, you will be asked to return another day to complete tasks from standard military fitness tests by testing the number of push-ups and sit-ups performed in two minutes You will be asked to perform as many pull-ups in 2 minutes as possible or a flex arm hang for time You will be tested on a horizontal jump a vertical jump, and a sit and reach Finally you will be asked to run 3 miles for time Ample water will be available throughout testing

EXCLUSIONARY CRITERIA
You should have completed a health-screening questionnaire to determine if you are eligible for the study You must be between the ages of 18 and 44 years To the best of your knowledge you should not have cardiovascular disease, pulmonary disease, diabetes mellitus, any symptoms of these diseases, or more than one known coronary disease risk factor If you are taking any medication that affects heart rate, you may not participate in the study If you think you may be pregnant, you may not participate in the study You must be considered physically active to participate in the study Additionally, if you have had a knee or back injury you must be pain free for six months before participation If you have had knee or back surgery, you must be at least 1 year post surgery

RISKS AND BENEFITS
RISKS If you decide to participate in this study, then you may face a risk of musculoskeletal injuries to the back or the lower extremities (such as legs, knees, ankles) Also, you may face a risk of abnormal blood pressure, fainting, irregular, fast or slow heart rhythm, and in rare instances heart attack, stroke or death The risk of serious consequences is considered to be low because of your health status as described under the exclusionary criteria Should an emergency situation arise, EMS would be contacted and CPR begun Finally, as with any research there is some possibility that you may be subject to risks that have not yet been identified

BENEFITS You may benefit by by learning about your own marksmanship and your performance on the low/high crawl and 3-5 second rush and stair-climbing These are crucial tasks on the battlefield

COSTS AND PAYMENTS
The researchers are unable to pay you for your participation in this research

NEW INFORMATION
If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you

CONFIDENTIALITY
Information collected about you will be kept confidential by the researchers The results of this study may be used in reports presentations and publications, but the researcher will not identify you

WITHDRAWAL PRIVILEGE
It is OK for you to say NO Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time Your decision will not affect your relationship with Old Dominion University or the ROTC program, or otherwise cause a loss of benefits to which you might otherwise be entitled The

researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, then your consent in this document does not waive any of your legal rights However, in the event of injury or illness arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury or illness In the event that you suffer injury or illness as a result of participation in this research project, you may contact Dr George Maihafer, the chair of the Institutional Review Board, at 757-683-4520, who will be glad to review the matter with you

VOLUNTARY CONSENT

By signing this form, you are saying several things You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits The researchers should have answered any questions you may have had about the research If you have any questions later on, then the researchers should be able to answer them Dr Stacie Ringleb, 757-683-5934

If at any time you feel pressured to participate, or if you have any questions about your rights or this form then you should call Dr George Maihafer at 757-683-4520 or the Old Dominion University Office of Research at 757-683-3460

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study The researcher should give you a copy of this form for your records

Subject's Printed Name & Signature	**Date**

INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating I am aware of my obligations under state and federal laws, and promise compliance I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study I have witnessed the above signature(s) on this consent form

Investigator's Printed Name & Signature	**Date**

Approved Institutional
Review Board - ODU

SEP 1 7 2009

Expires 1 year from date
Questions 757 683-3460

A.3 Data Collection Form

Military Performance Testing

Screening Form

Subject ID#________________ Date:____________________

☐ **Day 1:**

☐ **Section 1: (Anthropometric Data)**

Gender: Male / Female Age:__________

Height: ________(inches) ________ (cm) Weight: ________(lbs) ________(kg)

Body Fat Skin Fold Tester's Initials __________

Males: Chest: __________ Abdomen: ___________ Thigh: __________

Females: Triceps: __________ Suprailiac: ___________ Thigh: __________

Bodpod: ________

Total Body Fat: __________

☐ **Section 2: (Battlefield Tasks – with vest, helmet, weighted fake gun)**

Low Crawl: Time: Trial 1___________ Trial 2: __________ Trial 3: __________

Low Crawl: Average Height:____________ (cm) Max Height:__________ (cm)

Low Crawl: Average Velocity (Leg 1):__________

Low Crawl: Average Velocity (Leg 2):__________

Low Crawl: Average Velocity (Leg 3):__________

☐ **High Crawl:** Time: Trial 1: __________ Trial 2: ________ Trial 3: ________

High Crawl: Average Height: ______________ (cm) Max Height: _____________ (cm)

High Crawl: Average Velocity (Leg 1): _________

High Crawl: Average Velocity (Leg 2): __________

High Crawl: Average Velocity (Leg 3): __________

☐ **3-5 Second Rush:** Time: Trial 1:_______ Trial 2: ______ Trial 3: ________

3-5 Second Rush: Velocity: ___________________

☐ **Stairs:** Ascent Time: Trial 1:__________ Trial 2: __________ Trial 3: __________

☐ **Stairs:** Descent Time: Trial 1:__________ Trial 2: __________ Trial 3: __________

☐ **Section 3: (Marine Combat Fitness Test)**

The Tester reviewed proper lifting techniques with me. ________________________

880 Yard Run Time: __________________ Ammo Can Lift (2 minutes): __________

Maneuver Under Fire Time: ____________

Maneuver Under Fire Comments:

____

____

____

Day 2:

☐ **Section 4: (Fitness Test)**

Curl-ups (2 Minutes): ______________ Push-ups (2 Minutes): ______________

Sit & Reach : Trial 1:__________ Trial 2: ________ Trial 3: _________

Males: Pull-ups (2 minutes): __________

Females: Flex Arm Hang: _________(seconds)

Vertical Jump: Trial 1:__________ Trial 2: __________ Trial 3: __________

Horizontal Jump: Trial 1:__________ Trial 2: __________ Trial 3: __________

☐ **Section 5: (Aerobic Capacity)**

3 mile run time: __________________

Appendix B – IRB#10-076 Rushing Study

B.1 Internal Review Board Application and Exercise Questionnaire

IRB Identifier: ____________

APPENDIX C
OLD DOMINION UNIVERSITY
HUMAN SUBJECT RESEARCH REVIEW APPLICATION FORM

Responsible Project Investigator (RPI)

Responsible Project Investigator: The RPI must be a member of ODU faculty or staff who will serve as the project supervisor and be held accountable for all aspects of the project. Students cannot be listed as RPIs.

First Name: Stacie	**Middle Initial: I**	**Last Name: Ringleb**
Telephone: (757) 683-5934	**Fax Number: 683-5344**	**E-mail: sringleb@odu.edu**
Office Address: Mechanical Engineering, Kafuman Hall 238 C		
City: Norfolk	**State: VA**	**Zip: 23529**
Department: Mechanical Engineering	**College: Batten College of Engineering and Technology**	
Complete Title of Research Project: Effect of Physical Fitness on Military Performance With Respect to Rushing	**Code Name (one word): Rushing**	

Investigators
If more investigators exist than lines provide, please attach a separate list.

Investigator(s): Individuals who are directly responsible for any of the following: the project's design, implementation, consent process, data collection, and/or data analysis.

First Name: Elaine	**Middle Initial: M**	**Last Name: Blount**
Telephone: 898-3259	**Fax Number:**	**Email: eblou002@odu.edu**
Office Address: VMASC, 1030 University Blvd		
City: Suffolk	**State: VA**	**Zip: 23435**
Department: Modeling and Simulation	**College: Batten College of Engineering and Technology**	
Affiliation: __Faculty __Staff	_X_Graduate Student __Other____________	__Undergraduate Student

First Name: David	**Middle Initial: P**	**Last Name: Swain**
Telephone: 683-6028	**Fax Number: 683-4270**	**Email: dswain@odu.edu**
Office Address: Student Recreation Center 2026		
City: Norfolk	**State: VA**	**Zip: 23529**
Department: Human Movement Sciences	**College: Education**	
Affiliation: _X_Faculty __Staff	__Graduate Student __Other____________	__Undergraduate Student

List all information for additional investigators on attachment and check here _X_

IRB Identifier:
To Be Assigned by the IRB

First Name: Courtney	**Middle Initial:**	**Last Name: Butowicz**
Telephone:	**Fax Number:**	**Email: cbuto001@odu.edu**
Office Address: Student Recreation Center		
City:Norfolk	**State:VA**	**Zip:23529**
Department:	**College:**	

Affiliation: __Faculty _X_Graduate Student __ Undergraduate Student
__Staff __Other________________

Type of Research

1. This study is being conducted as part of (check all that apply):

_XFaculty Research
_XDoctoral Dissertation
__Masters Thesis
__Non-Thesis Graduate Student Research
__Honors or Individual Problems Project
__Other____________________

Funding

2. How is the research project funded?

__Research is **not funded (go to 3)**
_XResearch is **funded (go to 2a)**
__**Funding decision is pending** (funding decision has not been made) **(go to 2a)**

2a. What is the type of funding source? (Check all that apply)

_XFederal Grant or Contract
Agency Proposal Number Office of Naval Research: ONR N00014-10-1-0246
Grant Start Date (MM/DD/YY) 1/1/2010 Grant End Date (MM/DD/YY) 12/31/10
__State or Municipal Grant or Contract
__Private Foundation
__Corporate contract
__Other (specify):____

2b. Who is the point of contact at the funding source?

Name: **Roy Stripling**
Mailing Address:
Office of Naval Research
One Liberty Center
875 North Randolph Street - Suite 1425
Arlington, VA 2203-1995
703-696-0942
fax: 703-696-0066
roy.stripling@navy.mil

Research Dates

3a. Date you wish to start research (MM/DD/YY): ____07_/__01__/____10
3b. Date you plan to end research (MM/DD/YY): ____06_/__30__/____11 **(End date for data collection and analysis)**

Note: Protocols are approved for a maximum of 1 year. If a proposed project is intended to last beyond the approval period, continuing review and reapproval are necessary.

Research Location

IRB Identifier: ________
To Be Assigned by the IRB

4. Where will the experiment be conducted? (Check all that apply) _X_ On Campus (Building and Room Number) Student Recreation Center 2003 (Human Performance Laboratory) __ Off-Campus (Street Address)
5. Has this project been reviewed by any other committee (university, governmental, private sector) for the protection of human research subjects? __Yes _X No **(If no, go to 6)** **5a. If yes, is ODU conducting the "primary" review?** __Yes __No **(If no, go to 5b)** **5b. Who is conducting the primary review?**
Study Purpose

IRB Identifier:
(To Be Assigned by the IRB)

6. Describe the rationale for the research project.

The various military service branches currently perform physical fitness and assessment tests on a regular basis as shown in the table below: (http://www.military.com/military-fitness/)

Table 1- Standard Military Fitness Tests

Event	Air Force	Army	Coast Guard	Marines	Navy
Push-ups	1 minute	2 minutes	1 minute		2 minutes
Sit-Ups	1 minute	2 minutes	1 minute	2 minutes	2 minutes
Timed 2 Mile Run		X			
Timed 1.5 Mile Run	X		X		X
Sit & Reach			Distance		
Tread water 5 minutes			X		
Jump off 5 m platform, swim 100 meters					
Timed 3.0 Mile run				X	
"Dead Hang" Pull-ups				Number Until Failure (Males)	
"Flex Arm Hang"				Time Until Failure (Females)	
Body Composition or Weight	X	X	X	X	X

The Marines also recognize combat tests as important to determining whether soldiers are fit for battle and have created a new combat fitness test which incorporates crawling and short bursts of running similar to the 3-5 second rush.(http://www.military.com/military-report/marine-fitness-test-changes)

From the Field manuals published by the army, one of the most important tasks for battle is the **3-5 second rush**

a. FM 3-21.8 The Infantry Rifle Platoon and Squad paragraphs 1-47, 3-65, 3-83, 7-190, 7-220, 7-224, 7-228

b. FM 21-75 Combat Skills of the Soldier 3-2, 3-3, 3-4, 3-10,

The goal of this study is to collect data relevant to physical fitness assessment performed by the various military organizations, and the ability to perform 3-5 second rush. The fitness data will be compared and analyzed with respect to the performance of the 3-5 second rush to assess correlations. The data will be used for an agent based simulation that will look at tactical scenario performance and its relationship to the physical fitness. This study hopes to assess the liability of unfit soldiers and determine the level of fitness needed for a successful 3-5 second rush on the battlefield.

Subjects

IRB Identifier:

7. What will be the maximum number of subjects in the study? _____100___

7a. Indicate the approximate number of: **Males** ______75______ **Females**____25______

7b. What is the age of subjects? (Check all that apply)

__Children (1-17 years old) _X_Adults (18-65 years old)

__Elderly (64-years and older)

7c. Will students be enrolled in the study? (Check all that apply)

_X__Undergraduate students(dept)* _campus-wide__ ___Advanced students (dept)campus-wide

*If students are under 18 years old, parental consent must be obtained

7d. Provide rationale for the choice of subjects. Enumerate any additional defining characteristics, including age, of the subject population. (e.g., symptomatology, history, socio-economic status).

Target participants will be primarily male and female students ranging in age from 18-44 years as well as healthy individuals who exercise regularly. More men will be recruited to reflect the difference in the gender distribution in the military. Subjects shall be at low risk for cardiovascular disease according to ACSM's Guidelines of Exercise Testing and Prescription, 8th edition. They will not have any signs or symptoms of cardiovascular disease, and will not have any known cardiovascular, pulmonary or metabolic disease and will not have more than one major coronary heart disease risk factor. Exclusionary criteria will include any subject classified at moderate or high risk for cardiovascular disease according to the ACSM, anyone taking medications that influence heart rate, and anyone who is pregnant. A screening questionnaire is attached.

Vulnerable Subjects

8. Are research subjects being used whose ability to give informed voluntary consent may be in question? (e.g., children, persons with AIDS, mentally disabled, psychiatric patients, prisoners.)

__Yes (If yes, explain the procedures to be employed to enroll them and to ensure their protection).

_X_No

8b. What type of vulnerable subjects are being enrolled? (check all that apply)

__Critically Ill Patients __Mentally Disabled or Cognitively Impaired Individuals

__Prisoners __Physically Handicapped

__Pregnant Women __Children

__Other________________

Recruitment

9. How will participants be recruited? (Please submit a copy of the sign-up sheet, newspaper advertisement, or any other protocol or procedure which will be used to recruit subjects.)

__Internet

__Newspaper/radio/television advertising

_X_Posters/brochures/letters

_X_Other____

Comments:

Subjects will be recruited by making announcements through the ROTC program, posting flyers in the Student Recreation Center, and by word of mouth. If required number of subjects are not recruited, local military groups or gyms will be asked for help with recruitment.

Inclusion and Exclusion Criteria

IRB Identifier:
(To Be Assigned by the IRB)

10. Are subjects equitably chosen for participation in the study? (no one group is excluded without justification)

_X_Yes
__No (If no, specify criteria and justify in detail below.)

10a. Does the study require special evaluation and screening of potential subjects to determine their appropriateness for inclusion in the study?

_X_Yes *(If yes, briefly elaborate on the screening process and attach the screening questionnaire.)*
__No

A health screening questionnaire will be used to evaluate potential subjects. Anyone not meeting the age requirement or having knowledge of a cardiopulmonary or metabolic disease, or knowledge of a symptom of such diseases, or knowledge of two or more heart disease risk factors will be excluded. Potential subjects must also not be taking any blood pressure medications and female subject must believe they are not pregnant. If participants have had a knee or back injury, they must be pain free for six months before participation and if they have had surgery, they must be at least 1 year post surgery or have a doctor's note stating that they can resume activity at the pre-surgery level. Finally, participants must exercise vigorously for 75 minutes per week or 150 minutes per week of moderate exercise to ensure the proper fitness level.

Experimental Procedures

IRB Identifier:
(To Be Assigned by the IRB)

11. Describe the experimental procedures that will be followed. (Include a succinct, but comprehensive statement of the methodology relating to the human subjects. You are encouraged to include a discussion of statistical procedures used to determine the sample size.)

An informed consent document will be reviewed and signed by those agreeing to participate. Participating subjects will be required to wear adequate running shoes. The subject will have his/her age, height, and mass measured on a balance scale, and skinfold test with calipers will be used to measure body fat percentage using three sites (chest, abdomen, and thigh for males; triceps, suprailiac, and thigh for females. This data is also listed and described in Table 2 below.

Table 2 - Subject Descriptive Data

Measurement	Category	Method	Units
Age	Demographic	Question	Years
Sex	Demographic	Question	M/F
Height	Anthropometric	Height Rod	Centimeters
Weight	Anthropometric	Scale	Kilograms
Body Fat Percent	Body Composition	Calipers	%

Male subjects will put on a vest and helmet with a combined mass of 10kg and a backpack measuring 20 kg for a total extra weight of 30 kg and carry a simulated rubber M16. Females will also wear a vest and helmet with a mass of 10 kg, but the backpack will measure 10 kg for a total of 20 kg and carry a simulated rubber M16. The subject will perform three each of a series of 3-5 second rushes originating and ending in either prone, standing, or kneeling positions. Each of these tasks will be performed 3 times to get an average performance and are listed in Table 3 below. After completing the above, the subject will take off the helmet, vest, and relinquish the simulated gun. The subject will then be asked to perform a Marine combat fitness test which consists of three events: 1) an 880 yard run, ammo can lifts (lift 30 lb weight from the ground over head as many times as possible in two minutes), and maneuver under fire portion which will include a combat crawl, ammunition resupply, body drag, casualty carry, and a grenade throw (22 meters to target circle, grenade weighs about from 14 to 32 oz, http://www.armystudyguide.com/content/army_board_study_guide_topics/hand_grenades/hand-grenades-study-guide.shtml). Lap times will be taken when possible. For more information on Marine Combat Fitness test, see http://www.military.com/military-fitness/marine-corps-fitness-requirements/marine-corps-combat-fitness-test and http://www.tecom.usmc.mil/cft/cft.htm . Ample water will be available during completion of all of these battle tasks and the Marine Combat Fitness Tests.

Table 3 – Rushing Tasks and Marine Combat Fitness Test

Task	Measured Task	Measurement
3-5 Second Rush	15 Meter Rush – Standing to Standing	Time from starting to ending point in seconds
3-5 Second Rush	10 Meter Rush – Standing to Kneeling	Time from starting to ending point in seconds
3-5 Second Rush	5 meter Rush – Standing to kneeling	Time from starting to ending point in seconds
3-5 Second Rush	3 meter rush – kneeling to kneeling	Time from starting to ending point in seconds
3-5 Second Rush	6 meter rush – kneeling to kneeling	Time from starting to ending point in seconds
3-5 Second Rush	12 Meter Rush - Prone	Time from Prone to Prone
3-5 Second Rush	30 Meter Rush - Prone	Time from Prone to Prone
3-5 Second Rush	12 Meter Rush - Kneeling	Time from Kneeling to Kneeling
3-5 Second Rush	30 Meter Rush – Kneeling	Time from Kneeling to Kneeling
3-5 Second Rush	12 Meter Rush	Time from Standing to Standing
3-5 Second Rush	30 Meter Rush	Time from Standing to Standing
Marine Combat Fitness Test	Do not wear backpack, helmet, vest, or carry rubber M16. Wear all of these in Rushing Tasks Only.	Measure performance according to Marine standards.

The subject will be asked to return on a separate day to complete tasks for military fitness tests. The subject will be asked to perform military fitness tests listed in Table 4 by performing push-ups and curl-ups in two minutes, performing a sit & reach as a flexibility measurement and performing pull-ups or the flex arm hang if pull-ups cannot be performed by the subject. As a measurement of explosive power, the subject will perform a vertical jump and a horizontal broad jump. Finally the subject will run 3 miles for time. Ample water will be available throughout testing.

Measurement	Category	Method	Units
Push-Ups	Upper Body Strength-Endurance	# in 2 minutes	Number
Sit-Ups	Core Endurance	# in 2 minutes	Number
Timed Run	Aerobic Capacity	Timed	Minutes: Seconds
Sit & Reach	Flexibility	Average of 3	Centimeters
Pull-Ups(men)	Upper Body Strength-Endurance	# in 2 minutes	Number
Flex Arm Hang(women)	Upper Body Strength-Endurance	Time	Minutes: Seconds
Vertical Jump	Lower Body Power	Vertec	Centimeters

IRB Identifier: ______
(To Be Assigned by the IRB)

Compensation

12. How much time will be required of each subject?

The time required of each subject will be approximately 2-3 hours over two separate days.

12a. Will research subjects receive course credit for participating in the study?
__Yes (If yes, please explain in comments section.)
_X_No
Comments:

12b. Are there any other forms of compensation that may be used? (e.g. Money)
_X_Yes (If yes, please explain in comments section.)
__No
Comments: Participants will be paid $30 for completing the study.

12c. Are there any penalties for subjects who do not show up for a research session?
__Yes (If yes, please explain in comments section.)
_X_No
Comments:

Informed Consent

13. Do you intend to obtain informed consent from subjects?
_X_Yes (please answer question 13a)
__No (please complete Appendix F: Request for Waiver of Consent Form)

13a. Describe the procedures that will be used to obtain Informed Consent and attach the Informed Consent Document (follow the guidelines for preparation of the University Informed Consent Form).
Note: Subjects MUST be given a description of the procedures and rationale for the study to the extent possible. The benefits and ANY risks associated with participating in the study MUST be enumerated. The subjects MUST be informed of their right to terminate the experiment at any time. If there is no risk associated with the study and participants' signature on the informed consent sheet is the only identifying information about the name of the subject, then the subjects' signature may not be necessary.

Individuals who are interested in the study and pass the screening questionnaire will be scheduled for testing. The screening questionnaire will be formally reviewed and the subject will have the procedures and risks of the study verbally explained to them and given opportunity to read the informed consent document and ask questions before deciding to consent to the study. If the subject consents to the study, they will be asked to sign and date the form.

Risks

IRB Identifier:______
(To Be Assigned by the IRB)

14. What are potential risks of the research? (Check all that apply)
X physical harm
__psychological harm
X Release of confidential information
__Other________________________

14a. Describe any potential risks to subjects for the activities proposed and describe the steps that will be taken to minimize the risks. Include any risks to the subject's physical well being, privacy, dignity, emotions, employability, and criminal and legal status. A detailed, comparative statement of the risk (harm or likelihood) must also be described in the consent form.

Subjects could experience muscle or joint injury, inappropriate changes in blood pressure or heart rhythm, a heart attack, stroke or death during testing. The risk of these events is extremely low in individuals who are physically active and apparently healthy, as are these subjects. Phone access to EMS will be maintained during all testing.

The confidentiality of collected data will be protected by keeping hard copies in locked cabinets and electronic data in secured computer work stations. Only aggregate data will be used in research reports.

Please attach the following (if you have developed them)
__The script by the experimenter to disclose potential harm and likelihood (risk) prior to the subject's choice to participate.

Benefits

15. Assess the potential benefits that may accrue to the individual subject as well as to others as a result of the proposed study. Do the potential benefits justify the possible risks involved? Although you may mention general benefits to society, such speculative benefits should not be presented to a subject as a direct benefit for informed consent.

The subjects will be able to take a practice physical fitness test to help determine readiness for military physical test already necessary at least every year. The subjects will learn the speed of their rush. The knowledge could help them within a battlefield situation. The risks of injury to the subjects are low, and the benefits for the subjects outweigh the risks.

Protection of Anonymity

16. Describe in detail the procedures for protecting the anonymity (meaning that no one will ever be able to know the names) of the research subjects. If anonymity is impossible, then describe in detail the procedures for safeguarding data and confidential records. These procedures relate to how well you reduce the risk that a subject may be exposed or associated with the data.

Subjects will not be anonymous. The confidentiality of the collected data will be protected by keeping hard copies in locked file cabinets and electronic data in secured computer work stations. Only aggregate data will be used in research reports.

Drugs or Devices

17. Will any drugs, devices, or chemical biological agents be used with the subjects?
__Yes (If yes, please attach Appendix G: Drugs, Agents, and Devices Form)
X No

Biological Materials

18. Will this research involve the collection, analysis, or banking of human biological materials (cells, tissues, fluids, DNA?)
__Yes (If yes, please attach Appendix H: Biological Materials Form)
X No

Training

IRB Identifier:___________
To Be assigned by the IRB

19. Briefly explain the nature of the training and supervision of anyone who is involved in the actual data collection, research design, or in conducting the research. This information should be sufficient for the IRB to determine that the RPI and investigators possess the necessary skills or qualifications to conduct the study.

Dr. Ringleb is an expert in biomechanics, mechanical engineering and modeling and simulation. Dr. Swain has extensive experience in performing physiological testing and is a military veteran with shooting experience. Elaine has a BS and MS in computer science and MBA. She taught aerobics from 1995-1999. Elaine will be CPR certified and first aid trained. Student workers who may assist with testing will be trained by by Drs' Swain and will be identified to the IRB prior to testing.

Human Subjects and HIPPA Training

20.A. The RPI must document completion of NIH Training. (Attach a copy of the RPI's NIH Certificate for Human Participants Protections Education for Research Teams.) **Date RPI completed NIH Training:____5/10/2010____**

B. RPI's who propose studies with patient populations must document HIPPA training by accessing the NIH booklet entitled "Protecting Personal Health Information in Research: Understanding the HIPPA Privacy Rule" at: http://privacyruleandresearch.nih.gov/pr_02.asp. and must submit an attachment to the review application stating that the material has been read and will be adhered to in the proposed research. The attachment must include the date the material was read, which must be within the 12 months prior to the application. (If you are submitting this attachment with your application the RPI must initial here:________________

PLEASE NOTE:

- You may begin research when the University Human Subjects Review Board gives you final WRITTEN notice of its approval.
- *You MUST inform the committee of ANY adverse event, changes in the method, personnel, funding, or procedure.*
- At any time the committee reserves the right to re-review a research project, to request additional information, to monitor the research for compliance, to inspect the data and consent forms, to interview subjects that have participated in the research, and if necessary to terminate a research investigation.

Responsible Project Investigator (Must be original signature) Date

EXERCISE TEST SCREENING QUESTIONNAIRE

Read the questions to potential subjects and interpret the responses. Do not have the person fill out the questionnaire on his/her own.

Name ________________________ Sex ____ Date ________

Phone ________________ email ________________

I. Risk Factors

____1. Do you have a family history of heart disease? [heart attack, bypass surgery, angioplasty or sudden death prior to the age of 55 (father or brother) or 65 (mother or sister)]

____2. Have you smoked cigarettes in the past 6 months?

____3. Do you know if your blood pressure is typically 140/90 or more? Do you take blood pressure medication?

____4. Do you know if your LDL cholesterol is more than 130, or if your HDL cholesterol is less than 40? If you don't know your LDL, do you know if you total cholesterol is more than 200?

___5. Do you know if your fasting glucose is more than 100?
___6. What is your height and weight? [determine if BMI is > 30]
___7. Over the past three months, how much physical activity have you typically gotten each week? Consider moderate intensity activities, such as walking, slow bicycling, and gardening, and also consider vigorous intensity activities such as jogging, fast bicycling, and competitive sports. [physically active is at least 150 min/wk of moderate intensity, or at least 75 min/wk of vigorous, or a combination of the two, in which time spent in vigorous activities is doubled and added to time spent in moderate activities; less than this is considered sedentary, and a risk factor]

II. Symptoms

___1. Do you ever have pain or discomfort in your chest or surrounding areas? (i.e. ischemia)
___2. Do you ever feel faint or dizzy? (Other than when sitting up rapidly)
___3. Do you find it difficult to breathe when you are lying down or sleeping?
___4. Do your ankles ever become swollen? (Other than after a long period of standing)
___5. Do you ever have heart palpitations, or an unusual period of rapid heart rate?
___6. Do you ever experience pain in your legs? (i.e. intermittent claudication)
___7. Has a physician ever said you have a heart murmur? (Has he/she said it is OK, and safe for you to exercise?)
___8. Do you feel unusually fatigued or find it difficult to breathe with usual activities?

III. Other

___1. Do you have any of the following diseases? Heart disease, peripheral vascular disease, cerebrovascular disease, chronic obstructive pulmonary disease (emphysema or chronic bronchitis) asthma (chronic), interstitial lung disease, cystic fibrosis, diabetes mellitus, thyroid disorder, renal disease, or liver disease
___2. Are you younger than 18 or older than 44 years of age?
___3. (For women) Do you think you may be pregnant?
___4. Are you taking any medications, such as blood pressure medication, that would affect your heart rate?
___6. Do you have any problem that might make it difficult for you to do strenuous exercise?
___7. Have you had a knee or back injury during the last 6 months? Have you experienced back or knee pain during the last 6 months?
___8. Have you had knee or back surgery within the last year?
___9. If you have had knee or back surgery during the last year, do you have a doctor's note stating you can resume activity at the pre-surgery level?

Eligible for study if: Has no more than 1 risk factor from section I, has none of the symptoms in section II, answers "No" to all questions in section III except number 9, AND the person must be considered physically active (see question 7 in section I). If the subject has had knee or back surgery during the last year, the subject must have a doctor's note stating ability to resume pre-surgery activities.

Note: For individuals who do not know their blood glucose or blood lipid values, the ACSM assumes they have those risk factors if they are males over 44 years of age or females over 54 years of age, and assumes they do not have those risk factors if they are younger. Since all subjects in the current study will be 44 years old or less, if they do not know their blood values they will be assumed to not have those risk factors.

B.2 Approved Informed Consent Form

No.: 10 - 076

OLD DOMINION UNIVERSITY
HUMAN SUBJECTS INSTITUTIONAL REVIEW BOARD
RESEARCH PROPOSAL REVIEW NOTIFICATION FORM

TO Stacie Ringleb — *Responsible Project Investigator*

DATE: June 17, 2010 — *IRB Decision Date*

RE Effect of Physical Fitness on Military Performance with respect to Rushing
Name of Project

Please be informed that your research protocol has received approval by the Institutional Review Board Your research protocol is

___ Approved
___ Tabled/Disapproved
_X_ Approved, contingent on making the changes below*

____________________ **June 17, 2010**
IRB Chairperson's Signature *date*

Contact the IRB for clarification of the terms of your research, or if you wish to make ANY change to your research protocol

The approval expires one year from the IRB decision date You must submit a Progress Report and seek re-approval if you wish to continue data collection or analysis beyond that date, or a Close-out report You must report adverse events experienced by subjects to the IRB chair in a timely manner (see university policy)

---

* Approval of your research is CONTINGENT upon the satisfactory completion of the following changes and attestation to those changes by the chairperson of the Institutional Review Board Research may not begin until after this attestation

*** In the Application**

- Under 12 b, under Compensation, it should be changed to ___NO and be reflected as No in the informed consent as well
- Under 14, check ___release of confidential information since the investigators do discuss this in the subsequent narrative statements
- Under 20a, fill in the NIH human subjects compliance certificate date

In the Informed Consent

- Add "with Respect to Rushing" so that the title is the same on both the application and the informed consent
- Under Description of Research Study , in the fifth paragraph, delete the sentence that refers to the web site and web site address
- Add a sentence that describes the study sample size at some point in the Description section

- In the Exclusionary Criteria section, at the end of the last sentence, add the phrase, "and have a doctor's note that states that you may return to pre-surgery activity level' since this is stated in the application as a criterion for inclusion
- Under Cost and Payments, state that the investigators are unable to provide any payments for participation in the study at this time Delete the last sentence in the Withdrawal section that refers to the $30 00
- Under Compensation for Illness and Injury, add Dr Ringleb's name and phone number as a first person of contact for subjects

On the Flier

- Remove the reference to compensation being offered
- Under the second bullet, the word, "dawn" should be changed to "don"

Attestation

As directed by the Institutional Review Board, the Responsible Project Investigator made the above changes Research may begin

IRB Chairperson's Signature **July 13, 2010** _date_

TO Stacie Ringleb PhD
Responsible Project Investigator

FROM George Maihafer PT PhD
Chairperson IRB

RE Addendum Request to "Effect of Physical Fitness on Military Performance with Respect to Rushing"

DATE May 27, 2010

After review of the amended revisions to ODU IRB Project "Effect of Physical Fitness on Military Performance with Respect to Rushing" **(ODU IRB # 10 – 076)**

I approve the change in an expedited review manner The amendment to the methodology of the study is as follows

Remuneration of $30.00 will be provided to study participants at the completion of data collection. The recruitment flier states that compensation will be provided for the subjects' time.

A Progress report or Close out Report will still be required at the April 2011 IRB meeting, based upon the original approval of one year for this study

Please let me know if I can be of any further assistance

INFORMED CONSENT DOCUMENT
OLD DOMINION UNIVERSITY

PROJECT TITLE: Effect of Physical Fitness on Military Performance With Respect to Rushing

INTRODUCTION

The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research and to record the consent of those who say YES The research project will take place in the Human Performance Laboratory, room 2003 of the Student Recreation Center

RESEARCHERS

Stacie I Ringleb Ph D , Responsible Project Investigator
Elaine M Blount
David P Swain, PhD
Courtney Butowicz

DESCRIPTION OF RESEARCH STUDY

The goal of this study is to collect data from approximately 100 subjects relevant to physical fitness assessment performed by the various military organizations, and the ability to perform the 3-5 second rush The data from the simulated battlefield skills will be used as input for a computer model that aims to assess the liability of unfit soldiers and determine the level of fitness needed for successful task performance on the battlefield with respect to rushing

If you decide to participate, you will come to the exercise science laboratory facilities at Old Dominion University for preliminary assessment and information visit for a total of 2-3 hours of testing over two days You should already have filled out a questionnaire to assess your current level of physical activity and your health risks Additionally, we require that you currently exercise moderately for a minimum of 150 minutes per week or vigorously for 75 minutes per week If you are eligible for the study and agree to participate, you will be asked to return for physical testing

Body composition Your height and mass while wearing shorts and a t-shirt will be measured on a balance scale Then, the thickness of your skin and underlying fat will be measured with calipers at three sites We will also ask your age and sex (M/F)

You will put on a body armor vest and helmet with an approximate combined mass of 10kg and a backpack with a mass of 20 kg if you are male or a backpack with a mass of 10 kg if you are female You will be asked to perform a series of 3-5 second rushes originating from and ending in prone, kneeling, or standing positions while carrying a realistic simulation of a M16 while being measured for time Each of these tasks will be performed 3 times to obtain an average and can range in distance from 3 to 30 meters Ample water will be available throughout completion of these simulated battle tasks After the rushing battlefield tasks have been completed, the helmet, vest and simulated M16 will be relinquished

After completing the above, you will be asked to perform a marine combat fitness test which consists of three events 1) an 880 yard run ammo can lifts (lift 30 lb weight from the ground over head as many times as possible in two minutes), and maneuver under fire portion which will include a combat crawl ammunition resupply, body drag casualty carry and a grenade throw (22 meters to target circle grenade weighs about from 14 to 32 oz) Lap times will be taken when possible

At this point, you will be asked to return another day to complete tasks from standard military fitness tests by testing the number of push-ups and sit-ups performed in two minutes. You will be asked to perform as many pull-ups in 2 minutes as possible or a flex arm hang for time. You will be tested on a horizontal jump, a vertical jump, and a sit and reach. Finally you will be asked to run 3 miles for time. Ample water will be available throughout testing.

EXCLUSIONARY CRITERIA

You should have completed a health-screening questionnaire to determine if you are eligible for the study. You must be between the ages of 18 and 44 years. To the best of your knowledge, you should not have cardiovascular disease, pulmonary disease, diabetes mellitus, any symptoms of these diseases, or more than one known coronary disease risk factor. If you are taking any medication that affects heart rate, you may not participate in the study. If you think you may be pregnant, you may not participate in the study. You must be considered physically active to participate in the study. Additionally, if you have had a knee or back injury, you must be pain free for six months before participation. If you have had knee or back surgery, you must be at least 1 year post surgery and have a doctor's note that states that you may return to pre-surgery activity level..

RISKS AND BENEFITS

RISKS: If you decide to participate in this study, then you may face a risk of musculoskeletal injuries to the back or the lower extremities (such as legs, knees, ankles). Also, you may face a risk of abnormal blood pressure, fainting, irregular, fast or slow heart rhythm, and in rare instances heart attack, stroke or death. The risk of serious consequences is considered to be low because of your health status as described under the exclusionary criteria. Should an emergency situation arise, EMS would be contacted and CPR begun. Finally, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFITS: You may benefit by learning about your performance on the 3-5 second rush, fitness levels with respect to the various military fitness tests, and learning your body fat composition.

COSTS AND PAYMENTS

The researchers are unable to provide any payments for participation in the study at this time.

NEW INFORMATION

If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY

Information collected about you will be kept confidential by the researchers. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify you.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time. Your decision will not affect your relationship with Old Dominion University or the ROTC program, or otherwise cause a loss of benefits to which you might otherwise be entitled. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of injury or illness arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury or illness In the event that you suffer injury or illness as a result of participation in this research project you may contact Dr Stacie Ringleb the Responsible Project Investigator at 757-683-5934 who will be glad to review the matter with you

VOLUNTARY CONSENT

By signing this form you are saying several things You are saying that you have read this form or have had it read to you that you are satisfied that you understand this form the research study, and its risks and benefits The researchers should have answered any questions you may have had about the research If you have any questions later on, then the researchers should be able to answer them Dr Stacie Ringleb 757-683-5934

If at any time you feel pressured to participate or if you have any questions about your rights or this form then you should call Dr George Maihafer at 757-683-4520 or the Old Dominion University Office of Research at 757-683-3460

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study The researcher should give you a copy of this form for your records

Subject's Printed Name & Signature	**Date**

INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits risks costs, and any experimental procedures I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating I am aware of my obligations under state and federal laws and promise compliance I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study I have witnessed the above signature(s) on this consent form

Investigator's Printed Name & Signature	**Date**

Approved Institutional
Review Board - ODU
JUN 1 7 2010
Expires 1 year from date
Questions (757) 683-3460

B.3. Data Collection Form

Military Performance Testing

Screening Form

Subject ID#_______________

Day 1: Date:________ Temperature:________

Humidity:________ Precipitation:_______

Section 1: (Demographic Data)

Gender: Male / Female Age:__________

Race(Circle): Black, Non Hispanic Native American/Alaskan

Caucasian, Non Hispanic Hispanic

Asian/Pacific Islands Other/Unknown

Section 2: (Rushing – with vest, helmet, weighted fake gun, backpack)

3 Meters, Kneeling to Kneeling Time: ________

5 Meters, Standing to Kneeling Time: ________

6 Meters, Kneeling to Kneeling Time:________

10 Meters, Standing to Kneeling Time: ________

12 Meters, Prone to Prone Time: ___________

12 Meters, Kneeling to Kneeling Time: ________

12 Meters, Standing to Standing Time: ________

15 Meters, Standing to Standing Time: ________

30 Meters, Prone to Prone Time: ___________

30 Meters, Kneeling to Kneeling Time: ________

30 Meters, Standing to Standing Time: ________

Section 3: (Marine Combat Fitness Test)

The Tester reviewed proper lifting techniques with me. ______________________

880 Yard Run Time: ________________ Ammo Can Lift (2 minutes): __________

Maneuver Under Fire Time: __________

Maneuver Under Fire Comments:

____

____

____

Day 2: Date:________ Temperature:________ Humidity:________ Precipitation:________

☐ **Section 4: (Anthropometric Data)**

Height: ________(inches) ________ (cm) Weight: ________(lbs) ________(kg)

Body Fat Skin Fold Tester's Initials __________

Males: Chest: __________ Abdomen: __________ Thigh: __________

Females: Triceps: __________ Suprailiac: __________ Thigh: __________

Total Body Fat: __________

Section 5: (Fitness Test)

Curl-ups (2 Minutes): ____________ Push-ups (2 Minutes): ____________

Sit & Reach: *Trial 1:*__________ *Trial 2:* ________ *Trial 3:* ________

Pull-ups (2 minutes): __________

Flex Arm Hang: ________(seconds) (Only if no Pull-ups)

Vertical Jump: Trial 1: __________ Trial 2: __________ Trial 3: __________

Horizontal Jump: Trial 1: __________ Trial 2: __________ Trial 3: __________

☐ **Section 6: (Aerobic Capacity)**

3 mile run time: ________________

B.4 Advertisement Flyer

COMBAT SIMULATION

- Help create data for a combat simulation studying the effects of physical fitness on combat success
- Volunteer to don fighting gear and rush for time.
- Perform the Marine Combat Fitness Test and Marine Physical Fitness Test
- Perform standard Military Fitness Tests: pushups, sit-ups, pull-ups, vertical & horizontal jump, sit & reach, and 3 mile run.
- Data collected will be used as speed data for a variety of computer infantry scenarios
- Must perform 150 minutes of moderate or 75 minutes of vigorous exercise per week
- *Must be knee or back injury free for six months*
- Compensation will be provided for your time.

Email eblou002@odu.edu to get participation information and schedule your testing time!

fitness data Eblou002@odu edu
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Appendix C – Data Collected From Studies

C.1 Data Collected from Pilot Study

Table C.1.1 – Pilot Study Demographic Data Collected

Pilot Study Demographic Data						
Rusher ID	**Date**	**Gender**	**Age**	**Heigh**	**Weigh**	**Body Fat (Bod**
1	10/16/2009	M	23	69	195.5	18.1
2	10/19/2009	M	27	70	183.8	8.9
3	10/20/2009	M	27	72.5	199.8	7.1
4	10/29/2009	M	23	74	228.55	21
5	12/3/2009	F	26	66	155	21
6	12/4/2009	M				
7	12/8/2009	F	19			

Table C.1.2 – Pilot Study Movement Data Collected

Pilot Study Movement Data								
Rusher ID	**Low Crawl (Ave)**	**High Crawl (Ave)**	**Rush (Ave)**	**Stairs Ascent (Ave)**	**Stairs Descent (Ave)**	**Marine Combat Fitness Test**		
						880 Sprint (s)	**Ammo Cans**	**Maneuver**
1	8.2633	10.103	3.446	4.8533	5.7366	206	69	298
2	9.48	9.5966	2.903	4.23	4.2666	181.2	82	154.2
3	9.3333	7.84	3.096	4.2533	4.5533	164	91	188
4	8.0466	9.9433	3.016	4.5866	5.7	197	87	208
5	14.47	14.683	4.62	6.1833	6.3	21186	59	294.18
6	10.813	9.58	3.953	4.55	5.5	167	100	(98 points)
7	15.296	13.4	4.693	5.6033	6.5	0	60	

Table C.1.3 Pilot Study Physical Fitness Data Collected

ID	Push-Ups	Curl-Ups	Sit & Reach	Pull-Ups	Flex Arm Hang	Vertical Jump	Horizontal Jump	3 Mile Run
1	55	46	23	10		28.16667	95.33333	1564
2	65	86	40	13		125.5	8.6	1415
3	50	65	35.75	15		24.33333	91.66667	1268
4								
5								
6								
7	38	100	34.25		70	15.83333	62.5	

C.2 Data Collected from Rushing Study

Table C.2.2.1 Rushing Study Demographic Data Collected

Rushing Study Demographic Data						
Rusher ID	**Date**	**Gender**	**Age**	**Height**	**Weight**	**Body Fat (Caliper)**
1	8/9/2010	M	29	77.2	166	5.31
2	8/9/2010	M	24	70.9	158.25	11.6
3	8/17/2010	M	28	67	184	19.38
4	9/8/2010	M	36	65.7	131	12.94
5	9/8/2010	M	24	68.5	143	12.65
6	9/8/2010	M	29	70.5	191.5	14.97
7	9/8/2010	M	20	74	161	3.54
8	9/8/2010	M	23	71.25	190	5.78
9	9/13/2010	M	21	68.5	148.5	4.45
10	9/13/2010	M	29	67.5	174	16.98
11	9/13/2010	M	20	66.5	155	6.09
12	9/13/2010	M	20	71	187	6.09
13	9/14/2010	M	22	71.25	169	18.28
14	9/14/2010	M	21	70.5	159	5.41
15	9/20/2010	M	20	66.5	161	
16	9/20/2010	M	21	72.7	220.5	21.25
17	9/20/2010	M	22	75	173	6.94
18	9/20/2010	M	27	69	185	14.16
19	9/21/2010	M	21	72	204	16.78
20	10/4/2010	M	20	67.5	139	8.89
21	10/4/2010	M	19	75.5	161	11.2
22	10/4/2010	M	20	71.5	197	10.86
23	10/4/2010	M	18	71.3	169	6.19
24	10/5/2010	M	18	70.5	185	15.6
25	10/5/2010	M	27	68	176	11.64
26	10/5/2010	M	20	66	147	12.79
27	10/5/2010	M	18	66.7	176	19.72
28	10/12/2010	M	20	65.4	153	9.8
29	10/18/2010	F	19	62.5	121	22.78
30	10/18/2010	M	20	68	158.5	12.35
31	10/19/2010	M	39	71	176	13.42

Table C.2.2 – Pilot Study Movement Data Collected for 11 Rushes. KK = Kneeling to kneeling, SM = Standing to Kneeling, PP = Prone to Prone, SS = Standing to Standing. Time is in seconds.

ID	3 M KK	5 M SM	6 M KK	10 M SM	12 M PP	12 M KK	12 M SS	15 M SS	30 M PP	30 M KK	30 M SS
1	2.2	2.31	2.8	3.48	6.89	4.52	3.83	4.81	10.0	8.37	7.29
2	2.2	3.23	3.9	3.88	6.65	5.53	4.27	5.45	11.8	10.5	9.77
3	2.5	3.03	3.1	4.25	7.31	5.14	5.16	5.23	12.1	9.97	10.1
4	2.2	2.67	3.1	3.76	5.79	4.41	3.73	4.73	9.66	8.6	7.63
5	2.4	2.51	2.5	3.32	4.71	4.11	3.4	4.27	7.99	8.02	6.95
6	2.7	2.75	2.5	3.63	5.68	4.72	4.2	4.47	10.2	8.28	7.4
7	2.4	2.49	2.5	3.37	4.84	4.44	3.27	3.93	8.46	7.41	7.12
8	2.0	2.25	2.4	3.43	4.86	4.01	4.03	3.93	9.07	7.68	6.61
9	1.8	2.25	2.5	3.28	4.83	3.9	3.32	3.7	7.26	6.72	6.14
10	2.0	2.59	2.8	3.44	4.65	4.31	3.86	4.17	8.93	7.57	6.78
11	1.9	2.5	2.7	3.34	4.42	4	3.64	4.21	7.6	6.77	6.49
12	1.3	1.86	2.1	3.08	3.88	3.63	2.99	3.48	7.06	5.89	5.56
13	2.2	2.27	2.8	3.38	5.25	4.59	3.91	4.35	9.17	7.73	7.24
14	1.9	2.17	2.6	2.98	5.4	4.14	3.74	4.03	8.88	6.98	6.86
15	1.9	2.16	2.5	3.22	4.68	4.06	3.68	3.91	7.78	6.91	6.82
16	2.0	2.35	2.8	3.65	5.56	4.5	3.72	4.16	8.31	8.43	7.06
17	1.9	2	2.8	3.09	4.66	3.72	3.41	4.25	7.9	6.84	6.71
18	2.1	2.69	2.8	3.63	5.01	4.39	3.74	4.29	8.23	7.12	6.88
19	2.2	2.31	2.8	3.63	5	4.1	3.33	4.04	7.73	7.29	6.15
20	2.0	2.34	2.8	3.9	5.22	4.4	4.09	4.6	8.77	7.48	7.33
21	2.1	2.23	2.8	3.41	5.59	4.29	3.89	4.37	9.26	7.58	6.99
22	2.0	2.28	2.8	3.51	4.97	3.43	3.87	4.37	8.65	7.18	6.99
23	2.3	2.45	2.8	3.24	4.14	3.94	3.62	4.07	9.12	7.27	6.81
24	2.0	2.43	2.9	3.38	4.85	4.13	3.84	4.22	8.87	7.32	6.83
25	2.0	2.32	2.8	3.64	5.93	4.07	3.78	4.83	9.32	7.81	7.43
266	2.3	2.44	3.1	3.77	5.49	4.26	3.77	4.27	8.89	8.08	7.26
27	1.9	2.39	2.7	3.77	5.28	4.19	3.57	4.72	8.93	7.57	7.44
28	2.1	2.66	2.9	3.63	6.06	4.86	4	4.62	10.0	8.72	6.97
29	2.4	2.62	3.5	3.98	6.88	4.72	4.37	4.8	11.0	9.65	8.34
30	2.2	2.49	2.9	3.54	5.43	4.25	3.87	4.63	8.83	7.72	7.12
31	2.1	2.62	3.0	3.84	6.1	4.39	4.06	4.37	9.64	8.38	7.18

Table C.2.3 Marine Combat Fitness Scores from Rushing Study

ID	880 YD	Ammunition Can Lift	Maneuver Under Fire (seconds)
1	169.998	72	173.67
2	216.942	15	391.02
3	250.65	33	0
4	201	53	207
5	190	32	266
6	224	55	256
7	168	65	174
8	152	88	158
9	172	81	231
10	192	68	209
11	169	70	204
12	186.7	80	187
13	186	67	194.59
14	179	52	232.42
15	176	95	169
16	229	50	212
17	190	80	195
18	192	114	163
19	184	59	179.92
20	184	46	215
21	184	42	221
22	192	85	176
23	164	93	148
24	174	80	159
25	177	82	163
26	175	69	159
27	196	66	189
28	177	60	200
29	195	28	N/A
30	186	38	173
31	200	60	196

Table C.2.3 Rushing Study Physical Fitness Data Collected

ID	Push-Ups	Curl-Ups	Sit & Reach	Pull-Ups	Flex Arm Hang	Vertical Jump	Horizontal Jump	3 Mile Run (s)
1	42	77		8		21.16667	76.16667	1332
2	15	38	6.7	2		21.83333	86.5	
3	23	41	9.1	0	6.49	15.83333	66.5	1854
4	58	54	26	9		14.66667	68	1461
5	25	72	27.33333	10		22.66667	93.66667	1658
6	41	46	38.66667	3		21.5	73.83333	1873
7	83	112	25.83333	20		25.16667	85.16667	1180
8	85	81	26.33333	14		26.16667	91.41667	1146
9	63	86	40.205	18		29.33333	101.6667	1368
10	83	95	45.33333	20		23.5	82.5	1649
11	69	91	46.5	19		26.83333	97.83333	1832
12	59	88	39.16667	11		28.33333	105.8333	1832
13	69	69	41.66667	17		22.5	90.83333	1476
14	38	83	51.66667	19		30.33333	103.3333	1415
15	106	77	32	20		24.16667	78	1375
16	23	43	37	0		16.33333	68	1823
17	46	56	20.83333	10		28	102.1667	1746
18	60	105	29.33333	25		27.5	91.33333	1578
19	54	85	41.16667	9		29	95.16667	1611
20	65	64	34.5	15		26.33333	91.66667	1645
21	25	52	26	8		27.33333	98.33333	1527
22	70	93	28.33333	19		21.5	87.16667	1468
23	71	108	37	17		22.5	85	1293
24	69	130	32.1	6		21	77.66667	
25	68	118	36.66667	19		23.16667	72.33333	1267
26	59	61	12	14		19.33333	69.33333	1276
27	60	76	24	14		24.66667	83	
28	85	62	43.33333	15		22.83333	73.66667	1302
29	60	106	26	1		12.83333	44.66667	1423
30	50	62	40.7705	7		22.16667	59.33333	1547
31	40	66	28.66667	5		18.5	72.16667	1637

Appendix D – Marine Physical Fitness Test and Combat Fitness Test Information

D.1 Marine Physical Fitness Test

The U. S. Marine Combat Fitness Test consists of three events: pull-ups (flex-arm hang for females), crunches, and a 3-mile run. Pull-ups are not timed, and are judged by how many a participant can complete before dropping off of the bar. Crunches are timed, and are the number of crunches the participant can perform in 2 minutes. The 3-mile run is measured by how long the participant takes to complete the run. Scoring and minimum requirements are slightly different according to the age and gender of the participant. Females do not perform pull-ups, but instead perform the flex-arm hang. Scoring is performed according to Table D.2 for each event. The scores are then compared to Table D.1 to determine if the participant passes and their class.

Table D.1 Marine Corps PFT Classification Scores for Males and Females

	Ages 17-26	Ages 27-39	Ages 40-45	Ages 46+
Class 1	225	200	175	150
Class 2	175	150	125	100
Class 3	135	110	88	65
Does Not Pass	<135	<110	<88	<65

Table D.2 Points for Event Performance for Scoring Marine Physical Fitness Test.

Points	Crunches (Males & Females)	Pull-Ups (Males)	3-Mile Run (Males)	Flex-Arm Hang (Females)	3-Mile Run (Females)
100	100	20	18:00	70 seconds	21:00
99	99		18:10		21:10
98	98		18:20	69 seconds	21:20
97	97		18:30		21:30
96	96		18:40	68 seconds	21:40
95	95	19	18:50		21:50
94	94		19:00	67 seconds	22:00
93	93		19:10		22:10
92	92		19:20	66 seconds	22:20
91	91		19:30		22:30
90	90	18	19:40	65 seconds	22:40
89	89		19:50		22:50
88	88		20:00	64 seconds	23:00
87	87		20:10		23:10
86	86		20:20	63 seconds	23:20
85	85	17	20:30		23:30
84	84		20:40	62 seconds	23:40
83	83		20:50		23:50
82	82		21:00	61 seconds	24:00
81	81		21:10		24:10
80	80	16	21:20	60 seconds	24:20
79	79		21:30		24:30
78	78		21:40	59 seconds	24:40
77	77		21:50		24:50
76	76		22:00	58 seconds	25:00
75	75	15	22:10		25:10
74	74		22:20	57 seconds	25:20
73	73		22:30		25:30
72	72		22:40	56 seconds	25:40
71	71		22:50		25:50
70	70	14	23:00	55 seconds	26:00
69	69		23:10		26:10
68	68		23:20	54 seconds	26:20
67	67		23:30		26:30
66	66		23:40	53 seconds	26:40
65	65	13	23:50		26:50
64	64		24:00	52 seconds	27:00
63	63		24:10		27:10
62	62		24:20	51 seconds	27:20
61	61		24:30		27:30
60	60	12	24:40	50 seconds	27:40
59	59		24:50		27:50
58	58		25:00	49 seconds	28:00
57	57		25:10		28:10
56	56		25:20	48 seconds	28:20

Table D.2 Points for Event Performance for Scoring Marine Physical Fitness Test. (Continued)

Points	Crunches (Males & Females)	Pull-Ups (Males)	3-Mile Run (Males)	Flex-Arm Hang (Females)	3-Mile Run (Females)
55	55	11	25:30		28:30
54	54		25:40	47 seconds	28:40
53	53		25:50		28:50
52	52		26:00	46 seconds	29:00
51	51		26:10		29:10
50	50 Min Ages 17-26	10	26:20	45 seconds	29:20
49	49		26:30		29:30
48	48		26:40	44 seconds	29:40
47	47		26:50		29:50
46	46		27:00	43 seconds	30:00
45	45 Min Ages 27-45	9	27:10		30:10
44	44		27:20	42 seconds	30:20
43	43		27:30		30:30
42	42		27:40	41 seconds	30:40
41	41		27:50		30:50
40	40 Min All Ages 46+	8	28:00 Min Ages 17-26	40 seconds	31:00 Min Ages 17-26
39	X		28:10	39 seconds	31:10
38	X		28:20	38 seconds	31:20
37	X		28:30	37 seconds	31:30
36	X		28:40	36 seconds	31:40
35	X	7	28:50	35 seconds	31:50
34	X		29:00 Min Ages 27-39	34 seconds	32:00 Min Ages 27-39
33	X		29:10	33 seconds	32:10
32	X		29:20	32 seconds	32:20
31	X		29:30	31 seconds	32:30
30	X	6	29:40	30 seconds	32:40
29	X		29:50	29 seconds	32:50
28	X		30:00 Min Ages 40-45	28 seconds	33:00 Min Ages 40-45
27	X		30:10	27 seconds	33:10
26	X		30:20	26 seconds	33:20
25	X	5	30:30	25 seconds	33:30
24	X		30:40	24 seconds	33:40
23	X		30:50	23 seconds	33:50
22	X		31:00	22 seconds	34:00
21	X		31:10	21 seconds	34:10
20	X	4	31:20	20 seconds	34:20
19	X		31:30	19 seconds	34:30
18	X		31:40	18 seconds	34:40

Table D.2 Points for Event Performance for Scoring Marine Physical Fitness Test. (Continued)

Points	Crunches (Males & Females)	Pull-Ups (Males)	3-Mile Run (Males)	Flex-Arm Hang (Females)	3-Mile Run (Females)
17	X		31:50	17 seconds	34:50
16	X		32:00	16 seconds	35:00
15	X	3 Minimum for All Males	32:10	15 seconds Minimum for All Females	35:10
14	X	X	32:20		35:20
13	X	X	32:30		35:30
12	X	X	32:40		35:40
11	X	X	32:50		35:50
10	X	X	33:00 Min Ages 46+		36:00 Min Ages 46+

D.2 Marine Combat Fitness Test

The Marine Combat Fitness Test (CFT) is designed to test Marines with regard to combat readiness. It consists of three events: the 800 yard run, ammunition can lifts, and maneuver under fire. The 800 yard run consists of running 800 yards and is timed. The ammunition can lifts consists of lifting a 30 lb ammunition can overhead as many times as possible in 2 minutes. The maneuver under fire consists of the following:

1) rush 25 yards
2) jog a circle around a cone
3) perform high crawl for 10 yards
4) perform a modified high crawl for an additional 15 yards
5) rush in a zig-zag pattern around 5 cones for 25 yards
6) drag a casualty back around the last two cones
7) pick up the casualty using a fireman's carry and carry them in a zig-zag pattern around the remaining cones then straight back to the starting line
8) put the casualty down, pick up two 30 lb ammunition cans and rush straight back to the zig-zag cones,
9) rush around the zig-zag cones in the appropriate zig-zag pattern
10) puts down the ammunition cans and throws a grenade at a target 22.5 yards away
11) performs 3 push-ups 12) picks up the ammunition can and rushes back around the zig-zag cones for 25 yards and then straight the remaining 50 yards.

The maneuver under fire is timed and scored according to the time. The entire test is scored according to table D.3 with the individual components scored according to Tables D.4, D.5, and D.6.

Table D.3 CFT Classes for Passing

Class 1	270-300
Class 2	225-269
Class 3	190-224
Does Not Pass	<190

Table D.4 Scoring for Ammunition Can Lift.

REPS	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	M	F	M	F	M	F	M	F
97			100					
96			99					
95			99					
94			98					
93			98					
92			97					
91	100		97					
90	99		96					
89	99		95		100			
88	98		95		99			
87	97		94		99			
86	97		94		98		100	
85	96		93		98		99	
84	95		92		97		99	
83	94		92		97		98	
82	94		91		96		98	
81	93		91		96		97	
80	92		90		95		97	
79	92		90		95		96	
78	91		89		94		95	
77	90		88		93		95	
76	90		88		93		94	
75	89		87		92		94	
74	88		87		92		93	
73	88		86		91		93	
72	87		86		91		92	
71	86		85		90		91	
70	86		84		90		91	
69	85		84		89		90	
68	84		83		88		90	
67	83		83		88		89	

Table D.4 Scoring for Ammunition Can Lift. (Continued)

REPS	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	M	F	M	F	M	F	M	F
66	83		82		87		89	
65	82		81		87		88	
64	81		81		86		87	
63	81		80	100	86		87	
62	80		80	99	85		86	
61	79		79	98	85		86	
60	79	100	79	98	84		85	
59	78	99	78	97	84		85	
58	77	98	77	96	83		84	
57	77	97	77	95	82		83	
56	76	96	76	94	82		83	
55	75	95	76	94	81		82	
54	74	94	75	93	81		82	
53	74	93	74	92	80		81	
52	73	93	74	91	80		81	
51	72	92	73	90	79		80	
50	72	91	73	90	79		79	
49	71	90	72	89	78		79	
48	70	89	72	88	77		78	
47	70	88	71	87	77		78	
46	69	87	70	86	76		77	
45	68	86	70	86	76	100	77	
44	68	85	69	85	75	99	76	
43	67	84	69	84	75	98	75	
42	66	83	68	83	74	97	75	
41	66	82	68	82	74	96	74	100
40	65	81	67	82	73	95	74	99
39	64	80	66	81	73	94	73	98
38	63	80	66	80	72	93	73	97
37	63	79	65	79	71	92	72	96
36	62	78	65	78	71	91	72	95
35	61	77	64	78	70	90	71	94
34	61	76	63	77	70	89	70	93
33	60	75	63	76	69	88	70	92
32		74	62	75	69	87	69	91
31		73	62	74	68	86	69	90
30		72	61	74	68	85	68	89
29		71	61	73	67	84	68	88
28		70	60	72	66	83	67	86
27		69		71	66	82	66	85
26		68		70	65	81	66	84
25		67		70	65	80	65	83
24		67		69	64	79	65	81
23		66		68	64	78	64	80
22		65		67	63	77	64	79
21		64		66	63	76	63	78

Table D.4 Scoring for Ammunition Can Lift. (Continued)

REPS	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	M	F	M	F	M	F	M	F
20		63		66	62	75	62	76
19		62		65	62	74	62	75
18		61		64	61	73	61	74
17		60		63	60	72	61	73
16				62		71	60	71
15				62		70		70
14				61		69		69
13				60		68		68
12						66		66
11						65		65
10						64		64
9						63		63
8						61		61
7						60		60
6								

Table D.5 Scoring for the 880 Yd Movement to Contact

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
2:45	100	X	X	X	X	X	X	X
2:46	99							
2:47	99							
2:48	98							
2:49	98							
2:50	97							
2:51	97		100					
2:52	96		99					
2:53	96		99					
2:54	95		98					
2:55	95		98					
2:56	95		97					
2:57	94		97					
2:58	94		97					
2:59	93		96					
3:00	93		96					
3:01	92		95					
3:02	92		95					
3:03	91		95		100			
3:04	91		94		99			
3:05	91		94		99		100	
3:06	90		93		99		99	
3:07	90		93		99		99	
3:08	89		93		98		99	

Table D.5 Scoring for the 880 Yd Movement to Contact (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
3:09	89		92		98		99	
3:10	88		92		98		98	
3:11	88		91		97		98	
3:12	87		91		97		98	
3:13	87		91		97		97	
3:14	87		90		97		97	
3:15	86		90		96		97	
3:16	86		89		96		96	
3:17	85		89		96		96	
3:18	85		88		95		96	
3:19	84		88		95		95	
3:20	84		88		95		95	
3:21	83		87		94		95	
3:22	83		87		94		95	
3:23	83	100	86		94		94	
3:24	82	99	86		93		94	
3:25	82	99	86		93		94	
3:26	81	98	85		93		93	
3:27	81	98	85		92		93	
3:28	80	97	84		92		93	
3:29	80	97	84		92		92	
3:30	79	97	84	100	91		92	
3:31	79	96	83	99	91		92	
3:32	79	96	83	99	91		91	
3:33	78	96	82	98	90		91	
3:34	78	96	82	98	90		91	
3:35	77	96	82	98	90		90	
3:36	77	95	81	97	89		90	
3:37	76	95	81	97	89		90	
3:38	76	95	80	97	89		89	
3:39	75	94	80	96	88		89	
3:40	75	94	80	96	88		89	
3:41	75	94	79	96	88		88	
3:42	74	93	79	95	87		88	
3:43	74	93	78	95	87		88	
3:44	73	93	78	95	86		87	
3:45	73	92	78	94	86		87	
3:46	72	92	77	94	86		87	
3:47	72	92	77	94	85		86	
3:48	71	91	76	93	85		86	
3:49	71	91	76	93	84	100	86	
3:50	71	91	76	93	84	99	85	
3:51	70	90	75	92	84	99	85	
3:52	70	90	75	92	84	98	85	
3:53	69	90	74	92	83	98	84	
3:54	69	90	74	91	83	98	84	

Table D.5 Scoring for the 880 Yd Movement to Contact (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
3:55	68	89	74	91	83	97	84	100
3:56	68	89	73	91	82	97	84	99
3:57	67	89	73	90	82	96	83	99
3:58	67	88	72	90	82	96	83	98
3:59	67	88	72	90	81	96	83	98
4:00	66	88	72	89	81	95	82	98
4:01	66	87	71	89	81	95	82	97
4:02	65	87	71	89	80	95	82	97
4:03	65	87	70	88	80	94	81	97
4:04	64	86	70	88	80	94	81	96
4:05	64	86	70	88	79	93	81	96
4:06	63	86	69	87	79	93	80	96
4:07	63	85	69	87	79	93	80	95
4:08	63	85	68	87	78	92	80	95
4:09	62	85	68	86	78	92	79	95
4:10	62	85	67	86	78	92	79	94
4:11	61	84	67	86	77	91	79	94
4:12	61	84	67	85	77	91	78	94
4:13	60	84	66	85	77	90	78	93
4:14		83	66	85	77	90	78	93
4:15		83	65	84	76	90	77	93
4:16		83	65	84	76	89	77	92
4:17		82	65	84	76	89	77	92
4:18		82	64	83	75	89	76	92
4:19		82	64	83	75	88	76	91
4:20		81	63	83	75	88	76	91
4:21		81	63	83	74	88	75	91
4:22		81	63	82	74	87	75	90
4:23		80	62	82	74	87	75	90
4:24		80	62	82	73	86	74	90
4:25		80	61	81	73	86	74	89
4:26		79	61	81	73	86	74	89
4:27		79	61	81	72	85	74	88
4:28		79	60	80	72	85	73	88
4:29		79	60	80	72	85	73	88
4:30		78		80	71	84	73	87
4:31		78		79	71	84	72	87
4:32		78		79	71	83	72	87
4:33		77		79	71	83	72	86
4:34		77		78	70	83	71	86
4:35		77		78	70	82	71	86
4:36		76		78	70	82	71	85
4:37		76		77	69	82	70	85
4:38		76		77	69	81	70	85
4:39		75		77	69	81	70	84
4:40		75		76	68	80	69	84

Table D.5 Scoring for the 880 Yd Movement to Contact (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
4:41		75		76	68	80	69	84
4:42		74		76	68	80	69	83
4:43		74		75	67	79	68	83
4:44		74		75	67	79	68	83
4:45		73		75	67	79	68	82
4:46		73		74	66	78	67	82
4:47		73		74	66	78	67	82
4:48		73		74	66	78	67	81
4:49		72		73	65	77	66	81
4:50		72		73	65	77	66	81
4:51		72		73	65	76	66	80
4:52		71		72	64	76	65	80
4:53		71		72	64	76	65	80
4:54		71		72	64	75	65	79
4:55		70		71	64	75	64	79
4:56		70		71	63	75	64	79
4:57		70		71	63	74	64	78
4:58		69		70	63	74	63	78
4:59		69		70	62	73	63	78
5:00		69		70	62	73	63	77
5:01		68		69	62	73	62	77
5:02		68		69	61	72	62	77
5:03		68		69	61	72	62	76
5:04		68		68	61	72	61	76
5:05		67		68	60	71	61	76
5:06		67		68		71	61	75
5:07		67		67		71	60	75
5:08		66		67		70		75
5:09		66		67		70		74
5:10		66		66		69		74
5:11		65		66		69		74
5:12		65		66		69		73
5:13		65		65		68		73
5:14		64		65		68		73
5:15		64		65		68		72
5:16		64		64		67		72
5:17		63		64		67		72
5:18		63		64		66		71
5:19		63		63		66		71
5:20		62		63		66		71
5:21		62		63		65		70
5:22		62		62		65		70
5:23		62		62		65		70
5:24		61		62		64		69
5:25		61		61		64		69
5:26		61		61		63		68

Table D.5 Scoring for the 880 Yd Movement to Contact (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
5:27		60		61		63		68
5:28				60		63		68
5:29						62		67
5:30						62		67
5:31						62		67
5:32						61		66
5:33						61		66
5:34						61		66
5:35						60		65
5:36								65
5:37								65
5:38								64
5:39								64
5:40								64
5:41								63
5:42								63
5:43								63
5:44								62
5:45								62
5:46								62
5:47								61
5:48								61
5:49								61
5:50								60
5:20								
5:21								

Table D.6 CFT Maneuver Under Fire Scoring

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
2:14	100	X	X	X	X	X	X	X
2:15	99							
2:16	99							
2:17	98							
2:18	98							
2:19	97							
2:20	97							
2:21	97							
2:22	96							
2:23	96							
2:24	96							
2:25	95							
2:26	95		100					

Table D.6 CFT Maneuver Under Fire Scoring (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
2:27	94		99					
2:28	94		99					
2:29	94		99					
2:30	93		99					
2:31	93		99					
2:32	93		98					
2:33	92		98					
2:34	92		98		100			
2:35	91		97		99			
2:36	91		97		99			
2:37	91		97		99			
2:38	90		96		99			
2:39	90		96		98			
2:40	90		96		98			
2:41	89		96		98			
2:42	89		95		98			
2:43	88		95		98			
2:44	88		95		97			
2:45	88		94		97			
2:46	87		94		97			
2:47	87		94		97			
2:48	87		94		97			
2:49	86		93		97			
2:50	86		93		96			
2:51	85		93		96			
2:52	85		92		96		100	
2:53	85		92		96		99	
2:54	84		92		96		99	
2:55	84		92		95		99	
2:56	84		91		95		99	
2:57	83		91		95		98	
2:58	83		91		95		98	
2:59	82		90		95		98	
3:00	82		90		94		98	
3:01	82	100	90		94		98	
3:02	81	99	89		94		97	
3:03	81	99	89		94		97	
3:04	81	99	89		94		97	
3:05	80	99	89		93		97	
3:06	80	98	88		93		97	
3:07	79	98	88	100	93		96	
3:08	79	98	88	99	93		96	
3:09	79	98	87	99	93		96	
3:10	78	97	87	99	93		96	
3:11	78	97	87	99	92		96	
3:12	78	97	87	98	92		95	

Table D.6 CFT Maneuver Under Fire Scoring (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
3:13	77	97	86	98	92		95	
3:14	77	97	86	98	92		95	
3:15	76	96	86	98	92		95	
3:16	76	96	85	97	91		95	
3:17	76	96	85	97	91		94	
3:18	75	96	85	97	91		94	
3:19	75	95	85	97	91		94	
3:20	74	95	84	97	91		94	
3:21	74	95	84	96	90	100	94	
3:22	74	95	84	96	90	99	93	
3:23	73	95	83	96	90	99	93	
3:24	73	94	83	96	90	99	93	
3:25	73	94	83	95	90	99	93	
3:26	72	94	82	95	90	98	93	
3:27	72	94	82	95	89	98	92	
3:28	71	94	82	95	89	98	92	
3:29	71	93	82	95	89	98	92	
3:30	71	93	81	94	89	98	92	
3:31	70	93	81	94	89	97	92	
3:32	70	93	81	94	88	97	91	
3:33	70	92	80	94	88	97	91	
3:34	69	92	80	93	88	97	91	
3:35	69	92	80	93	88	96	91	
3:36	68	92	80	93	88	96	91	
3:37	68	92	79	93	87	96	90	
3:38	68	91	79	93	87	96	90	
3:39	67	91	78	92	87	96	90	
3:40	67	91	78	92	87	95	90	
3:41	67	91	78	92	87	95	90	
3:42	66	90	78	92	86	95	89	
3:43	66	90	78	91	86	95	89	
3:44	65	90	77	91	86	95	89	100
3:45	65	90	77	91	86	94	89	99
3:46	65	90	77	91	86	94	88	99
3:47	64	89	76	91	86	94	88	99
3:48	64	89	76	90	85	94	88	99
3:49	64	89	76	90	85	93	88	98
3:50	63	89	75	90	85	93	88	98
3:51	63	88	75	90	85	93	87	98
3:52	62	88	75	89	85	93	87	98
3:53	62	88	75	89	84	93	87	97
3:54	62	88	74	89	84	92	87	97
3:55	61	88	74	89	84	92	87	97
3:56	61	87	74	89	84	92	86	96
3:57	61	87	73	88	84	92	86	96
3:58	60	87	73	88	83	92	86	96

Table D.6 CFT Maneuver Under Fire Scoring (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
3:59		87	73	88	83	91	86	96
4:00		87	73	88	83	91	86	96
4:01		86	72	88	83	91	85	95
4:02		86	72	87	83	91	85	95
4:03		86	72	87	82	91	85	95
4:04		86	71	87	82	90	85	95
4:05		85	71	87	82	90	85	95
4:06		85	71	86	82	90	84	94
4:07		85	71	86	82	90	84	94
4:08		85	70	86	82	89	84	94
4:09		85	70	86	81	89	84	94
4:10		84	70	86	81	89	84	93
4:11		84	69	85	81	89	84	93
4:12		84	69	85	81	89	83	93
4:13		84	69	85	81	88	83	93
4:14		83	68	85	80	88	83	92
4:15		83	68	84	80	88	83	92
4:16		83	68	84	80	88	83	92
4:17		83	68	84	80	88	82	92
4:18		83	67	84	80	87	82	91
4:19		82	67	84	79	87	82	91
4:20		82	67	83	79	87	82	91
4:21		82	66	83	79	87	81	91
4:22		82	66	83	79	86	81	91
4:23		81	66	83	79	86	81	90
4:24		81	66	82	78	86	81	90
4:25		81	65	82	78	86	80	90
4:26		81	65	82	78	86	80	90
4:27		81	65	82	78	85	80	89
4:28		80	64	82	78	85	80	89
4:29		80	64	81	78	85	80	89
4:30		80	64	81	77	85	80	89
4:31		80	63	81	77	85	79	88
4:32		80	63	81	77	84	79	88
4:33		79	63	80	77	84	79	88
4:34		79	63	80	77	84	79	88
4:35		79	62	80	76	84	79	87
4:36		79	62	80	76	84	78	87
4:37		78	62	80	76	83	78	87
4:38		78	61	79	76	83	78	87
4:39		78	61	79	76	83	78	87
4:40		78	61	79	75	83	78	86
4:41		78	61	79	75	82	77	86
4:42		77	60	78	75	82	77	86
4:43		77		78	75	82	77	86
4:44		77		78	75	82	77	85

Table D.6 CFT Maneuver Under Fire Scoring (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
4:45		77		78	74	82	77	85
4:46		76		78	74	81	76	85
4:47		76		77	74	81	76	85
4:48		76		77	74	81	76	84
4:49		76		77	74	81	76	84
4:50		76		77	74	81	76	84
4:51		75		76	73	80	75	84
4:52		75		76	73	80	75	83
4:53		75		76	73	80	75	83
4:54		75		76	73	80	75	83
4:55		74		76	73	79	75	83
4:56		74		75	72	79	74	83
4:57		74		75	72	79	74	82
4:58		74		75	72	79	74	82
4:59		74		75	72	79	74	82
5:00		73		74	72	78	74	82
5:01		73		74	71	78	73	81
5:02		73		74	71	78	73	81
5:03		73		74	71	78	73	81
5:04		73		74	71	78	73	81
5:05		72		73	71	77	73	80
5:06		72		73	71	77	72	80
5:07		72		73	70	77	72	80
5:08		72		73	70	77	72	80
5:09		71		72	70	77	72	79
5:10		71		72	70	76	72	79
5:11		71		72	70	76	71	79
5:12		71		72	69	76	71	79
5:13		71		72	69	76	71	79
5:14		70		71	69	75	71	78
5:15		70		71	69	75	71	78
5:16		70		71	69	75	70	78
5:17		70		71	68	75	70	78
5:18		69		70	68	75	70	77
5:19		69		70	68	74	70	77
5:20		69		70	68	74	70	77
5:21		69		70	68	74	69	77
5:22		69		70	67	74	69	77
5:23		68		79	67	74	69	76
5:24		68		69	67	73	69	76
5:25		68		69	67	73	68	76
5:26		68		69	67	73	68	76
5:27		67		69	67	73	68	75
5:28		67		68	66	72	68	75
5:29		67		68	66	72	68	75
5:30		67		68	66	72	67	75

Table D.6 CFT Maneuver Under Fire Scoring (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
5:31		67		68	66	72	67	74
5:32		66		67	66	72	67	74
5:33		66		67	65	72	67	74
5:34		66		67	65	71	67	74
5:35		66		67	65	71	66	73
5:36		65		67	65	71	66	73
5:37		65		66	65	71	66	73
5:38		65		66	64	70	66	73
5:39		65		66	64	70	66	73
5:40		65		66	64	70	65	72
5:41		64		65	64	70	65	72
5:42		64		65	64	70	65	72
5:43		64		65	63	69	65	72
5:44		64		65	63	69	65	71
5:45		64		65	63	69	64	71
5:46		63		64	63	69	64	71
5:47		63		64	63	68	64	71
5:48		63		64	63	68	64	70
5:49		63		64	62	68	64	70
5:50		62		63	62	68	63	70
5:51		62		63	62	68	63	70
5:52		62		63	62	67	63	69
5:53		62		63	62	67	63	69
5:54		62		63	61	67	63	69
5:55		61		62	61	67	62	69
5:56		61		62	61	67	62	68
5:57		61		62	61	66	62	68
5:58		61		62	61	66	62	68
5:59		60		61	60	66	62	68
6:00				61		66	61	68
6:01				61		66	61	67
6:02				61		65	61	67
6:03				61		65	61	67
6:04				60		65	61	67
6:05						65	60	67
6:06						64		66
6:07						64		66
6:08						64		66
6:09						64		65
6:10						64		65
6:11						63		65
6:12						63		65
6:13						63		64
6:14						63		64
6:15						63		64
6:16						63		64

Table D.6 CFT Maneuver Under Fire Scoring (Continued)

Time	Ages 17-26		Ages 27-39		Ages 40-45		Ages 46+	
	Male	Female	Male	Female	Male	Female	Male	Female
6:17						62		64
6:18						62		63
6:19						62		63
6:20						62		63
6:21						62		63
6:22						61		62
6:23						61		62
6:24						61		62
6:25						60		62
6:26								61
6:27								61
6:28								61
6:29								61
6:30								60

Appendix E – Lookup Tables for Hits and Shots

Below is a table for hits and shots using the distance, posture, rushing velocity, shooting accuracy, and shooting cadence. Only the hits and shots for 10% accuracy are given. To change the hits, multiply the number of shots by a different shooting accuracy.

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence.

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.169	1.69	3	SS	Slow	1.591	0.1	0.5	0.5	N
0.153	1.53	3	SS	Medium	1.928	0.1	0.5	0.5	N
0.145	1.45	3	SS	Fast	2.155	0.1	0.5	0.5	N
0.121	1.21	3	SS	Very Fast	3.289	0.1	0.5	0.5	N
0.201	2.01	6	SS	Slow	2.383	0.1	0.5	0.5	N
0.189	1.89	6	SS	Medium	2.622	0.1	0.5	0.5	N
0.166	1.66	6	SS	Fast	3.279	0.1	0.5	0.5	N
0.164	1.64	6	SS	Very Fast	3.386	0.1	0.5	0.5	N
0.289	2.89	12	SS	Slow	2.81	0.1	0.5	0.5	Y
0.264	2.64	12	SS	Medium	3.175	0.1	0.5	0.5	Y
0.238	2.38	12	SS	Fast	3.67	0.1	0.5	0.5	Y
0.225	2.25	12	SS	Very Fast	4.013	0.1	0.5	0.5	Y
0.316	3.16	15	SS	Slow	3.11	0.1	0.5	0.5	Y
0.289	2.89	15	SS	Medium	3.497	0.1	0.5	0.5	Y
0.26	2.6	15	SS	Fast	4.051	0.1	0.5	0.5	Y
0.249	2.49	15	SS	Very Fast	4.31	0.1	0.5	0.5	Y
0.494	4.94	30	SS	Slow	3.579	0.1	0.5	0.5	Y
0.424	4.24	30	SS	Medium	4.292	0.1	0.5	0.5	Y
0.382	3.82	30	SS	Fast	4.886	0.1	0.5	0.5	Y
0.353	3.53	30	SS	Very Fast	5.396	0.1	0.5	0.5	Y
0.197	1.97	3	KK	Slow	1.225	0.1	0.5	0.5	Y
0.18	1.8	3	KK	Medium	1.429	0.1	0.5	0.5	Y
0.166	1.66	3	KK	Fast	1.64	0.1	0.5	0.5	Y
0.14	1.4	3	KK	Very Fast	2.308	0.1	0.5	0.5	Y
0.233	2.33	6	KK	Slow	1.893	0.1	0.5	0.5	Y
0.217	2.17	6	KK	Medium	2.12	0.1	0.5	0.5	Y
0.195	1.95	6	KK	Fast	2.5	0.1	0.5	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.183	1.83	6	KK	Very Fast	2.778	0.1	0.5	0.5	Y
0.318	3.18	12	KK	Slow	2.469	0.1	0.5	0.5	Y
0.288	2.88	12	KK	Medium	2.817	0.1	0.5	0.5	Y
0.256	2.56	12	KK	Fast	3.306	0.1	0.5	0.5	Y
0.246	2.46	12	KK	Very Fast	3.499	0.1	0.5	0.5	Y
0.351	3.51	15	KK	Slow	2.715	0.1	0.5	0.5	N
0.319	3.19	15	KK	Medium	3.075	0.1	0.5	0.5	N
0.28	2.8	15	KK	Fast	3.659	0.1	0.5	0.5	N
0.465	4.65	15	KK	Very Fast	3.878	0.1	0.5	0.5	N
0.557	5.57	30	KK	Slow	3.109	0.1	0.5	0.5	Y
0.454	4.54	30	KK	Medium	3.958	0.1	0.5	0.5	Y
0.411	4.11	30	KK	Fast	4.464	0.1	0.5	0.5	Y
0.37	3.7	30	KK	Very Fast	5.093	0.1	0.5	0.5	Y
0.274	2.74	3	PP	Slow	0.752	0.1	0.5	0.5	N
0.24	2.4	3	PP	Medium	0.907	0.1	0.5	0.5	N
0.203	2.03	3	PP	Fast	1.173	0.1	0.5	0.5	N
0.175	1.75	3	PP	Very Fast	1.502	0.1	0.5	0.5	N
0.312	3.12	6	PP	Slow	1.264	0.1	0.5	0.5	N
0.275	2.75	6	PP	Medium	1.497	0.1	0.5	0.5	N
0.24	2.4	6	PP	Fast	1.814	0.1	0.5	0.5	N
0.218	2.18	6	PP	Very Fast	2.1	0.1	0.5	0.5	N
0.419	4.19	12	PP	Slow	1.744	0.1	0.5	0.5	Y
0.337	3.37	12	PP	Medium	2.286	0.1	0.5	0.5	Y
0.282	2.82	12	PP	Fast	2.899	0.1	0.5	0.5	Y
0.269	2.69	12	PP	Very Fast	3.093	0.1	0.5	0.5	Y
0.428	4.28	15	PP	Slow	2.124	0.1	0.5	0.5	N
0.373	3.73	15	PP	Medium	2.516	0.1	0.5	0.5	N
0.316	3.16	15	PP	Fast	3.108	0.1	0.5	0.5	N
0.303	3.03	15	PP	Very Fast	3.286	0.1	0.5	0.5	N
0.627	6.27	30	PP	Slow	2.715	0.1	0.5	0.5	Y
0.519	5.19	30	PP	Medium	3.375	0.1	0.5	0.5	Y
0.438	4.38	30	PP	Fast	4.132	0.1	0.5	0.5	Y
0.428	4.28	30	PP	Very Fast	4.249	0.1	0.5	0.5	Y
0.239	2.39	3	SS	Slow	1.591	0.1	1	0.5	N
0.206	2.06	3	SS	Medium	1.928	0.1	1	0.5	N
0.189	1.89	3	SS	Fast	2.155	0.1	1	0.5	N

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.141	1.41	3	SS	Very Fast	3.289	0.1	1	0.5	N
0.302	3.02	6	SS	Slow	2.383	0.1	1	0.5	N
0.279	2.79	6	SS	Medium	2.622	0.1	1	0.5	N
0.233	2.33	6	SS	Fast	3.279	0.1	1	0.5	N
0.227	2.27	6	SS	Very Fast	3.386	0.1	1	0.5	N
0.477	4.77	12	SS	Slow	2.81	0.1	1	0.5	Y
0.428	4.28	12	SS	Medium	3.175	0.1	1	0.5	Y
0.377	3.77	12	SS	Fast	3.67	0.1	1	0.5	Y
0.349	3.49	12	SS	Very Fast	4.013	0.1	1	0.5	Y
0.532	5.32	15	SS	Slow	3.11	0.1	1	0.5	Y
0.479	4.79	15	SS	Medium	3.497	0.1	1	0.5	Y
0.42	4.2	15	SS	Fast	4.051	0.1	1	0.5	Y
0.398	3.98	15	SS	Very Fast	4.31	0.1	1	0.5	Y
0.888	8.88	30	SS	Slow	3.579	0.1	1	0.5	Y
0.749	7.49	30	SS	Medium	4.292	0.1	1	0.5	Y
0.664	6.64	30	SS	Fast	4.886	0.1	1	0.5	Y
0.606	6.06	30	SS	Very Fast	5.396	0.1	1	0.5	Y
0.295	2.95	3	KK	Slow	1.225	0.1	1	0.5	Y
0.26	2.6	3	KK	Medium	1.429	0.1	1	0.5	Y
0.233	2.33	3	KK	Fast	1.64	0.1	1	0.5	Y
0.18	1.8	3	KK	Very Fast	2.308	0.1	1	0.5	Y
0.367	3.67	6	KK	Slow	1.893	0.1	1	0.5	Y
0.333	3.33	6	KK	Medium	2.12	0.1	1	0.5	Y
0.29	2.9	6	KK	Fast	2.5	0.1	1	0.5	Y
0.266	2.66	6	KK	Very Fast	2.778	0.1	1	0.5	Y
0.536	5.36	12	KK	Slow	2.469	0.1	1	0.5	Y
0.476	4.76	12	KK	Medium	2.817	0.1	1	0.5	Y
0.413	4.13	12	KK	Fast	3.306	0.1	1	0.5	Y
0.393	3.93	12	KK	Very Fast	3.499	0.1	1	0.5	Y
0.602	6.02	15	KK	Slow	2.715	0.1	1	0.5	N
0.538	5.38	15	KK	Medium	3.075	0.1	1	0.5	N
0.46	4.6	15	KK	Fast	3.659	0.1	1	0.5	N
0.437	4.37	15	KK	Very Fast	3.878	0.1	1	0.5	N
1.015	10.15	30	KK	Slow	3.109	0.1	1	0.5	Y
0.808	8.08	30	KK	Medium	3.958	0.1	1	0.5	Y
0.722	7.22	30	KK	Fast	4.464	0.1	1	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.639	6.39	30	KK	Very Fast	5.093	0.1	1	0.5	Y
0.449	4.49	3	PP	Slow	0.752	0.1	1	0.5	N
0.381	3.81	3	PP	Medium	0.907	0.1	1	0.5	N
0.306	3.06	3	PP	Fast	1.173	0.1	1	0.5	N
0.25	2.5	3	PP	Very Fast	1.502	0.1	1	0.5	N
0.525	5.25	6	PP	Slow	1.264	0.1	1	0.5	N
0.451	4.51	6	PP	Medium	1.497	0.1	1	0.5	N
0.381	3.81	6	PP	Fast	1.814	0.1	1	0.5	N
0.336	3.36	6	PP	Very Fast	2.1	0.1	1	0.5	N
0.738	7.38	12	PP	Slow	1.744	0.1	1	0.5	Y
0.575	5.75	12	PP	Medium	2.286	0.1	1	0.5	Y
0.464	4.64	12	PP	Fast	2.899	0.1	1	0.5	Y
0.438	4.38	12	PP	Very Fast	3.093	0.1	1	0.5	Y
0.756	7.56	15	PP	Slow	2.124	0.1	1	0.5	N
0.646	6.46	15	PP	Medium	2.516	0.1	1	0.5	N
0.533	5.33	15	PP	Fast	3.108	0.1	1	0.5	N
0.506	5.06	15	PP	Very Fast	3.286	0.1	1	0.5	N
1.155	11.55	30	PP	Slow	2.715	0.1	1	0.5	Y
0.939	9.39	30	PP	Medium	3.375	0.1	1	0.5	Y
0.776	7.76	30	PP	Fast	4.132	0.1	1	0.5	Y
0.756	7.56	30	PP	Very Fast	4.249	0.1	1	0.5	Y
0.392	3.92	3	KK	Slow	1.225	0.1	1.5	0.5	Y
0.308	3.08	3	SS	Slow	1.591	0.1	1.5	0.5	N
0.258	2.58	3	SS	Medium	1.928	0.1	1.5	0.5	N
0.234	2.34	3	SS	Fast	2.155	0.1	1.5	0.5	N
0.162	1.62	3	SS	Very Fast	3.289	0.1	1.5	0.5	N
0.403	4.03	6	SS	Slow	2.383	0.1	1.5	0.5	N
0.368	3.68	6	SS	Medium	2.622	0.1	1.5	0.5	N
0.299	2.99	6	SS	Fast	3.279	0.1	1.5	0.5	N
0.291	2.91	6	SS	Very Fast	3.386	0.1	1.5	0.5	N
0.666	6.66	12	SS	Slow	2.81	0.1	1.5	0.5	Y
0.592	5.92	12	SS	Medium	3.175	0.1	1.5	0.5	Y
0.515	5.15	12	SS	Fast	3.67	0.1	1.5	0.5	Y
0.474	4.74	12	SS	Very Fast	4.013	0.1	1.5	0.5	Y
0.748	7.48	15	SS	Slow	3.11	0.1	1.5	0.5	Y
0.668	6.68	15	SS	Medium	3.497	0.1	1.5	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.58	5.8	15	SS	Fast	4.051	0.1	1.5	0.5	Y
0.547	5.47	15	SS	Very Fast	4.31	0.1	1.5	0.5	Y
1.282	12.82	30	SS	Slow	3.579	0.1	1.5	0.5	Y
1.073	10.73	30	SS	Medium	4.292	0.1	1.5	0.5	Y
0.946	9.46	30	SS	Fast	4.886	0.1	1.5	0.5	Y
0.859	8.59	30	SS	Very Fast	5.396	0.1	1.5	0.5	Y
0.34	3.4	3	KK	Medium	1.429	0.1	1.5	0.5	Y
0.299	2.99	3	KK	Fast	1.64	0.1	1.5	0.5	Y
0.22	2.2	3	KK	Very Fast	2.308	0.1	1.5	0.5	Y
0.5	5	6	KK	Slow	1.893	0.1	1.5	0.5	Y
0.45	4.5	6	KK	Medium	2.12	0.1	1.5	0.5	Y
0.385	3.85	6	KK	Fast	2.5	0.1	1.5	0.5	Y
0.349	3.49	6	KK	Very Fast	2.778	0.1	1.5	0.5	Y
0.754	7.54	12	KK	Slow	2.469	0.1	1.5	0.5	Y
0.664	6.64	12	KK	Medium	2.817	0.1	1.5	0.5	Y
0.569	5.69	12	KK	Fast	3.306	0.1	1.5	0.5	Y
0.539	5.39	12	KK	Very Fast	3.499	0.1	1.5	0.5	Y
0.854	8.54	15	KK	Slow	2.715	0.1	1.5	0.5	N
0.757	7.57	15	KK	Medium	3.075	0.1	1.5	0.5	N
0.64	6.4	15	KK	Fast	3.659	0.1	1.5	0.5	N
0.605	6.05	15	KK	Very Fast	3.878	0.1	1.5	0.5	N
1.472	14.72	30	KK	Slow	3.109	0.1	1.5	0.5	Y
1.162	11.62	30	KK	Medium	3.958	0.1	1.5	0.5	Y
1.033	10.33	30	KK	Fast	4.464	0.1	1.5	0.5	Y
0.909	9.09	30	KK	Very Fast	5.093	0.1	1.5	0.5	Y
0.623	6.23	3	PP	Slow	0.752	0.1	1.5	0.5	N
0.521	5.21	3	PP	Medium	0.907	0.1	1.5	0.5	N
0.409	4.09	3	PP	Fast	1.173	0.1	1.5	0.5	N
0.325	3.25	3	PP	Very Fast	1.502	0.1	1.5	0.5	N
0.737	7.37	6	PP	Slow	1.264	0.1	1.5	0.5	N
0.626	6.26	6	PP	Medium	1.497	0.1	1.5	0.5	N
0.521	5.21	6	PP	Fast	1.814	0.1	1.5	0.5	N
0.454	4.54	6	PP	Very Fast	2.1	0.1	1.5	0.5	N
1.057	10.57	12	PP	Slow	1.744	0.1	1.5	0.5	Y
0.812	8.12	12	PP	Medium	2.286	0.1	1.5	0.5	Y
0.646	6.46	12	PP	Fast	2.899	0.1	1.5	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.607	6.07	12	PP	Very Fast	3.093	0.1	1.5	0.5	Y
1.084	10.84	15	PP	Slow	2.124	0.1	1.5	0.5	N
0.919	9.19	15	PP	Medium	2.516	0.1	1.5	0.5	N
0.749	7.49	15	PP	Fast	3.108	0.1	1.5	0.5	N
0.71	7.1	15	PP	Very Fast	3.286	0.1	1.5	0.5	N
1.682	16.82	30	PP	Slow	2.715	0.1	1.5	0.5	Y
1.358	13.58	30	PP	Medium	3.375	0.1	1.5	0.5	Y
1.114	11.14	30	PP	Fast	4.132	0.1	1.5	0.5	Y
1.084	10.84	30	PP	Very Fast	4.249	0.1	1.5	0.5	Y
0.377	3.77	3	SS	Slow	1.591	0.1	2	0.5	N
0.311	3.11	3	SS	Medium	1.928	0.1	2	0.5	N
0.278	2.78	3	SS	Fast	2.155	0.1	2	0.5	N
0.182	1.82	3	SS	Very Fast	3.289	0.1	2	0.5	N
0.504	5.04	6	SS	Slow	2.383	0.1	2	0.5	N
0.458	4.58	6	SS	Medium	2.622	0.1	2	0.5	N
0.366	3.66	6	SS	Fast	3.279	0.1	2	0.5	N
0.354	3.54	6	SS	Very Fast	3.386	0.1	2	0.5	N
0.854	8.54	12	SS	Slow	2.81	0.1	2	0.5	Y
0.756	7.56	12	SS	Medium	3.175	0.1	2	0.5	Y
0.654	6.54	12	SS	Fast	3.67	0.1	2	0.5	Y
0.598	5.98	12	SS	Very Fast	4.013	0.1	2	0.5	Y
0.965	9.65	15	SS	Slow	3.11	0.1	2	0.5	Y
0.858	8.58	15	SS	Medium	3.497	0.1	2	0.5	Y
0.741	7.41	15	SS	Fast	4.051	0.1	2	0.5	Y
0.696	6.96	15	SS	Very Fast	4.31	0.1	2	0.5	Y
1.676	16.76	30	SS	Slow	3.579	0.1	2	0.5	Y
1.398	13.98	30	SS	Medium	4.292	0.1	2	0.5	Y
1.228	12.28	30	SS	Fast	4.886	0.1	2	0.5	Y
1.112	11.12	30	SS	Very Fast	5.396	0.1	2	0.5	Y
0.49	4.9	3	KK	Slow	1.225	0.1	2	0.5	Y
0.42	4.2	3	KK	Medium	1.429	0.1	2	0.5	Y
0.366	3.66	3	KK	Fast	1.64	0.1	2	0.5	Y
0.26	2.6	3	KK	Very Fast	2.308	0.1	2	0.5	Y
0.634	6.34	6	KK	Slow	1.893	0.1	2	0.5	Y
0.566	5.66	6	KK	Medium	2.12	0.1	2	0.5	Y
0.48	4.8	6	KK	Fast	2.5	0.1	2	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.432	4.32	6	KK	Very Fast	2.778	0.1	2	0.5	Y
0.972	9.72	12	KK	Slow	2.469	0.1	2	0.5	Y
0.852	8.52	12	KK	Medium	2.817	0.1	2	0.5	Y
0.726	7.26	12	KK	Fast	3.306	0.1	2	0.5	Y
0.686	6.86	12	KK	Very Fast	3.499	0.1	2	0.5	Y
1.105	11.05	15	KK	Slow	2.715	0.1	2	0.5	N
0.976	9.76	15	KK	Medium	3.075	0.1	2	0.5	N
0.82	8.2	15	KK	Fast	3.659	0.1	2	0.5	N
0.774	7.74	15	KK	Very Fast	3.878	0.1	2	0.5	N
1.93	19.3	30	KK	Slow	3.109	0.1	2	0.5	Y
1.516	15.16	30	KK	Medium	3.958	0.1	2	0.5	Y
1.344	13.44	30	KK	Fast	4.464	0.1	2	0.5	Y
1.178	11.78	30	KK	Very Fast	5.093	0.1	2	0.5	Y
0.798	7.98	3	PP	Slow	0.752	0.1	2	0.5	N
0.662	6.62	3	PP	Medium	0.907	0.1	2	0.5	N
0.512	5.12	3	PP	Fast	1.173	0.1	2	0.5	N
0.399	3.99	3	PP	Very Fast	1.502	0.1	2	0.5	N
0.949	9.49	6	PP	Slow	1.264	0.1	2	0.5	N
0.802	8.02	6	PP	Medium	1.497	0.1	2	0.5	N
0.662	6.62	6	PP	Fast	1.814	0.1	2	0.5	N
0.571	5.71	6	PP	Very Fast	2.1	0.1	2	0.5	N
1.376	13.76	12	PP	Slow	1.744	0.1	2	0.5	Y
1.05	10.5	12	PP	Medium	2.286	0.1	2	0.5	Y
0.828	8.28	12	PP	Fast	2.899	0.1	2	0.5	Y
0.776	7.76	12	PP	Very Fast	3.093	0.1	2	0.5	Y
1.412	14.12	15	PP	Slow	2.124	0.1	2	0.5	N
1.192	11.92	15	PP	Medium	2.516	0.1	2	0.5	N
0.965	9.65	15	PP	Fast	3.108	0.1	2	0.5	N
0.913	9.13	15	PP	Very Fast	3.286	0.1	2	0.5	N
2.21	22.1	30	PP	Slow	2.715	0.1	2	0.5	Y
1.778	17.78	30	PP	Medium	3.375	0.1	2	0.5	Y
1.452	14.52	30	PP	Fast	4.132	0.1	2	0.5	Y
1.412	14.12	30	PP	Very Fast	4.249	0.1	2	0.5	Y
0.445	4.446	3	SS	Slow	1.591	0.1	2.5	0.5	N
0.364	3.64	3	SS	Medium	1.928	0.1	2.5	0.5	N
0.323	3.23	3	SS	Fast	2.155	0.1	2.5	0.5	N

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.203	2.03	3	SS	Very Fast	3.289	0.1	2.5	0.5	N
0.604	6.04	6	SS	Slow	2.383	0.1	2.5	0.5	N
0.547	5.47	6	SS	Medium	2.622	0.1	2.5	0.5	N
0.432	4.32	6	SS	Fast	3.279	0.1	2.5	0.5	N
0.418	4.18	6	SS	Very Fast	3.386	0.1	2.5	0.5	N
1.043	10.43	12	SS	Slow	2.81	0.1	2.5	0.5	Y
0.92	9.2	12	SS	Medium	3.175	0.1	2.5	0.5	Y
0.792	7.92	12	SS	Fast	3.67	0.1	2.5	0.5	Y
0.723	7.23	12	SS	Very Fast	4.013	0.1	2.5	0.5	Y
1.181	11.81	15	SS	Slow	3.11	0.1	2.5	0.5	Y
1.047	10.47	15	SS	Medium	3.497	0.1	2.5	0.5	Y
0.901	9.01	15	SS	Fast	4.051	0.1	2.5	0.5	Y
0.845	8.45	15	SS	Very Fast	4.31	0.1	2.5	0.5	Y
2.071	20.71	30	SS	Slow	3.579	0.1	2.5	0.5	Y
1.722	17.22	30	SS	Medium	4.292	0.1	2.5	0.5	Y
1.51	15.1	30	SS	Fast	4.886	0.1	2.5	0.5	Y
1.365	13.65	30	SS	Very Fast	5.396	0.1	2.5	0.5	Y
0.587	5.87	3	KK	Slow	1.225	0.1	2.5	0.5	Y
0.5	5	3	KK	Medium	1.429	0.1	2.5	0.5	Y
0.432	4.32	3	KK	Fast	1.64	0.1	2.5	0.5	Y
0.3	3	3	KK	Very Fast	2.308	0.1	2.5	0.5	Y
0.767	7.67	6	KK	Slow	1.893	0.1	2.5	0.5	Y
0.683	6.83	6	KK	Medium	2.12	0.1	2.5	0.5	Y
0.575	5.75	6	KK	Fast	2.5	0.1	2.5	0.5	Y
0.515	5.15	6	KK	Very Fast	2.778	0.1	2.5	0.5	Y
1.19	11.9	12	KK	Slow	2.469	0.1	2.5	0.5	Y
1.04	10.4	12	KK	Medium	2.817	0.1	2.5	0.5	Y
0.882	8.82	12	KK	Fast	3.306	0.1	2.5	0.5	Y
0.832	8.32	12	KK	Very Fast	3.499	0.1	2.5	0.5	Y
1.356	13.56	15	KK	Slow	2.715	0.1	2.5	0.5	N
1.195	11.95	15	KK	Medium	3.075	0.1	2.5	0.5	N
1	10	15	KK	Fast	3.659	0.1	2.5	0.5	N
0.942	9.42	15	KK	Very Fast	3.878	0.1	2.5	0.5	N
2.387	23.87	30	KK	Slow	3.109	0.1	2.5	0.5	Y
1.87	18.7	30	KK	Medium	3.958	0.1	2.5	0.5	Y
1.655	16.55	30	KK	Fast	4.464	0.1	2.5	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
1.448	14.48	30	KK	Very Fast	5.093	0.1	2.5	0.5	Y
0.972	9.72	3	PP	Slow	0.752	0.1	2.5	0.5	N
0.802	8.02	3	PP	Medium	0.907	0.1	2.5	0.5	N
0.614	6.14	3	PP	Fast	1.173	0.1	2.5	0.5	N
0.474	4.74	3	PP	Very Fast	1.502	0.1	2.5	0.5	N
1.162	11.62	6	PP	Slow	1.264	0.1	2.5	0.5	N
0.977	9.77	6	PP	Medium	1.497	0.1	2.5	0.5	N
0.802	8.02	6	PP	Fast	1.814	0.1	2.5	0.5	N
0.689	6.89	6	PP	Very Fast	2.1	0.1	2.5	0.5	N
1.695	16.95	12	PP	Slow	1.744	0.1	2.5	0.5	Y
1.287	12.87	12	PP	Medium	2.286	0.1	2.5	0.5	Y
1.01	10.1	12	PP	Fast	2.899	0.1	2.5	0.5	Y
0.945	9.45	12	PP	Very Fast	3.093	0.1	2.5	0.5	Y
1.741	17.41	15	PP	Slow	2.124	0.1	2.5	0.5	N
1.465	14.65	15	PP	Medium	2.516	0.1	2.5	0.5	N
1.182	11.82	15	PP	Fast	3.108	0.1	2.5	0.5	N
1.116	11.16	15	PP	Very Fast	3.286	0.1	2.5	0.5	N
2.737	27.37	30	PP	Slow	2.715	0.1	2.5	0.5	Y
2.197	21.97	30	PP	Medium	3.375	0.1	2.5	0.5	Y
1.79	17.9	30	PP	Fast	4.132	0.1	2.5	0.5	Y
1.74	17.4	30	PP	Very Fast	4.249	0.1	2.5	0.5	Y
0.516	5.16	3	SS	Slow	1.591	0.1	3	0.5	N
0.417	4.17	3	SS	Medium	1.928	0.1	3	0.5	N
0.368	3.68	3	SS	Fast	2.155	0.1	3	0.5	N
0.224	2.24	3	SS	Very Fast	3.289	0.1	3	0.5	N
0.705	7.05	6	SS	Slow	2.383	0.1	3	0.5	N
0.636	6.36	6	SS	Medium	2.622	0.1	3	0.5	N
0.499	4.99	6	SS	Fast	3.279	0.1	3	0.5	N
0.482	4.82	6	SS	Very Fast	3.386	0.1	3	0.5	N
1.231	12.31	12	SS	Slow	2.81	0.1	3	0.5	Y
1.084	10.84	12	SS	Medium	3.175	0.1	3	0.5	Y
0.931	9.31	12	SS	Fast	3.67	0.1	3	0.5	Y
0.847	8.47	12	SS	Very Fast	4.013	0.1	3	0.5	Y
1.397	13.97	15	SS	Slow	3.11	0.1	3	0.5	Y
1.237	12.37	15	SS	Medium	3.497	0.1	3	0.5	Y
1.061	10.61	15	SS	Fast	4.051	0.1	3	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.994	9.94	15	SS	Very Fast	4.31	0.1	3	0.5	Y
2.465	24.65	30	SS	Slow	3.579	0.1	3	0.5	Y
2.047	20.47	30	SS	Medium	4.292	0.1	3	0.5	Y
1.792	17.92	30	SS	Fast	4.886	0.1	3	0.5	Y
1.618	16.18	30	SS	Very Fast	5.396	0.1	3	0.5	Y
0.685	6.85	3	KK	Slow	1.225	0.1	3	0.5	Y
0.58	5.8	3	KK	Medium	1.429	0.1	3	0.5	Y
0.499	4.99	3	KK	Fast	1.64	0.1	3	0.5	Y
0.34	3.4	3	KK	Very Fast	2.308	0.1	3	0.5	Y
0.901	9.01	6	KK	Slow	1.893	0.1	3	0.5	Y
0.799	7.99	6	KK	Medium	2.12	0.1	3	0.5	Y
0.67	6.7	6	KK	Fast	2.5	0.1	3	0.5	Y
0.598	5.98	6	KK	Very Fast	2.778	0.1	3	0.5	Y
1.408	14.08	12	KK	Slow	2.469	0.1	3	0.5	Y
1.228	12.28	12	KK	Medium	2.817	0.1	3	0.5	Y
1.039	10.39	12	KK	Fast	3.306	0.1	3	0.5	Y
0.979	9.79	12	KK	Very Fast	3.499	0.1	3	0.5	Y
1.607	16.07	15	KK	Slow	2.715	0.1	3	0.5	N
1.413	14.13	15	KK	Medium	3.075	0.1	3	0.5	N
1.18	11.8	15	KK	Fast	3.659	0.1	3	0.5	N
1.11	11.1	15	KK	Very Fast	3.878	0.1	3	0.5	N
2.845	28.45	30	KK	Slow	3.109	0.1	3	0.5	Y
2.224	22.24	30	KK	Medium	3.958	0.1	3	0.5	Y
1.966	19.66	30	KK	Fast	4.464	0.1	3	0.5	Y
1.717	17.17	30	KK	Very Fast	5.093	0.1	3	0.5	Y
1.147	11.47	3	PP	Slow	0.752	0.1	3	0.5	N
0.942	9.42	3	PP	Medium	0.907	0.1	3	0.5	N
0.717	7.17	3	PP	Fast	1.173	0.1	3	0.5	N
0.549	5.49	3	PP	Very Fast	1.502	0.1	3	0.5	N
1.374	13.74	6	PP	Slow	1.264	0.1	3	0.5	N
1.152	11.52	6	PP	Medium	1.497	0.1	3	0.5	N
0.942	9.42	6	PP	Fast	1.814	0.1	3	0.5	N
0.807	8.07	6	PP	Very Fast	2.1	0.1	3	0.5	N
2.014	20.14	12	PP	Slow	1.744	0.1	3	0.5	Y
1.525	15.25	12	PP	Medium	2.286	0.1	3	0.5	Y
1.192	11.92	12	PP	Fast	2.899	0.1	3	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
1.114	11.14	12	PP	Very Fast	3.093	0.1	3	0.5	Y
2.069	20.69	15	PP	Slow	2.124	0.1	3	0.5	N
1.739	17.39	15	PP	Medium	2.516	0.1	3	0.5	N
1.398	13.98	15	PP	Fast	3.108	0.1	3	0.5	N
1.319	13.19	15	PP	Very Fast	3.286	0.1	3	0.5	N
3.265	32.65	30	PP	Slow	2.715	0.1	3	0.5	Y
2.617	26.17	30	PP	Medium	3.375	0.1	3	0.5	Y
2.128	21.28	30	PP	Fast	4.132	0.1	3	0.5	Y
2.068	20.68	30	PP	Very Fast	4.249	0.1	3	0.5	Y
0.585	5.85	3	SS	Slow	1.591	0.1	3.5	0.5	N
0.47	4.7	3	SS	Medium	1.928	0.1	3.5	0.5	N
0.412	4.12	3	SS	Fast	2.155	0.1	3.5	0.5	N
0.244	2.44	3	SS	Very Fast	3.289	0.1	3.5	0.5	N
0.806	8.06	6	SS	Slow	2.383	0.1	3.5	0.5	N
0.726	7.26	6	SS	Medium	2.622	0.1	3.5	0.5	N
0.565	5.65	6	SS	Fast	3.279	0.1	3.5	0.5	N
0.545	5.45	6	SS	Very Fast	3.386	0.1	3.5	0.5	N
1.42	14.2	12	SS	Slow	2.81	0.1	3.5	0.5	Y
1.248	12.48	12	SS	Medium	3.175	0.1	3.5	0.5	Y
1.069	10.69	12	SS	Fast	3.67	0.1	3.5	0.5	Y
0.972	9.72	12	SS	Very Fast	4.013	0.1	3.5	0.5	Y
1.613	16.13	15	SS	Slow	3.11	0.1	3.5	0.5	Y
1.426	14.26	15	SS	Medium	3.497	0.1	3.5	0.5	Y
1.221	12.21	15	SS	Fast	4.051	0.1	3.5	0.5	Y
1.143	11.43	15	SS	Very Fast	4.31	0.1	3.5	0.5	Y
2.859	28.59	30	SS	Slow	3.579	0.1	3.5	0.5	Y
2.371	23.71	30	SS	Medium	4.292	0.1	3.5	0.5	Y
2.074	20.74	30	SS	Fast	4.886	0.1	3.5	0.5	Y
1.871	18.71	30	SS	Very Fast	5.396	0.1	3.5	0.5	Y
0.782	7.82	3	KK	Slow	1.225	0.1	3.5	0.5	Y
0.66	6.6	3	KK	Medium	1.429	0.1	3.5	0.5	Y
0.565	5.65	3	KK	Fast	1.64	0.1	3.5	0.5	Y
0.38	3.8	3	KK	Very Fast	2.308	0.1	3.5	0.5	Y
1.034	10.34	6	KK	Slow	1.893	0.1	3.5	0.5	Y
0.916	9.16	6	KK	Medium	2.12	0.1	3.5	0.5	Y
0.765	7.65	6	KK	Fast	2.5	0.1	3.5	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.681	6.81	6	KK	Very Fast	2.778	0.1	3.5	0.5	Y
1.626	16.26	12	KK	Slow	2.469	0.1	3.5	0.5	Y
1.416	14.16	12	KK	Medium	2.817	0.1	3.5	0.5	Y
1.195	11.95	12	KK	Fast	3.306	0.1	3.5	0.5	Y
1.125	11.25	12	KK	Very Fast	3.499	0.1	3.5	0.5	Y
1.859	18.59	15	KK	Slow	2.715	0.1	3.5	0.5	N
1.632	16.32	15	KK	Medium	3.075	0.1	3.5	0.5	N
1.36	13.6	15	KK	Fast	3.659	0.1	3.5	0.5	N
1.279	12.79	15	KK	Very Fast	3.878	0.1	3.5	0.5	N
3.302	33.02	30	KK	Slow	3.109	0.1	3.5	0.5	Y
2.578	25.78	30	KK	Medium	3.958	0.1	3.5	0.5	Y
2.277	22.77	30	KK	Fast	4.464	0.1	3.5	0.5	Y
1.987	19.87	30	KK	Very Fast	5.093	0.1	3.5	0.5	Y
1.321	13.21	3	PP	Slow	0.752	0.1	3.5	0.5	N
1.083	10.83	3	PP	Medium	0.907	0.1	3.5	0.5	N
0.82	8.2	3	PP	Fast	1.173	0.1	3.5	0.5	N
0.624	6.24	3	PP	Very Fast	1.502	0.1	3.5	0.5	N
1.586	15.86	6	PP	Slow	1.264	0.1	3.5	0.5	N
1.328	13.28	6	PP	Medium	1.497	0.1	3.5	0.5	N
1.083	10.83	6	PP	Fast	1.814	0.1	3.5	0.5	N
0.925	9.25	6	PP	Very Fast	2.1	0.1	3.5	0.5	N
2.333	23.33	12	PP	Slow	1.744	0.1	3.5	0.5	Y
1.762	17.62	12	PP	Medium	2.286	0.1	3.5	0.5	Y
1.374	13.74	12	PP	Fast	2.899	0.1	3.5	0.5	Y
1.283	12.83	12	PP	Very Fast	3.093	0.1	3.5	0.5	Y
2.397	23.97	15	PP	Slow	2.124	0.1	3.5	0.5	N
2.012	20.12	15	PP	Medium	2.516	0.1	3.5	0.5	N
1.614	16.14	15	PP	Fast	3.108	0.1	3.5	0.5	N
1.523	15.23	15	PP	Very Fast	3.286	0.1	3.5	0.5	N
3.792	37.92	30	PP	Slow	2.715	0.1	3.5	0.5	Y
3.036	30.36	30	PP	Medium	3.375	0.1	3.5	0.5	Y
2.466	24.66	30	PP	Fast	4.132	0.1	3.5	0.5	Y
2.396	23.96	30	PP	Very Fast	4.249	0.1	3.5	0.5	Y
0.654	6.54	3	SS	Slow	1.591	0.1	4	0.5	N
0.522	5.22	3	SS	Medium	1.928	0.1	4	0.5	N
0.457	4.57	3	SS	Fast	2.155	0.1	4	0.5	N

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.265	2.65	3	SS	Very Fast	3.289	0.1	4	0.5	N
0.907	9.07	6	SS	Slow	2.383	0.1	4	0.5	N
0.815	8.15	6	SS	Medium	2.622	0.1	4	0.5	N
0.632	6.32	6	SS	Fast	3.279	0.1	4	0.5	N
0.609	6.09	6	SS	Very Fast	3.386	0.1	4	0.5	N
1.608	16.08	12	SS	Slow	2.81	0.1	4	0.5	Y
1.412	14.12	12	SS	Medium	3.175	0.1	4	0.5	Y
1.208	12.08	12	SS	Fast	3.67	0.1	4	0.5	Y
1.096	10.96	12	SS	Very Fast	4.013	0.1	4	0.5	Y
1.829	18.29	15	SS	Slow	3.11	0.1	4	0.5	Y
1.616	16.16	15	SS	Medium	3.497	0.1	4	0.5	Y
1.381	13.81	15	SS	Fast	4.051	0.1	4	0.5	Y
1.292	12.92	15	SS	Very Fast	4.31	0.1	4	0.5	Y
3.253	32.53	30	SS	Slow	3.579	0.1	4	0.5	Y
2.696	26.96	30	SS	Medium	4.292	0.1	4	0.5	Y
2.356	23.56	30	SS	Fast	4.886	0.1	4	0.5	Y
2.124	21.24	30	SS	Very Fast	5.396	0.1	4	0.5	Y
0.88	8.8	3	KK	Slow	1.225	0.1	4	0.5	Y
0.74	7.4	3	KK	Medium	1.429	0.1	4	0.5	Y
0.632	6.32	3	KK	Fast	1.64	0.1	4	0.5	Y
0.42	4.2	3	KK	Very Fast	2.308	0.1	4	0.5	Y
1.168	11.68	6	KK	Slow	1.893	0.1	4	0.5	Y
1.032	10.32	6	KK	Medium	2.12	0.1	4	0.5	Y
0.86	8.6	6	KK	Fast	2.5	0.1	4	0.5	Y
0.764	7.64	6	KK	Very Fast	2.778	0.1	4	0.5	Y
1.844	18.44	12	KK	Slow	2.469	0.1	4	0.5	Y
1.604	16.04	12	KK	Medium	2.817	0.1	4	0.5	Y
1.352	13.52	12	KK	Fast	3.306	0.1	4	0.5	Y
1.272	12.72	12	KK	Very Fast	3.499	0.1	4	0.5	Y
2.11	21.1	15	KK	Slow	2.715	0.1	4	0.5	N
1.851	18.51	15	KK	Medium	3.075	0.1	4	0.5	N
1.54	15.4	15	KK	Fast	3.659	0.1	4	0.5	N
1.447	14.47	15	KK	Very Fast	3.878	0.1	4	0.5	N
3.76	37.6	30	KK	Slow	3.109	0.1	4	0.5	Y
2.932	29.32	30	KK	Medium	3.958	0.1	4	0.5	Y
2.588	25.88	30	KK	Fast	4.464	0.1	4	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
2.256	22.56	30	KK	Very Fast	5.093	0.1	4	0.5	Y
1.496	14.96	3	PP	Slow	0.752	0.1	4	0.5	N
1.223	12.23	3	PP	Medium	0.907	0.1	4	0.5	N
0.923	9.23	3	PP	Fast	1.173	0.1	4	0.5	N
0.699	6.99	3	PP	Very Fast	1.502	0.1	4	0.5	N
1.799	17.99	6	PP	Slow	1.264	0.1	4	0.5	N
1.503	15.03	6	PP	Medium	1.497	0.1	4	0.5	N
1.223	12.23	6	PP	Fast	1.814	0.1	4	0.5	N
1.043	10.43	6	PP	Very Fast	2.1	0.1	4	0.5	N
2.652	26.52	12	PP	Slow	1.744	0.1	4	0.5	Y
2	20	12	PP	Medium	2.286	0.1	4	0.5	Y
1.556	15.56	12	PP	Fast	2.899	0.1	4	0.5	Y
1.452	14.52	12	PP	Very Fast	3.093	0.1	4	0.5	Y
2.397	23.97	15	PP	Slow	2.124	0.1	4	0.5	N
2.012	20.12	15	PP	Medium	2.516	0.1	4	0.5	N
1.614	16.14	15	PP	Fast	3.108	0.1	4	0.5	N
1.523	15.23	15	PP	Very Fast	3.286	0.1	4	0.5	N
4.32	43.2	30	PP	Slow	2.715	0.1	4	0.5	Y
3.456	34.56	30	PP	Medium	3.375	0.1	4	0.5	Y
2.804	28.04	30	PP	Fast	4.132	0.1	4	0.5	Y
2.724	27.24	30	PP	Very Fast	4.249	0.1	4	0.5	Y
0.724	7.24	3	SS	Slow	1.591	0.1	4.5	0.5	N
0.575	5.75	3	SS	Medium	1.928	0.1	4.5	0.5	N
0.501	5.01	3	SS	Fast	2.155	0.1	4.5	0.5	N
0.285	2.85	3	SS	Very Fast	3.289	0.1	4.5	0.5	N
1.008	10.08	6	SS	Slow	2.383	0.1	4.5	0.5	N
0.905	9.05	6	SS	Medium	2.622	0.1	4.5	0.5	N
0.698	6.98	6	SS	Fast	3.279	0.1	4.5	0.5	N
0.672	6.72	6	SS	Very Fast	3.386	0.1	4.5	0.5	N
1.797	17.97	12	SS	Slow	2.81	0.1	4.5	0.5	Y
1.576	15.76	12	SS	Medium	3.175	0.1	4.5	0.5	Y
1.346	13.46	12	SS	Fast	3.67	0.1	4.5	0.5	Y
1.221	12.21	12	SS	Very Fast	4.013	0.1	4.5	0.5	Y
2.045	20.45	15	SS	Slow	3.11	0.1	4.5	0.5	Y
1.805	18.05	15	SS	Medium	3.497	0.1	4.5	0.5	Y
1.541	15.41	15	SS	Fast	4.051	0.1	4.5	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
1.441	14.41	15	SS	Very Fast	4.31	0.1	4.5	0.5	Y
3.647	36.47	30	SS	Slow	3.579	0.1	4.5	0.5	Y
3.02	30.2	30	SS	Medium	4.292	0.1	4.5	0.5	Y
2.638	26.38	30	SS	Fast	4.886	0.1	4.5	0.5	Y
2.377	23.77	30	SS	Very Fast	5.396	0.1	4.5	0.5	Y
0.977	9.77	3	KK	Slow	1.225	0.1	4.5	0.5	Y
0.82	8.2	3	KK	Medium	1.429	0.1	4.5	0.5	Y
0.698	6.98	3	KK	Fast	1.64	0.1	4.5	0.5	Y
0.46	4.6	3	KK	Very Fast	2.308	0.1	4.5	0.5	Y
1.301	13.01	6	KK	Slow	1.893	0.1	4.5	0.5	Y
1.149	11.49	6	KK	Medium	2.12	0.1	4.5	0.5	Y
0.955	9.55	6	KK	Fast	2.5	0.1	4.5	0.5	Y
0.847	8.47	6	KK	Very Fast	2.778	0.1	4.5	0.5	Y
2.062	20.62	12	KK	Slow	2.469	0.1	4.5	0.5	Y
179.2	1792	12	KK	Medium	2.817	0.1	4.5	0.5	Y
1.508	15.08	12	KK	Fast	3.306	0.1	4.5	0.5	Y
1.418	14.18	12	KK	Very Fast	3.499	0.1	4.5	0.5	Y
2.361	23.61	15	KK	Slow	2.715	0.1	4.5	0.5	N
2.07	20.7	15	KK	Medium	3.075	0.1	4.5	0.5	N
1.72	17.2	15	KK	Fast	3.659	0.1	4.5	0.5	N
1.616	16.16	15	KK	Very Fast	3.878	0.1	4.5	0.5	N
4.217	42.17	30	KK	Slow	3.109	0.1	4.5	0.5	Y
3.286	32.86	30	KK	Medium	3.958	0.1	4.5	0.5	Y
2.899	28.99	30	KK	Fast	4.464	0.1	4.5	0.5	Y
2.526	25.26	30	KK	Very Fast	5.093	0.1	4.5	0.5	Y
1.67	16.7	3	PP	Slow	0.752	0.1	4.5	0.5	N
1.363	13.63	3	PP	Medium	0.907	0.1	4.5	0.5	N
1.026	10.26	3	PP	Fast	1.173	0.1	4.5	0.5	N
0.774	7.74	3	PP	Very Fast	1.502	0.1	4.5	0.5	N
2.011	20.11	6	PP	Slow	1.264	0.1	4.5	0.5	N
1.679	16.79	6	PP	Medium	1.497	0.1	4.5	0.5	N
1.363	13.63	6	PP	Fast	1.814	0.1	4.5	0.5	N
1.161	11.61	6	PP	Very Fast	2.1	0.1	4.5	0.5	N
2.971	29.71	12	PP	Slow	1.744	0.1	4.5	0.5	Y
2.237	22.37	12	PP	Medium	2.286	0.1	4.5	0.5	Y
1.738	17.38	12	PP	Fast	2.899	0.1	4.5	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
1.621	16.21	12	PP	Very Fast	3.093	0.1	4.5	0.5	Y
2.725	27.25	15	PP	Slow	2.124	0.1	4.5	0.5	N
2.285	22.85	15	PP	Medium	2.516	0.1	4.5	0.5	N
1.831	18.31	15	PP	Fast	3.108	0.1	4.5	0.5	N
1.726	17.26	15	PP	Very Fast	3.286	0.1	4.5	0.5	N
4.847	48.47	30	PP	Slow	2.715	0.1	4.5	0.5	Y
3.875	38.75	30	PP	Medium	3.375	0.1	4.5	0.5	Y
3.142	31.42	30	PP	Fast	4.132	0.1	4.5	0.5	Y
3.052	30.52	30	PP	Very Fast	4.249	0.1	4.5	0.5	Y
0.793	7.93	3	SS	Slow	1.591	0.1	5	0.5	N
0.628	6.28	3	SS	Medium	1.928	0.1	5	0.5	N
0.546	5.46	3	SS	Fast	2.155	0.1	5	0.5	N
0.306	3.06	3	SS	Very Fast	3.289	0.1	5	0.5	N
1.109	11.09	6	SS	Slow	2.383	0.1	5	0.5	N
0.994	9.94	6	SS	Medium	2.622	0.1	5	0.5	N
0.765	7.65	6	SS	Fast	3.279	0.1	5	0.5	N
0.736	7.36	6	SS	Very Fast	3.386	0.1	5	0.5	N
1.985	19.85	12	SS	Slow	2.81	0.1	5	0.5	Y
1.74	17.4	12	SS	Medium	3.175	0.1	5	0.5	Y
1.485	14.85	12	SS	Fast	3.67	0.1	5	0.5	Y
1.345	13.45	12	SS	Very Fast	4.013	0.1	5	0.5	Y
2.262	22.62	15	SS	Slow	3.11	0.1	5	0.5	Y
1.995	19.95	15	SS	Medium	3.497	0.1	5	0.5	Y
1.701	17.01	15	SS	Fast	4.051	0.1	5	0.5	Y
1.59	15.9	15	SS	Very Fast	4.31	0.1	5	0.5	Y
4.041	40.41	30	SS	Slow	3.579	0.1	5	0.5	Y
3.345	33.45	30	SS	Medium	4.292	0.1	5	0.5	Y
2.92	29.2	30	SS	Fast	4.886	0.1	5	0.5	Y
2.63	26.3	30	SS	Very Fast	5.396	0.1	5	0.5	Y
1.074	10.74	3	KK	Slow	1.225	0.1	5	0.5	Y
0.9	9	3	KK	Medium	1.429	0.1	5	0.5	Y
0.765	7.65	3	KK	Fast	1.64	0.1	5	0.5	Y
0.5	5	3	KK	Very Fast	2.308	0.1	5	0.5	Y
1.435	14.35	6	KK	Slow	1.893	0.1	5	0.5	Y
1.265	12.65	6	KK	Medium	2.12	0.1	5	0.5	Y
1.05	10.5	6	KK	Fast	2.5	0.1	5	0.5	Y

Table E.1. Lookup Table to Find Hits or Shots Given Distance, Velocity, Posture, Shooting Accuracy and Shooting Cadence. (Continued)

Hits	Shots	Distance	Posture	Mode	Rushing Velocity	Shooting Accuracy	Shooting Cadence	Reaction Time	Position Measured
0.93	9.3	6	KK	Very Fast	2.778	0.1	5	0.5	Y
2.28	22.8	12	KK	Slow	2.469	0.1	5	0.5	Y
1.98	19.8	12	KK	Medium	2.817	0.1	5	0.5	Y
1.665	16.65	12	KK	Fast	3.306	0.1	5	0.5	Y
1.565	15.65	12	KK	Very Fast	3.499	0.1	5	0.5	Y
2.612	26.12	15	KK	Slow	2.715	0.1	5	0.5	N
2.289	22.89	15	KK	Medium	3.075	0.1	5	0.5	N
1.9	19	15	KK	Fast	3.659	0.1	5	0.5	N
1.784	17.84	15	KK	Very Fast	3.878	0.1	5	0.5	N
4.675	46.75	30	KK	Slow	3.109	0.1	5	0.5	Y
3.64	36.4	30	KK	Medium	3.958	0.1	5	0.5	Y
3.21	32.1	30	KK	Fast	4.464	0.1	5	0.5	Y
2.795	27.95	30	KK	Very Fast	5.093	0.1	5	0.5	Y
1.845	18.45	3	PP	Slow	0.752	0.1	5	0.5	N
1.504	15.04	3	PP	Medium	0.907	0.1	5	0.5	N
1.129	11.29	3	PP	Fast	1.173	0.1	5	0.5	N
0.849	8.49	3	PP	Very Fast	1.502	0.1	5	0.5	N
2.223	22.23	6	PP	Slow	1.264	0.1	5	0.5	N
1.854	18.54	6	PP	Medium	1.497	0.1	5	0.5	N
1.504	15.04	6	PP	Fast	1.814	0.1	5	0.5	N
1.279	12.79	6	PP	Very Fast	2.1	0.1	5	0.5	N
3.29	32.9	12	PP	Slow	1.744	0.1	5	0.5	Y
2.475	24.75	12	PP	Medium	2.286	0.1	5	0.5	Y
1.92	19.2	12	PP	Fast	2.899	0.1	5	0.5	Y
1.79	17.9	12	PP	Very Fast	3.093	0.1	5	0.5	Y
3.381	33.81	15	PP	Slow	2.124	0.1	5	0.5	N
2.831	28.31	15	PP	Medium	2.516	0.1	5	0.5	N
2.263	22.63	15	PP	Fast	3.108	0.1	5	0.5	N
2.132	21.32	15	PP	Very Fast	3.286	0.1	5	0.5	N
5.375	53.75	30	PP	Slow	2.715	0.1	5	0.5	Y
4.294	42.94	30	PP	Medium	3.375	0.1	5	0.5	Y
3.48	34.8	30	PP	Fast	4.132	0.1	5	0.5	Y
3.38	33.8	30	PP	Very Fast	4.249	0.1	5	0.5	Y

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EDUCATION

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M.S. Computer Science 2000, **College of William and Mary, Williamsburg, VA**

M.B.A 1991, **Frostburg State University, Frostburg, MD**

B.S. Computer Science, Minor: Math, 1986 **Virginia Polytechnic Institute and State University, Blacksburg, VA**

EXPERIENCE

Unisys Incorporated, Hampton, VA (January 2000-July 2007)
Simulation Software Engineer

- Designed software to improve use of SCRAMNet access to work in heap and shared memory.
- Designed and wrote updates to sound system in flight simulation cockpits to send sound information via TCP/IP to Windows computers from flight simulations run on a Linux platform.
- Designed and wrote software which changed the composition of the cockpit panels to enable exchange of various hardware panels without changes to simulation and enable intermittent updates from hardware.
- Updated graphics software to enable execution on Windows in addition to the Linux platforms.
- Team Lead for the Generic Aircraft Software. Software consisted of a main thread, and threads for each hardware component with the system.
- Unisys Team Lead for CMMI (Capability Maturity Model Integration) Implementation.
- Listed as one of several contributors to the LaSRS++ Framework.

HealthTek Solutions, Inc, Norfolk, VA (October 1996- January 2001)
Consultant

- Wrote customized software solutions for medical accounting systems including hospitals and physician systems

Riverside Regional Medical Center, Newport News, VA (1990-1995)
Systems Analyst

- Maintained On-Call Support for MediPAC Patient Accounting System
- Extended MediPAC Patient Accounting System features by writing COBOL and JCL software

Alleghany Ballistics Laboratory, Rocket Center, WV (1986-1990)
Programmer Analyst

- Wrote and designed software for Human Resources in 4GL FOCUS
- Helped finalize system for statistical database of solid rocket motor propellant dog bone samples in SAS
- Designed software for CSCS contract management in 4GL FOCUS
- Maintained COBOL software used in contract negotiations