

Defining Adaptation of Space Medicine within Military Medicine

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Abstract

Aim: The study aims to determine the viability of integration between Military Medicine and Space Medicine for clinicians to improve their scope of practice, casualty variety, and confidence in unexpected situations that may influence other medical specialties over time through the development of Space Warfare Medicine.

Methods: Methods chosen facilitate the search for specific literature that applies to Space Medicine or Military Medicine while also observing perspectives from clinicians in the respective medical specialties.

Results: The integration of Space Medicine into Military Medicine is essential in the medical community as demands increase for clinicians trained in both Emergency Medicine and Space Medicine practices with the development of the USSF and commercialized space travel. Furthermore, Space Medicine is still very dangerous and proves to be far more complex than other specialties in which clinicians have limited time to adapt at the point of injury where unexpected events are likely to occur.

Conclusion: The significance of the ability to adapt to adverse conditions as the main connection between Military Medicine and Space Medicine justifies Space Medicine's high affinity with Military Medicine to integrate into Space Warfare Medicine.

Keywords: Military Medicine; Space Medicine; Space Warfare Medicine; space casualties; space travel; microgravity; United States Space Force (USSF)

Introduction

Medicine is the branch of science that involves the study of the human body and how to reestablish proper functionality when the body is unbalanced and in danger. When the body is wounded or unbalanced, medical practices are used to treat the body, these practices include numerous types of drugs and physical interventions that are scaled from minor to major [1]. Major interventions can include amputation or other surgeries, minor interventions can include topical drug application or store-bought drug treatment. Medicine contains several different specialties including Military Medicine and Space Medicine. Military Medicine is the study of medicine utilized by military personnel, its practice covers medicine practiced on the battlefield (prehospital medicine) to medicine practiced in Military Treatment Facilities (MTFs). On the other hand, Space Medicine is the study of medicine utilized in microgravity (also known as zero gravity) and for patients that have experienced prolonged exposure to microgravity [2].

Currently, as emphasis increases on space travel and exploration, human presence aside from unmanned machinery will become essential as machinery may not sustain functionality in unexpected events that disable electronic systems [3]. To prepare for such occurrences, the specialties of Space Medicine practice must be integrated into Military Medicine and provide training to medical personnel in the event casualties occurring from unexpected sources are covered by Military Medicine's scope of practice. At the moment,

there are no studies that directly advocate for the integration of Space Medicine into Military Medicine as a means to expand Military Medicine's scope of practice. Current literature focuses on observing the effects of microgravity upon the human body and how to maintain optimum functionality in sustained microgravity environments [2]. While Space Medicine literature focuses on the impact of microgravity, Military Medicine literature focuses on the prolonged use of prehospital medicine and improving the efficacy of prehospital medicine at the point of injury or en route to an MTF [4]. Military Medicine currently covers the point of injury and en route treatment in terrestrial environments and has no reference for microgravity environments before reaching a well-equipped medical facility. Although astronauts are trained similarly to paramedics with similar certifications, in preparation for the possibility of public space transportation where there may be several untrained personnel at any given moment, military personnel should also be trained with Space Medicine practices where military protection is needed in Space.

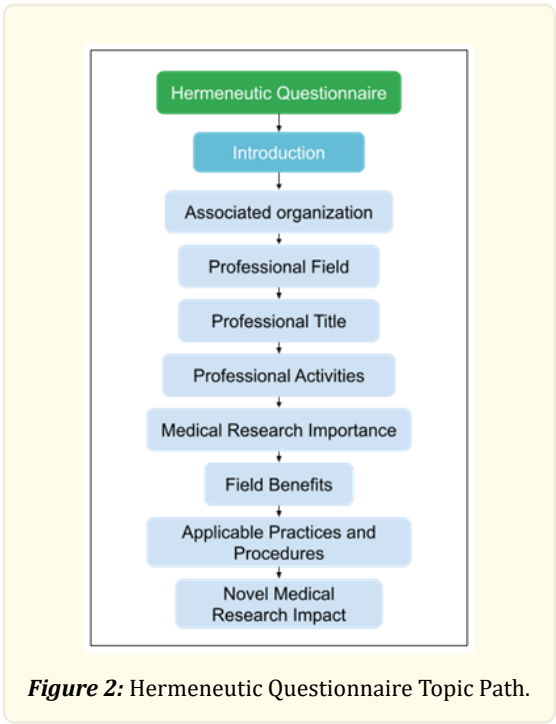
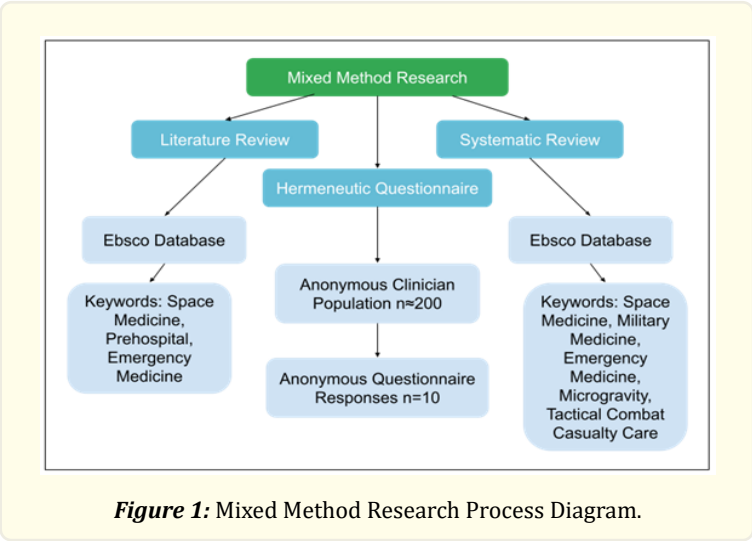
Aim

This research study has been developed to acknowledge and address the gap in Military Medicine information in relation to Space or microgravity environments through the lenses of medical, space, and military professionals. Subsequently, the study designs and demarcates the areas of care covered by Military Medicine that are absent in Space Medicine and their limits through the application of professional subject lenses. There appears to be a deficiency of understanding of Military Medicine's application within Space Medicine that impacts the medical industry by causing uncertainty concerning prehospital care and combat environments in space, especially with the implementation of the United States Space Force (USSF). The study aims to determine the viability of integration between Military Medicine and Space Medicine for clinicians to improve their scope of practice, casualty variety, and confidence in unexpected situations that may influence other medical specialties over time through the development of Space Warfare Medicine.

Methods

The method chosen shown in figures 1 and 2 is mixed-method research approved by a local institutional review board that combines literature review, systematic review, and hermeneutic research, specifically the use of a questionnaire to observe Military Medicine and Space Medicine clinicians' perceptions of their counterparts in the study. Questionnaires directed to Space Medicine clinicians succinctly asked questions regarding their perceptions of Military Medicine and select practices from Military Medicine. (Appendices A & B) Questionnaires were also directed to Military Medicine clinicians that would ask questions regarding their perceptions of Space Medicine and select practices from Space Medicine. Questions 1-4 of the questionnaires inquire about the background of each of the participants anonymously and the activities related to their professions for reference. Questions 5 and 6 gauge the participants' understanding of research and the importance of policy or procedure changes whereas questions 7 and 8 inquire about the benefits of Space Medicine practices and procedures to Military Medicine and vice versa. Questions 9-11 direct the participants' attention to practices and procedures of Military Medicine that could apply to Space Medicine, and reciprocally. Question 12 ends the questionnaires by gauging the impact of Space Medicine and Military Medicine research on each other from the perspectives of the participants.

Besides the hermeneutic research, a systematic review was conducted, mainly using the EBSCO research database, to observe the practices of Space Medicine in the research literature that could be integrated into Military Medicine. The research literature targeted included Space Medicine studies that involved the use of medicine in emergencies, mid-flight treatment, and other research involving the effects of microgravity on the human body. Other research literature targeted included Military Medicine studies that involved the scope of practice of Military Medicine in addition to prehospital medicine studies. Additionally, a literature review was conducted to describe the ability of current research literature to relate Space Medicine and Military Medicine without the conclusive approach that the systematic review utilizes. The research methods chosen to conduct this study were chosen as other methods required access to patient data or would fail to properly depict the purpose of the study from the researcher's perspective. This extensive literature search excluded published works that were not written in English, did not relate to Military Medicine or prehospital Space Medicine, that included animal models, or opinion articles.



Hence, the mixed-method chosen best aligned with the research question as it allows the researcher to search for literature that applies to Space Medicine or Military Medicine specifically while also gathering perspectives from clinicians from their respective medical specialties. All research conducted in this study is designed to define areas of Military Medicine that do not cover microgravity environments and similar Space Medicine situations. The study is also designed to address the lack of integration between Military Medicine and Space Medicine as Space Warfare Medicine to the effect that future research can be conducted to implement practices and procedures that further prepare medical personnel of both Space Medicine and Military Medicine backgrounds for unexpected medical complications in microgravity environments.

Results

Literature Review

Current medical research literature displays several facets where Military Medicine and Space Medicine can benefit from integration, an example in Military Medicine is the introduction of Tactical Combat Casualty Care (TCCC) developed in Afghanistan and its basis on immediate evidence based-treatment algorithms for combat environments preventing mortal injury [5]. The majority of casualties on the conventional battlefield are not survivable and roughly a quarter of casualties observed were survivable [6]. In microgravity, non-survivable casualties are exaggerated further and the percentage of survivable casualties is likely to be less than the 25% of survivable casualties observed in the military environment. Since most casualties related to hemorrhage, the types of prehospital interventions taken in Afghanistan that were typically successful were the most common interventions [1]. The expansion of injuries and specialties posed by Space Medicine and microgravity environments requires more training for medical practitioners in Military Medicine for applications related to microgravity and Space Medicine. TCCC in space requires the understanding of space weaponry and war as types of anti-satellite (ASAT) technology are expected to be used in space combat such as those that use light amplification by the stimulated emission of radiation (LASER), radiation, or hypervelocity technology thus impacting the variety of casualties sustained in space warfare in contrast to conventional warfare [7]. In addition to the increased variation of injuries in microgravity environments, it has been proven that the usage of detailed documentation and analysis can be used in conjunction with TCCC to address key issues and improve its efficacy [4, 8, 9].

Another adaptation is through the implementation of military Medical Evacuation (MEDEVAC) practices in space as well as policies adopted by Helicopter Emergency Medical Services (HEMS) using critical care-trained flight paramedics (CCFP) that is important to sustain the life of a severely injured casualty where Civilian Treatment Facilities (CTFs) or Military Treatment Facilities (MTFs) are likely to be days away from the point of injury (POI) [10]. Typically, less severe casualties mostly utilize Conventional Military Retrieval (CMR) as opposed to HEMS or Advanced Military Retrieval (AMR), however, the nature of CMR requires a terrestrial vehicle and thus cannot be utilized where AMR will be the only transportation medium used unless the injuries occur in the context of a terrestrial environment where MTFs are available [11]. Although there have been minimal changes in terrestrial mortality between the two methods in low, mid, and high-rated injury, the time to operate in both mid and high-rated injuries was less with AMR. Changes described between retrieval methods in terrestrial studies show that AMR and HEMS have a higher rate of mortality, however, it should be noted that this increase in mortality is related to the use of HEMS for higher priority triage casualties [12]. Regarding microgravity mortality between the two methods, it should be stated that AMR in spacecraft is speculated to be far less intrusive than CMR in space and as such would provide a lower mortality rate with a far faster time to operation. Spacecraft in the role of AMR is less reliant on gravity and terrain to provide a surface for CMR vehicles to travel on that could introduce interruptions of care through external forces. The role of a space medicine provider is to overcome the challenges that are faced in microgravity situations where there is limited access to the full capabilities of an established hospital, this can be assisted with the use of telehealth for medical intervention during missions [2, 13]. Adaptation of military telehealth services can benefit emergency medical care in microgravity environments where personnel may not be confident in their treatment of casualties and life-sustaining care beyond TCCC as there are several approaches to medical situations while in microgravity and the approaches differ from similar terrestrial medicine treatment.

Systematic Review

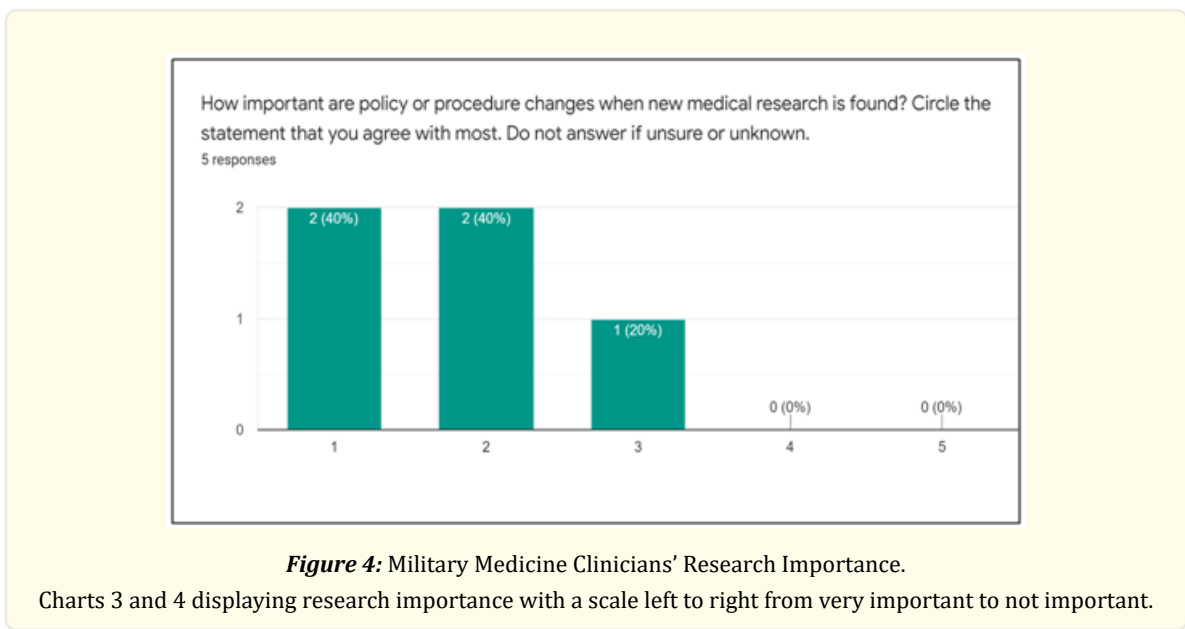
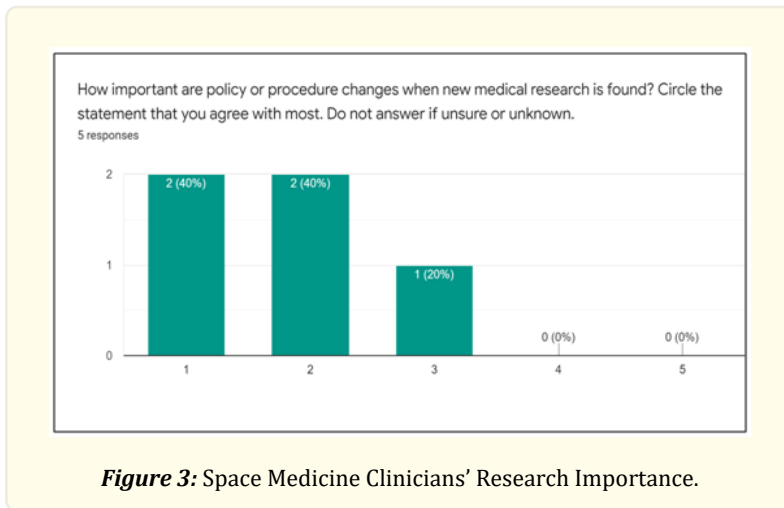
Modern Military Medicine itself has progressed significantly from previous decades, the implementation of Tactical Combat Casualty Care (TCCC) has improved care from the point of injury and enroute treatment significantly which are both conditions that Space Medicine clinicians are familiar with on space expeditions. TCCC was developed in 2013 as "more than 24% of prehospital deaths on the battlefield are categorized as 'potentially survivable,'" the Joint Trauma System (JTS) established in 2006 had determined that the introduction of TCCC and the Prehospital Trauma Registry (PHTR) would increase survivability at the point of injury [5, 14]. Since the implementation of TCCC, survivability has significantly improved from previous wars such as World War II (80%) and Vietnam (84%)

to surpassing 90% survivability from explosive fragmentation and gunshot wounds [6]. During the United States military involvement in Operation Iraqi Freedom and Operation Enduring Freedom (OIF/OEF), approximately 87.3% of all mortalities were before reaching an MTF and of those mortalities, 24.3% were classified as possibly survivable with mostly hemorrhage, airway obstruction, or tension pneumothorax [6, 15].

Modern Military Medicine has proven that it can adapt to different specialties and areas of care throughout its lifespan. The adaptation of TCCC used to treat pediatric casualties in Afghanistan and Iraq during OIF/OEF relays that although TCCC was not designed for pediatric treatment, medical clinicians in the field adapted their practices to treat the casualties to the best of their ability [16]. Situations in which medical clinicians are able to adapt at the point of injury are extremely important in prehospital care conditions where the initial treatment can decide if the casualty will survive long enough that further life-saving treatment can be administered. However, in the case of Space Medicine and microgravity environments, clinicians may not have enough time to adapt at the point of injury as dangers such as extreme pressure vacuums and temperature can advance the mortality of the casualty substantially. Additionally, during long-term space expeditions, it has been observed that approximately 60% of astronauts had reduced vision which would also effectively decrease a clinician's ability to adapt to the effects of microgravity [17]. The utilization of emergency physicians and clinicians will be necessary for the near future as emphasis shifts from post-flight to in-flight care for astronauts where long-term expeditions will require capacity for clinicians and medical equipment [17]. Furthermore, the importance of increased prehospital microgravity medical training for specialists of other medical specialties will be needed in the future as improvements in commercial space travel require more clinicians than any previous government-funded expedition. To fulfill such a demand, the training of Military Medicine clinicians has been observed to be the most efficient and optimal solution as they are already trained in first aid, TCCC, and other emergency medicine practices. The success of prehospital care relies on accurate triage where less accurate triage can unnecessarily lower treatment passed the acceptable standard of care or deviate from the correct diagnoses [18]. The utilization of Military Medicine clinicians is essential as they are already trained in triage practices and are more likely to accurately triage prehospital casualties as Military Medicine has extensive experience in triage out of other medical specialties. As the United States Space Force (USSF) continues to develop, it has designated space as its area of responsibility where US assets need protection and maintenance [19]. The development of Military personnel to understand the complexities of Space Medicine is essential as branches aside from the USSF should also be expected to be prepared for space expeditions in instances when Space Force expeditions may require more medical personnel than currently available within their branch.

Hermeneutic Questionnaire

The second method that contributed to the mixed method design was an anonymous 12-question hermeneutic questionnaire that was administered to participants associated with the European Space Agency (ESA), University of Texas Medical Branch (UTMB), National Aeronautics and Space Administration (NASA), United States Navy (USN), United States Air Force Research Laboratory (USAFRL), Royal Air Force, and the United States Army (USAR). The results are 66% short answer questions and 33% multiple-choice questions that the participants were not required to answer. The participants all work in Space Medicine and maintain professional degrees in medicine and the majority of participants perform medical research at their respective institutions which contributed to the main support of new research in the questionnaire. As described in figures 3 and 4, Participants acknowledged that new research provides new opportunities and data for the medical community to reflect on. The Space Medicine clinicians responded that their work benefits from Military Medicine procedures and practices and acknowledged that Military Medicine provides adjustment to topics such as multiple casualty events, mass casualty events, resource shortages, surge capacity, exigent or demanding communication, temporizing measures, triage, and others.



The Military Medicine clinicians responded that their work benefits from Space Medicine procedures and practices and acknowledged that Space Medicine provides adjustment to topics such as bone loss, orthostatic hypotension, cardiovascular deconditioning, the relationship between the space flight surgeon and the astronaut, telemedicine, life support systems, and the understanding of human physiology when operating in unusual environmental conditions [3, 13]. Within the multiple-choice segment of the questionnaire shown in figures 5-7, the best connections between Military Medicine and Space Medicine were limited resources, medical evacuation, triage, burn or chemical burn treatment, and mental health maintenance. Furthermore, clinicians emphasized the importance of TCCC in both microgravity and terrestrial environments in the free-response segment relating to their choices to the prior question.

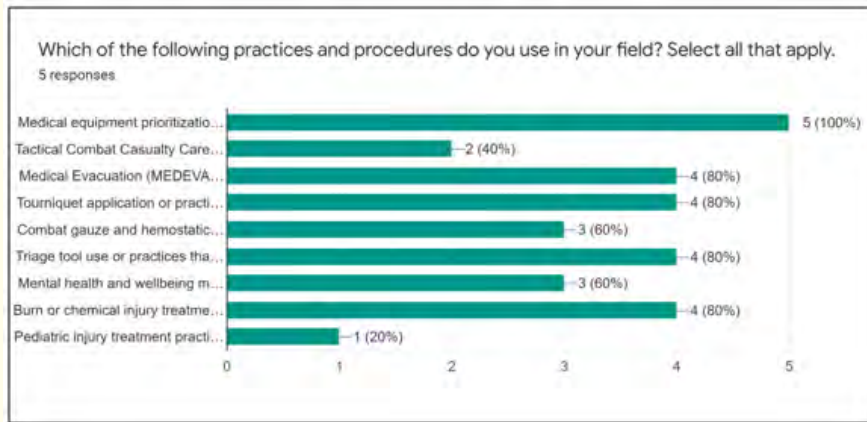


Figure 5: Space Medicine Clinicians' Usage.



Figure 6: Military Medicine Clinicians' Usage.

Charts 5 and 6 displaying practice usage within each specialty and the amount of clinicians that agree with the application of the stated practices.

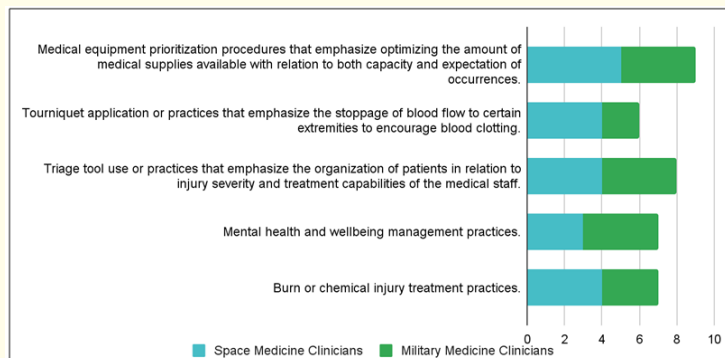


Figure 7: Convergence between Clinicians.

Chart 7 displaying practice usage convergence and the amount of clinicians that agree with the application of the stated practices.

Discussion

The results of the study describe how Military Medicine and Space Medicine are both specialties that are uncommon within the civilian world today. It was observed that medical practices in Military Medicine are designed to adapt to various situations regardless of the condition of the patient, clinician, or environment. Meanwhile, medical practices in Space Medicine are designed for the sole purpose of adapting and maintaining the human body in microgravity environments. Military Medicine as a medium for treatment is exceptionally expansive as it relates to life-sustaining practices for almost every aspect of the human body. The integration of Space Medicine into Military Medicine as Space Warfare Medicine is essential in the medical community as demands increase for clinicians trained in both prehospital medicine and Space Medicine practices with the development of the USSF and commercialized space travel. Space Medicine is unique as it is based in an environment that is inherently different from all other medical specialties, as such Space Medicine is still very dangerous and proves to be far more complex than other specialties. Clinicians in space have limited time to adapt at the point of injury and with dangers such as extreme pressure vacuums, extreme temperatures, or ASAT usage that can advance the mortality of the casualty substantially, having prior knowledge of Space Medicine practices and procedures is essential for space travel [7]. Military Medicine itself has little connection to space and microgravity environments as all Military areas of responsibility in the past have been terrestrial zones that are defined by geography, this trend is beginning to shift as organizations such as the USSF hold space as their area of responsibility [19]. The transition from geological to astronomical areas of responsibility requires that all medical military personnel be prepared for situations in microgravity as space remains an environment where unexpected events are likely to occur. Subsequently, there will be an increase in long-term space expeditions in the future as return to the moon and travel to Mars are both goals of astronomic expeditionary associations. Long-term space expeditions shift the emphasis from post-flight to in-flight care for astronauts and Military personnel should be developed to understand the complexities of Space Medicine in branches aside from the USSF that should also be expected to have personnel prepared for space expeditions in instances when Space Force expeditions may require more medical personnel than currently available within their branch. Military medical personnel has been observed to be well trained in emergency prehospital medicine which sets them to be the most qualified compared to other medical specialties for development with Space Medicine practices and procedures [1]. Results from questionnaire participants further describe how Military Medicine and Space Medicine are interrelated through practices related to limited resources, medical evacuation, triage, burn or chemical burn treatment, and mental health maintenance. During Military and Space operations, it can be expected that return will not be anticipated for several weeks, months, or even years, as such it is necessary that medical personnel and supplies are best

equipped for the expedition without exceeding the storage capacity available [17]. Both Military Medicine clinicians and Space Medicine clinicians are subject to situations in which any number of unexpected events could cause casualties and mortalities in addition to daily maintenance of the health and wellbeing of other personnel during an expedition. Based on the data found in the hermeneutic research questionnaire, Medical clinicians are aware of how Space Medicine practices and procedures are related to Military Medicine practices and procedures, however, the systematic review shows that current medical research literature only serves to indirectly lead to the compatibility of Space Medicine and Military Medicine as specialties.

Conclusion

Current research literature has no mention of the integration of Military Medicine and Space Medicine in the modern medical field which causes uncertainty as their relationship is not directly stated in the popular medical literature. This research study has displayed that Military Medicine is a similar specialty of medicine that emphasizes treatment at the point of injury in adverse conditions. Furthermore, it has also shown that Military Medicine can be integrated with Space Medicine to bolster the variety of conditions that Military Medicine can be utilized in and improve Space Medicine practices and procedures for future endeavors. The prioritized focus to adapt Space Medicine into Military Medicine may be very beneficial as Space Medicine is still a new specialty of Medicine that requires more data to improve. Adaptation may also allow Military Medicine clinicians to increase the amount of information they consider and also set a basis for clinicians within larger space-traveling populations. The TCCC and life-sustaining services are essential concepts that are needed in Space Medicine where such concepts have become inevitable in the light of the recent creation of the USSF to the extent that the application of Space Medicine practices and procedures to Military Medicine is essential to prevent catastrophe or disorganization within future Military and Civilian operations in space. This research provides the foundation for developing Space Warfare Medicine policies, develops the theory of Space Warfare Medicine for researchers and professionals to improve, assists in preventing space casualties through advocacy of improved practices, and provokes further research into the impact of Space Warfare Medicine on specific cohorts. The study was fundamentally limited as it does not specify treatments or policies to be implemented where space battlefields are unknown environments as no country has fought in space except for satellite-based warfare [7]. The research was only able to exist using a mixed method of a systematic review and hermeneutic research as a cohort or case study would not be applicable as space travel is still highly rare and it presumes procedure implementation is applicable for the majority of cohorts that could engage in space travel in the future. The availability of medical research literature regarding Space Medicine practices and procedures that could interact with Military Medicine practices was extremely limited as the majority of literature in the systematic review was pertaining to general practices of Military Medicine and Space Medicine rather than specific literature relating to their integration. The availability of participants also limited the results of the research study as only 10 responses were garnered from a cohort of over 200 professionals in the medical industry. Medical personnel from both Military Medicine and Space Medicine should further emphasize the integration and training of clinicians to adopt perspectives relative to Space Warfare Medicine to sufficiently expand their scopes of practice. This research study defines the ability to adapt Space Medicine within Military Medicine by encouraging the medical community to increase medical literature and develop the two specialties into Space Warfare Medicine. There must be future research conducted on the subject of Space Warfare Medicine and the adaptation of practices and procedures between the two specialties such that wide-scale space travel becomes more viable and improved procedures are designed for Space Warfare Medicine that may be distributed throughout other medical specialties as new research theories will be discovered in the community.

Conflict of interest

No conflict of interest.

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Appendix A

IRB Specialty Questionnaire Type A

IRB Specialty Questionnaire

The purpose of this research is to address the lack of information regarding Military Medicine in relation to Space Medicine. The intent is to mark the areas of care covered by Space Medicine that are absent in Military Medicine with the objective of incorporating Space Medicine practices and procedures within Military Medicine and vice versa.

If you have questions:
The main researcher conducting this study is Bryce Williams, a student at Palm Desert High School. Please ask any questions you have now. If you have questions later, you may contact Bryce Williams at bryce.williams@myds.us. Or their faculty supervisor Rebecca Smith at rebecca.smith2@desertsands.us.

If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) for Human Participants at rebecca.smith2@desertsands.us.

Participant's Associated organization (optional)

Short answer text
.....

What professional field do you work in? *

Short answer text
.....

What is your professional title / degree? *

Short answer text
.....

What activities do you typically perform in your field? *

Long answer text
.....

How important are policy or procedure changes when new medical research is found? Circle the statement that you agree with most. Do not answer if unsure or unknown.

1 2 3 4 5

Very Impactful ○ ○ ○ ○ ○ Not Impactful

If you answered the previous question, please explain your reasoning.

Long answer text
.....

Are there any particular aspects of your work that benefit from Space Medicine (medicine performed in space) policies or procedures?

Yes

No

Unsure/Unknown

If you selected yes in the previous question, please explain your reasoning.

Long answer text

Which of the following practices and procedures do you use in your field? Select all that apply.

Medical equipment prioritization procedures that emphasize optimizing the amount of medical supplies a...

Telehealth medicine or practices that emphasize the use of communication systems in order to provide m...

Tourniquet application or practices that emphasize the stoppage of blood flow to certain extremities to en...

Triage tool use or practices that emphasize the organization of patients in relation to injury severity and tr...

Mental health and wellbeing management practices.

Burn or chemical injury treatment practices.

Pediatric injury treatment practices.

If there were any practices and procedures that you do not use in your field (unchecked practices and procedures), do you think any of them could apply to your work?

Yes

No

Unsure/Unknown

If you selected yes in the previous question, please explain your reasoning for each practice or procedure that applies.

Long answer text

How does medical research regarding Space Medicine policies or procedures impact your work when new information is found?

Long answer text

Appendix B

IRB Specialty Questionnaire Type B

IRB Specialty Questionnaire

The purpose of this research is to address the lack of information regarding Military Medicine in relation to Space Medicine. The intent is to mark the areas of care covered by Space Medicine that are absent in Military Medicine with the objective of incorporating Space Medicine practices and procedures within Military Medicine and vice versa.

If you have questions:
The main researcher conducting this study is Bryce Williams, a student at Palm Desert High School. Please ask any questions you have now. If you have questions later, you may contact Bryce Williams at bryce.williams@myds.us. Or their faculty supervisor Rebecca Smith at rebecca.smith2@desertsands.us.

If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) for Human Participants at rebecca.smith2@desertsands.us.

Participant's Associated organization (optional)

Short answer text
.....

What professional field do you work in? *

Short answer text
.....

What is your professional title / degree? *

Short answer text
.....

What activities do you typically perform in your field? *

Long answer text
.....

How important are policy or procedure changes when new medical research is found? Circle the statement that you agree with most. Do not answer if unsure or unknown.

1 2 3 4 5

Very Impactful ○ ○ ○ ○ ○ Not Impactful

If you answered the previous question, please explain your reasoning.

Short answer text

Are there any particular aspects of your work that benefit from Military Medicine (medicine used in the military) policies or procedures?

Yes

No

Unsure/Unknown

If you selected yes in the previous question, please explain your reasoning.

Long answer text

Which of the following practices and procedures do you use in your field? Select all that apply.

- Medical equipment prioritization procedures that emphasize optimizing the amount of medical supplies a...
- Tactical Combat Casualty Care (TCCC) or procedures that emphasize the immediate first aid of a casualty ...
- Medical Evacuation (MEDEVAC) services or procedures that emphasize the stability of a patient en route t...
- Tourniquet application or practices that emphasize the stoppage of blood flow to certain extremities to en...
- Combat gauze and hemostatic dressing application or practices that emphasize the disinfection and treat...
- Triage tool use or practices that emphasize the organization of patients in relation to injury severity and tr...
- Mental health and wellbeing management practices.
- Burn or chemical injury treatment practices.
- Pediatric injury treatment practices.

If there were any practices and procedures that you do not use in your field (unchecked practices and procedures), do you think any of them could apply to your work?

Yes

No

Unsure/Unknown

If you selected yes in the previous question, please explain your reasoning for each practice or procedure that applies.

Long answer text

How does medical research regarding Military Medicine policies or procedures impact your work when new information is found?

Long answer text

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