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بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

In this era of rapid technological development, the proliferative and accelerated adaptation of technology means that distancing oneself from Science and Technology (S&T) is no longer an option.

In order for the Royal Brunei Armed Forces (RBAF) to remain as a resource efficient and prudent armed forces, it is necessary to not only embrace Defence S&T for technological advantage in primary military capabilities but also to look beyond the conventional realm of Defence S&T into emerging trends within the wider technological landscape. These trends include the use of autonomous, unmanned or augmentative systems in medical, transportation and disaster recovery fields; the rapid development of next generation machine learning and artificial intelligence algorithms; as well as the ubiquitous deployment of big data in every industries.

On that note, it is my wish that FRONTIER will be able to create a platform to share and inculcate innovation within the Ministry of Defence (MINDEF) and the RBAF communities, further propelling technological adaptation within the organisation. This is in line with Brunei Darussalam's National Vision 2035 for the accomplishments of its well-educated and highly-skilled people to be recognised internationally.

Lastly, I would like to congratulate the FRONTIER Editorial Board and Publication Team on the publication of this inaugural issue of FRONTIER, and will look forward to receiving future issues of FRONTIER. As with all our practices, we respect and adhere to the *Melayu Islam Beraja* philosophy as the mainstay of any consideration and action we do. May Allah guide us in our endeavours and towards a successful future.

Wabilahitaufiq Walhidayah Was'salamualaikum Warahmatulahhi' Wabarkatuh

FOREWORD

Brigadier General (Retired) Dato Seri Pahlawan Shahril Anwar
bin Haji Ma'awiah
PERMANENT SECRETARY, MINISTRY OF DEFENCE

السلام عليكم ورحمة الله وبركاته

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

Science and Technology (S&T) plays a vital role in contributing to Brunei Darussalam's defence and security. It provides the technological advantage in military capabilities, and the systematic methodologies necessary to inform improvements in the way military organisations function and operate; both of which are especially critical for a compact force like the Royal Brunei Armed Forces (RBAF).

The importance of S&T as a force enabler and multiplier for national security was highlighted in the Defence White Paper (DWP) 2011. Subsequently, in 2016, the Defence Science and Technology Policy Framework (DSTPF) – in alignment with the DWP 2011 and the Brunei Vision 2035 – was developed for the Ministry of Defence (MINDEF) and the RBAF as efforts to increase the productivity, efficiency and effectiveness in performing Defence S&T.

Under the DSTPF, five directorates/units within MINDEF and RBAF have been identified as the Defence Science and Technology Group (DSTG), which works concertedly as a synergistic group to complement each other's niche capabilities in providing S&T knowledge and expertise. Building on the DSTG's continuous efforts to increase the sharing of knowledge, promote innovations, create awareness and generate discussions in S&T, FRONTIER – an internal Defence S&T publication – will serve as a platform for the periodic showcase of a curated set of articles, reports and technical papers written by members of MINDEF and RBAF.

It is my hope that FRONTIER will instill a culture of learning and continual improvement, and underscores the significance of institutionalising scientific and technological knowledge for future references and generation of new knowledge. Last but not least, I would like to extend my congratulations to the Editorial Board and Publication Team, as well as my appreciation to the contributing authors, who collectively made this publication possible.

Wabilahitaufiq Walhidayah Was'salamualaikum Warahmatulahhi' Wabarkatuh

EDITORIAL FOREWORD

Pg Dr Hj Md Esa Al-Islam bin Pg Hj Md Yunus
EDITOR-IN-CHIEF

السلام عليكم ورحمة الله وبركاته

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

First of all, we would like to give special thanks to Permanent Secretary and Deputy Permanent Secretary, Ministry of Defence, Brunei Darussalam for their advisory input and providing professional guidance towards this publication from idea to print. Our sincerest appreciation also goes to the Editorial Board and the Publication Team, who have been working hard in ensuring the publication is of quality and meets the deadline.

FRONTIER is the first publication on Defence Science and Technology (DS&T) for the Ministry of Defence (MINDEF) and Royal Brunei Armed Forces (RBAF). By publishing, this shows how important DS&T is for the organisation and our commitment to bring forward the agenda and achievement of DS&T. This will also bring about the success of DS&T in extending the frontiers of knowledge. This publication marks the beginning of MINDEF and RBAF's commitment towards Science and Technology, thus the theme "A New Beginning" was chosen. This first edition of FRONTIER features three articles that have been curated to present the existing work in various discipline.

"Anterior Cruciate Ligament (ACL) Injury in the Royal Brunei Armed Forces" explores the prevalence of ACL injury in the RBAF uniformed personnel, the common causes of ACL injury, the time taken to recover from ACL reconstruction and also the outcome of these personnel after undergoing ACL repair and recovery period.

"The Importance of Infrastructure Design and its Impact on Energy Efficiency with respect to Swimming Pools" investigates the possible avenues of energy saving, particularly within the swimming pools of the MINDEF, as pool schematics and information regarding their energy usage is readily available and easily calculable.

"Recommendations on Physical Training During Ramadan Fasting for Royal Brunei Armed Forces Soldiers" provides strategies and suggestions that can assist RBAF personnel to continue and maintain their physical activities during Ramadan.

Through this publication, we hope that readers will be able to learn about the various fields of DS&T that exist in MINDEF and RBAF and thus gain a better understanding of individual contributions to DS&T in Brunei Darussalam. In future, we would like to urge more MINDEF and RBAF personnel to join our efforts and contribute towards FRONTIER. Last but not least, we would like to express our appreciation to the authors for their hard work and dedication. We hope that FRONTIER will continue to enrich our readers through sharing their knowledge, findings and innovation. Thank you.

Wabilahitaufiq Walhidayah Was'salamualaikum Warahmatulahhi' Wabarkatuh

What FRONTIER is

FRONTIER is an internal, annual Defence Science and Technology (DS&T) journal formatted under the guidance of the Defence Science and Technology Group (DSTG), for the periodic publication of a curated set of articles, reports and technical papers written by members of the Ministry of Defence (MINDEF) and the Royal Brunei Armed Forces (RBAF), in support of the ongoing effort to institutionalise knowledge within the organisation. Moreover, through publication and hence sharing of DS&T content, FRONTIER aspires to be a platform that creates awareness, generates discussion and inculcates innovation among members of MINDEF and RBAF.

In alignment with the ongoing digitisation effort spearheaded by DSTG, FRONTIER will be made available primarily as soft copy, via MINDEF Intranet and DSTG Core, both accessible via MINDEF Defence Administrative Network (DAN). Limited hard copies of FRONTIER will also be distributed to MINDEF and RBAF's leaderships and made available in MINDEF and RBAF's libraries.

"A DSTG Initiative"

Anterior Cruciate Ligament (ACL) Injury in the Royal Brunei Armed Forces

About the Author

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ABSTRACT

Introduction: Currently, there is a lack of data on anterior cruciate ligament (ACL) injury in Brunei Darussalam and there is no published data on the military population despite the nature of their jobs which is more physically challenging. This research aims to determine the prevalence of ACL injury in the Royal Brunei Armed Forces (RBAF) uniformed personnel, the common causes of ACL injury, the time taken to recover from ACL reconstruction and also the outcome of these personnel after undergoing ACL repair and recovery period. **Methods:** A cross-sectional study was conducted where personnel with or a history of ACL injury were identified from the medical board registry from each Medical Reception Station (MRS) and the medical documents of each relevant personnel were reviewed to answer the objectives mentioned above. **Results:** Eighty-seven participants were analysed in this research. The prevalence of ACL injury in the RBAF uniformed personnel was 0.01. The most common cause of ACL injury in this population was sport activities, particularly football. Most of the participants in this research underwent ACL repair before 16 months from the date of knee injury. Majority of those who underwent ACL reconstruction however ended up being on permanent medical board. **Conclusions:** ACL injury is not uncommon in the RBAF uniformed personnel. Sport activities were the main cause for ACL injury for 62.1% of the participants, whereas military activities only affected 18.4%. Out of the 87 participants, 16.1% were upgraded to fully fit for all military duties post ACL reconstruction. Further research is needed to determine the reasons for delay in recovery and low success rate of ACL repair.

Introduction

The anterior cruciate ligament (ACL) is one of the most common ligaments in the knee to be injured.[1] The injury usually occurs as a result of low-velocity, deceleration, and non-contact activities and it can also occur in activities with contact with rotational component especially sports that involve a high frequency of cutting and pivoting such as football and basketball. [1,2] Currently, there is limited data published on ACL injury in the population of Brunei Darussalam. On top of that, no research has ever been done on ACL injury on the Royal Brunei Armed Forces uniformed personnel. From observations, knee injuries are not uncommon for consultations in the Medical Reception Stations (MRS) of the RBAF. Some of these knee injury do turn into chronic problems and consequently, hinder the personnel from being able to perform their full military duties.

When a knee injury has been suspected or diagnosed by the medical officer at MRS as an ACL injury either via history or clinical examination, the affected personnel would be referred to the Orthopaedics Department, Raja Isteri Pengiran Anak Saleha (RIPAS) Hospital as soon as possible for further investigations and management. At the same time, the personnel would be put on light duty until the ACL injury is confirmed by the Orthopaedics. Once confirmed, the personnel would be put on medical board until his ACL treatment and rehabilitation have been completed and the personnel is able to perform activities without significant symptoms. A clear confirmation from Orthopaedics that he is fit to perform full military duties is also necessary.

In an article by Benjamin, 2013, in between 1 January 2008 and 31 December 2010, there were 214 ACL reconstructions with hamstring autografts performed exclusively in RIPAS Hospital in Brunei Darussalam. On average, 2 cases of ACL reconstruction were performed per week.[3] From the 214 patients, 96% of them were males and the injuries were caused by a wide variety of sports.[4] Compared with the United States where an estimated 200,000 ACL-related injuries occur annually with approximately 95,000 are ACL ruptures. The incidence of ACL injuries also correlated with Brunei Darussalam's where it was higher in people who participate in high-risk sports such as basketball and football.[1,2] Although the study conducted by Benjamin was nationwide, there was no mention of how many of his subjects were from the military. This research aims to determine the prevalence of ACL injury for RBAF uniformed personnel. It is also of great interest to investigate the common causes of ACL injury and if it would be supporting Benjamin's findings or would it be more due to military activities.

A knee with an injured ACL has been associated with increased rate of early osteoarthritis and meniscal injuries.[4] Hence, the common practice now is to progress to ACL reconstruction without much delay.[5] Consequently, in the US alone, approximately 60,000-75,000 ACL reconstructions are performed annually.[1] Another objective of this research is to investigate the amount of time delay between injury date to when ACL reconstruction was performed and whether the longer delay result in longer recovery time and poor outcome. The long-term success rate of ACL reconstruction in restoring activity and stability is between 75-95%.[1] Since all military personnel are expected to be fit for all physical activities and duties (provided they are free from other health problems), they are expected to undergo ACL reconstruction if advised to do so by the Orthopaedics specialists.

According to Bristol Orthopaedics and Sports Injury Clinic, the average amount of time for a patient to be able to return to work will be dependent on the nature of their jobs. For an average military patient, they should be able to run including on rough ground and perform activities with twisting components after 6 months.[6] By a year, patients should be able to return to preinjury state.[6] Currently, the consensus from Orthopaedics Department, RIPAS Hospital is anyone who has undergone ACL reconstruction should be able to resume physical activities by 9 months. The Medical Services of RBAF is following this timeline at the moment. However, if the personnel are unable to recover within the time advised, they can either be continually downgraded via medical board or be medically discharged from the military if necessary. At the moment, there is no set maximum amount of time a personnel is allowed for medical board for ACL injury and the criteria to medically discharge a personnel due to complicated ACL injury are still on a case-to-case basis.

Methodology

The research is a retrospective cross-sectional study, conducted in all Medical Reception Stations (MRS) of the Royal Brunei Armed Forces except in MRS Bangar. MRS Bangar was excluded because there was no permanent staff or personnel. Any personnel who were or has been put on medical board that was related either to ACL injury, chronic knee pain, or ACL reconstruction were selected for review before proceeding to the data collection process. hese patient were identified via the medical board registry of each MRS. A medical board is decided when a uniformed personnel suffers from a medical

or health issue that necessitate for them to be put on restrictions in terms of physical activities and also the duties they are able to perform in their daily job in the military. The decision to board must be made by at least one medical officer of the RBAF. If a case is more complicated, the board must consists of two or three members. A medical board is dynamic such that a date is set for review where a personnel can be upgraded from a temporary medical board to fully fit or they can be put on permanent medical board depending on the findings during each review. The upgrading of a medical board is usually with support from relevant specialists' opinions, although it is not always necessary. In this research, the selection of relevant medical boards were from the medical board registry was between 2010 to 2015.

Any medical board that fit the selection criteria would be identified and the details from it would be used to retrieve the medical documents of each personnel. Initially, data such as the military number (to allow efficiency in referring back in case further data was needed), the date of birth (to estimate the age of the personnel when the ACL injury occurred), the gender, the knee affected (right vs left), the cause of their ACL injuries (the common cause mentioned by the participant during consultations at MRS would be the one considered), and the Bru-HIMs number (to enable going through Ministry of Health digital medical records for clarification of information that it was not recorded or unclear), would be obtained from the medical documents of each personnel. The cause of ACL injury would be recorded as either 1) Sports activities 2) Military activities 3) Others i.e. not related to sports nor military activities such as accidentally slipped in the toilet, motor vehicle accident, etc. A personnel would be considered to have ACL injury based on either 1) a positive history: twisted their knee and heard a 'pop' sound, developed a large haemarthrosis within a few hours after injury, pain and instability of the knee causing inability to return to play[1], 2) a positive clinical examination by Orthopaedics: positive Lachman test or positive pivot shift test or positive anterior drawer test or a combination of the three1, 3) diagnostic confirmation by either MRI or arthroscopic examination (via Orthopaedics) before or during the reconstructive procedures. Exclusion criteria include any fractures, ACL reconstruction done before joining the military, or having other medical issues that required them to be on medical board.

The second phase involved noting the date of when the knee injury occurred (at least down to the year) and also the date of when ACL reconstruction was performed (month and year). The time between these two dates would be noted as the time ACL reconstruction was delayed.

The third phase of this research was to investigate the time that has elapsed since the ACL reconstruction was performed. This was worded in such a way because not all personnel did recover post ACL reconstructions. For those who did recover, the time elapsed would be the recovery time i.e. time from ACL reconstruction was performed to the date they are upgraded to fully fit from medical board. For those who have not recovered, the time elapsed would be counted from the date ACL reconstruction was performed to the date of data was collected.

The last phase was to determine the outcome of those with ACL injury which was divided in to 3 groups: 1) Upgraded to fully fit 2) On permanent medical board 3) On temporary medical board (which means they were still under the expected recovery time period).

Written approval from the Commander of the Royal Brunei Armed Forces was obtained before this research was conducted. Consequently, the approval from the Medical and Health Research and Ethics Committee was also obtained after the Commander's approval was received. Written consent was obtained from all participants for their data to be used in the analysis of this research although anonymity was maintained for the participants in terms of data presented in this research paper.

Data gathered for this research was analysed using IBM SPSS Statistics Version 21.

Literature Review

The research of interest was on the RBAF uniformed population, but not many literatures on the military population was encountered. A PUBMED electronic database search was conducted using Boolean search and Truncation. In the search box, it was typed, "(anterior cruciate ligament OR ACL) AND (injur*) AND (military OR army OR navy OR naval OR airforce) resulting in 177 articles. Only English-language case-control and prospective cohort studies designed to identify anterior cruciate ligament injury within the military were selected. The title and abstract (where electronically available) for these papers were individually reviewed and a total of 62 articles were included in this research. After further filtering, only 9 articles were used in this research.

One of the articles was on a nation-wide study done in Sweden on cruciate ligament injury between 2001 – 2009, which revealed that the overall incidence of cruciate ligament injury in Sweden was 78 per 100,000 persons. Males made

up 60 percent of those with ACL injury and half of the group was younger than 30 years old. Of those who had ACL injury, only 36% underwent ACL reconstruction surgery and only a third of them had the surgery performed within a year after the injury occurred.[7]

With regards to the causes of ACL injury, in a study conducted on military personnel in Malaysia in two military hospitals demonstrated that among those who had undergone ACL reconstruction, 82% of the ACL injury were as a result of sporting activities. Only 14% were due to military training. [8]

Data gathered from the U.S. Army Aviation Epidemiology Data Register in the period of 1988-95 revealed 76% of ACL injury do require ACL reconstruction. Those that do underwent reconstruction and were injury free before entering the service, 94.3% of them returned to aviation service whereas 2.3% of them were aeromedically terminated.[9]

In a study done in San Diego, US on 120 military patients who underwent ACL reconstruction, only 77% of them returned to full duty whereas the remaining 23% were medically discharged from military service. This study also showed that by undergoing ACL reconstruction, personnel have higher chance to return to full duty compared to those opting for non-operative treatment.[10]

Results

After going through the selection process, only 87 participants were included in this research. Medical board registry of each MRS from 2010 to 2015 was reviewed. By referring to Table 1, all the participants in this research were males. Majority of them were non-commissioned officers (93.1%). With regards to the site of injury, 55.2% have ACL injury affecting the right knee and 44.8% affecting the left knee. The age distribution of participants was between 18 to 44 years old. The age group with the most participants was between 21 – 30 years old (66.7%) and only 1 participant was from the 41 – 50 years old age group (1.1%).

As shown in Table 2, out of the 87, 54 (62.1%) attributed their ACL injuries to sports activities. Somehow, military activities were found to be the lowest in causing ACL injury in RBAF uniformed personnel (18.4%).

The time delay in undergoing ACL reconstruction is shown in Table 3. 19.5%) underwent ACL reconstructions after suffering from the ACL injury between 11 – 15 months. Only 6.9% underwent ACL reconstructions less than 5 months after the injury occurred. Significant amount of participants (26.4%) however, only underwent ACL reconstructions after nearly 2 years from the time of injury. At the time data was collected, 23 (26.4%) have not undergone ACL reconstructions.

From the 87 participants, 18 (20.7%) recently underwent the procedure i.e 1 – 12 months ago. More significant result is that 16 participants that had ACL reconstruction more than 48 months ago were still on medical board. If considering the 9-month recovery period as advised by Othopaedics Department, RIPAS, more than 46 participants were well over this.

Referring to Table 5, only 14 participants (16.1%) were upgraded to fully fit with no physical activity or duty restrictions. However, majority of them were put on medical board permanently [64 (73.6%)]. This includes 1 participant who was graded as unfit for military service.

Table 1: Participants Demographics

		n (%)
Gender		
	Male	87 (100.0)
	Female	0 (0.0)
Rank		
	Officers	6 (6.9)
	Non-officers	81 (93.1)
Site of Injury		
	Right knee	48 (55.2)
	Left knee	39 (44.8)
Age		
	20 years old or less	4 (4.6)
	21-30 years old	58 (66.7)
	31 - 40 years old	24 (27.6)
	41 - 50 years old	1 (1.1)

Table 2: Distributions of Participants according to the Common Causes of ACL injury in RBAF Uniformed Personnel

Common Causes of ACL injury	n (%)
Sports Activities	54 (62.1)
Military Activities	16 (18.4)
Others	17 (19.5)

Table 3: Distribution of Participants according to the Time Between ACL Injury and Reconstruction in RBAF Uniformed Personnel

Time Between ACL Injury and Reconstruction	n (%)
Less than 5 months	6 (6.9)
6 - 10 months	13 (14.9)
11 - 15 months	17 (19.5)
16 - 20 months	3 (3.4)
21 - 25 months	4 (4.6)
26 - 30 months	0 (0.0)
31 - 40 months	5 (5.7)
41 - 50 months	3 (3.4)
51 - 60 months	2 (2.3)
61 - 70 months	4 (4.6)
More than 70 months	5 (5.7)
No injury date recorded	2 (2.3)
Have not undergone reconstruction	23 (26.4)

Table 4: Distributions of Participants according to the Time Elapsed Since ACL Reconstruction

Time Elapsed Since ACL Reconstructions	n (%)
1 - 12 months	18 (20.7)
13 - 24 months	12 (13.8)
25 - 36 months	10 (11.5)
37 - 48 months	8 (9.2)
More than 48 months	16 (18.4)
Have not undergone reconstruction	23 (26.4)

One of the main concerns of ACL injuries in the RBAF uniformed personnel is the significant amount of those who have not undergone ACL reconstructions [23 (26.4%)]. The breakdown of the reasons why is shown in Table 6. Although, some of the participants have legitimate reasons for not having ACL reconstructions done yet, there were 7 participants who still refuse the procedure. The exact reasons for refusals were unknown. Further research needs to be done as to why some patients are refusing ACL reconstructions as studies have shown that ACL deficient knee has been associated with increased risk of degenerative changes and meniscal injuries.[4] Therefore, it is highly advisable for those who have been diagnosed with ACL injury to be put on restricted physical activities and to undergo ACL repair as soon as possible.

When cross-analysis was done between the time of knee injury and ACL reconstruction vs outcome, it was found that Table 7 shows that the lesser the time
between the knee was injured (less than 20 months) and when the ACL reconstruction was performed, more participants were able to be upgraded to fully
fit. The longer the delay of ACL reconstruction, more participants were observed to be on permanent medical board.

Table 5: Distributions of Participants according to the Outcome from ACL Reconstruction

Outcome from ACL Reconstruction	n (%)
Upgraded to fit	14 (16.1)
Permanent medical board	64 (73.6)
Temporary medical board	9 (10.3)

Table 6: Distribution of Participants who have not undergone ACL Reconstruction according to reasons specified in medical

Reasons Why Have Not Undergone ACL Reconstruction	n (%)
Postponed/Awaiting	3 (13.0)
Patient refused	7 (30.4)
Physiotheraphy only	3 (13.0)
Not Advisable by Orthopaedics	3 (13.0)
Others	7 (30.4)

Discussions

From this research, the prevalence of ACL injury in the RBAF uniformed personnel was found to be 0.01. Most of the ACL injury happened to those in the age group of 21 – 30 years old. As hypothesised by Benjamin, 2013, unlike in most Western society, the gender most affected by ACL injury was male.[3] This study also revealed that the common cause for ACL injury amongst RBAF uniformed personnel was sports activities, particularly football.

Many of the participants underwent ACL reconstruction about 15 months or less from when the injury occurred (51.3%). Five participants actually waited more than 70 months before having their ACL repaired. The delay in having ACL repaired could be due to multiple factors. One of the common reasons would be patient's refusal or inhibition in wanting to have the procedure done so soon. There was insufficient data to explain why ACL reconstruction was delayed but it was hypothesised that it could either be due to patients' lack of understanding of ACL injury and its impact if left untreated, negative views from relatives or colleagues who have undergone reconstruction, and denial in the diagnosis and phobia towards being put on medical board leading to participants continuing strenuous physical activities despite suffering from knee pain and instability.

In this research, it was found that 20.7% participants were only recently going for ACL reconstruction i.e. about 12 months or less. However, 16 (18.4%) were found to have undergone reconstruction more than 48 months ago. Investigating further, only 14 out of 87

Table 7: Cross-analysis between Time between Knee Injury and ACL Reconstruction vs Outcome

	Time Between Injury and ACL Reconstruction						
	Less than 5 months	6 - 10 months	11 - 15 months	16 - 20 months	21 - 25 months	26 - 30 months	31 - 40 months
Outcome				n (%)			
Upgraded to Fit	2 (14.3)	3 (21.4)	4 (28.6)	1 (7.1)	0 (0.0)	0 (0.0)	1 (7.1)
Permanent Medical Board	2 (3.1)	8 (12.5)	10 (15.6)	2 (3.1)	4 (6.3)	0 (0.0)	4 (6.3)
Temporary MB	2 (22.2)	2 (22.2)	3 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total	6 (6.9)	13 (14.9)	17 (19.5)	3 (3.4)	4 (4.6)	0 (0.0)	5 (5.7)

	Time Between Injury and ACL Reconstruction					
	41 - 50 months	51 - 60 months	61 - 70 months	More than 70 months	No Injury Date Specified	No ACL Reconstruction Done
Outcome				n (%)		
Upgraded to Fit	0 (0.0)	0 (0.0)	1 (7.1)	0 (0.0)	1 (7.1)	0 (0.0)
Permanent Medical Board	3 (4.7)	3 (4.7)	4 (6.3)	3 (4.7)	1 (1.6)	23 (35.9)
Temporary MB	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Total	3 (3.4)	2 (2.3)	4 (4.6)	5 (5.7)	2 (2.3)	23 (26.4)

participants (16.1%) were upgraded to fully fit after undergoing ACL reconstruction. Majority of them (73.6%) were put on medical board and not able to return to their preinjury state. The large number on permanent medical board could be due to multiple factors. ACL reconstruction success rate is dependent the orthopaedics surgeon, graft failure rate, any complications faced post-surgery, or any further injury to the same knee post procedure. However, just because a participant has been upgraded to fully fit does not fully guarantee that he was back to his preinjury state. There is possibility of residual knee pain post ACL repair but not reported to the surgeon or medical officer due to the avoidance attitude towards medical board. The reverse could occur towards permanent medical board. This was highly likely if a personnel was planning to retire within the next few years and it already holding a rank he was satisfied with. When this happened, there was no incentive to undergo ACL reconstruction hence the laidback attitude towards ACL repair and attempting to return to preinjury state. Another explanation to favouring being on medical board is the fear of re-injury to the same knee and having to go through the whole process of surgery and rehabilitation.[11] This explanation would be more applicable to the younger personnel and of lower ranks.

Conclusions

The prevalence of ACL injury in RBAF uniformed personnel was 0.01. It was found that many of the ACL injury was due to sports activities rather than military activities. From the 87 participants, only 16.1% were upgraded to fully fit post ACL reconstruction. Majority of them were put on medical board permanently (73.6%). Further research is needed to determine the reasons for delay in recovery and low success rate of ACL repair.

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The Importance of Infrastructure Design and its Impact on Energy Efficiency with respect to Swimming Pool

About the Author

Miss Teo Siang Wen is currently a Project Engineer working for the Research and IT Unit in the Directorate of Development and Work Services. Holding a Master of Science from University College London in Chemical Process Engineering, Miss Teo primarily works as a researcher, delving into improving the maintenance of current infrastructure and the modernisation of current building techniques. Miss Teo grew up as the competitive middle child between two brothers and spends her free time reading Penguin classics and browsing for the next best South Korean beauty product.

ABSTRACT

Energy efficiency is a major concern for the Ministry of Defence (MINDEF). This research was undertaken to investigate possible avenues of energy saving, particularly within the swimming pools of MINDEF, as pool schematics and information regarding their energy usage is readily available and easily calculable. The research determined a pool's energy efficiency by calculating the minimum energy requirements to run the pool and comparing that to how the pool is currently being run. There are many factors which determine a pool's efficiency, one of which is the design of the pool and its pump room utilities. The research showed that with proper initial design, a pool can be made to be more energy efficient from the beginning of its service life.

Introduction

The requirement to reduce power consumption is both an environmental and economic issue; the continued high usage of power will cause environmental setbacks which would make the cost of energy in the future more expensive. Brunei Darussalam is the highest energy consuming country within South-East Asia. [1] The total consumption of energy in the country per year is 3.77 billion kWh, of which, 29% is attributed to government use. [1, 2]

Due to reports that military camps are consuming considerable amounts of power, MINDEF has increased its efforts to reduce energy consumption, resulting in the creation of the Ministry of Defence Energy Efficiency (EE) Policy [3]. It is this policy's guidelines that dictates at what time the lights are switched on/off, or at what temperatures the air-conditioning should be set [4]. With the initiatives for lighting and air-conditioning in place, it was decided that research should be conducted within the context of swimming pools, which are a measurable outlet of energy usage, and how they may be more energy efficient.

Objectives

The aim of this research is to determine how swimming pools within MINDEF may be more energy efficient. This is done through gaining information about how swimming pools are made to be energy efficient in different situations. The research is also concerned with a more in-depth knowledge of the pools that are in operation in MINDEF, specifically in their initial design and current operations.

Methodology

The research delved into the different swimming pools within the different military camps, studying available schematics and drawings. Information on how pool efficiency was achieved in other countries was also extracted from literature to compare to currently applied methods. Where available, pool schematics were calculated and compared to suggested energy efficient designs, while the operation schedules of the pools were extracted from respective pool pump room operators. Further clarification was also sought from one of the Ministry's pool consultants.

Procedures and Results

Limitations on a pool's energy efficiency arise from the distance of the pool to the pump room, the size of the pool, its frequency of use and its purpose. All these decide the pool's turnover, that is, the amount of time it takes for all the water in the pool to have cycled through the filtration system at least once. Water parks and Olympic standard swimming pools would have a much lower turnover of half an hour to one hour, which in turn require a larger amount of energy to pump such large amounts of water within such a short period, as opposed to generic public or private swimming pools, which would have a longer turnover and therefore require less energy. [5, 6, 7, 8]

For the interests of this article, it was decided to only focus on the Performance Optimisation Centre (POC) swimming pool, located in Bolkiah Garrison. The pool has dimensions of 25 m x 3.5 m x 2.14 m, and a ramp that is approximately 7.8 m x 1.2 m x 0.63 m, which totals a pool capacity of around 128.4 m^3. Taking a maximum turnover of 4 hours, the minimum flow rate (the flow rate that at least must be reached to achieve the turnover) would be calculated to be 32.1 $m^3 h^{-1}$.

The POC swimming pool is used for rehabilitation, helping users overcome injuries through the resistance provided by training in water. So, while at any other time it may run through a conventional pumping, filtration and chlorination system, the pool water can be altered to suit the needs of the end users - heated water may be supplied through a pool heater, and be sanitised by bypassing the chlorinator and using an ozonator and ioniser system to prevent the use of chemicals like chlorine which may be too harsh on the targeted end users.

The added components increase the 'head loss' in the system, that is the amount of pressure that would be lost transporting water through the various components of the system, effected by the smoothness of the pipe, changes in the direction of flow, the length of the pipe and even the type of fluid. In the POC swimming pool, the total head loss is calculated to be 24 m - head loss is measured in terms of length. The pump that is installed must then be able to overcome this head loss while still transporting the pool water at an acceptable rate to meet the pool turnover requirement, all this while still being energy efficient. For this article, two different pumps from the same brand will be compared.

The most used brand of pumps within the Ministry of Defence are Southern Cross pumps so this data was most readily available. From studying the specifications of the Southern Cross centrifugal pumps as shown in Figure 1, two pumps were found to achieve specification, the Southern Cross MHC 80 x 50 - 315, and the Southern Cross MHC 80 x 50 - 250. [9] The first two numbers on both pump models indicate the inlet and outlet diameters of the pipes that are attached to these pumps. Larger pipes are more expensive than smaller pipes, however as both pipe diameter requirements on either pump are the same, this is not a contributing factor to the decision between either pump.

The pump curve of the MHC 80 x 50 - 315 model, as shown in Figure 2, indicates that an impeller size of 291 mm is required to run at 3.3 kW. [9] Accounting for a 20% pump motor energy loss, the motor size needs to then be bumped up to a 5 kW motor. In the situation where the head drops, this would increase the velocity of the flow, thereby increasing the volumetric flowrate, and this would burn out the 5 kW motor, so a 6 kW motor would be more appropriate.

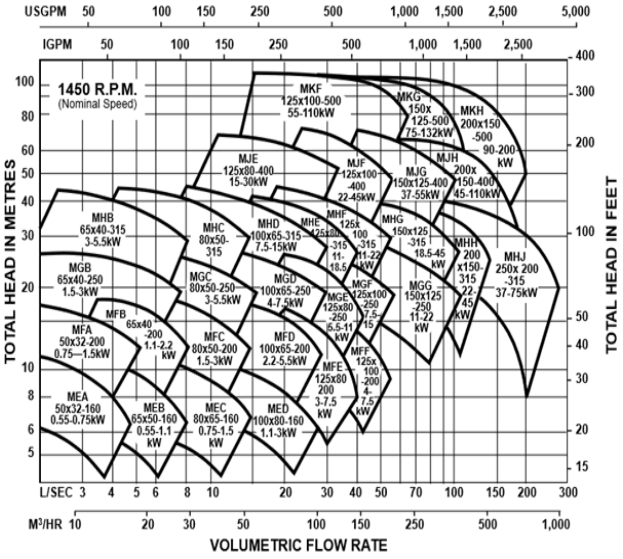

Figure 1: Chart of possible pumps and their flow capacities at operating head [9]

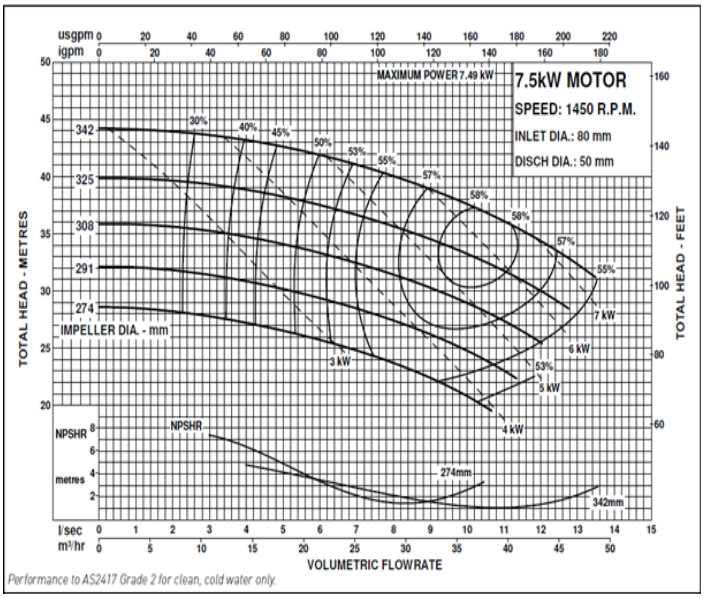

Figure 2: Pump curve of the 80 x 50 - 315 7.5 kW motor model [9]

Alternatively, the pump curve of the MHC 80 x 50 - 250 model, as shown in Figure 3, indicates that an impeller size of 264 mm is required to run at 3 kW [9]. As before, accounting for the 20% pump motor energy loss, the motor size would then have to be a 4 kW motor. However, in the situation of a head drop, the increase in volumetric flowrate will require the motor to be a 5.5 kW motor, which is the maximum power motor available, and is inadvisable as head drops are a common occurrence and the likelihood of a pump burnout is increased.

The MHC 80 x 50 - 315 pump is around 0.5 kWh less efficient than the MHC 80 x 50 - 250 pump, however the former is working around 56% capacity while the latter is working around 66% capacity, making the latter more likely to burnout [9]. This displays one of the challenges of increasing energy efficiency through design, while the latter pump would be more energy efficient, it is more susceptible to burnout, and would not be recommended for the long term running of the system.

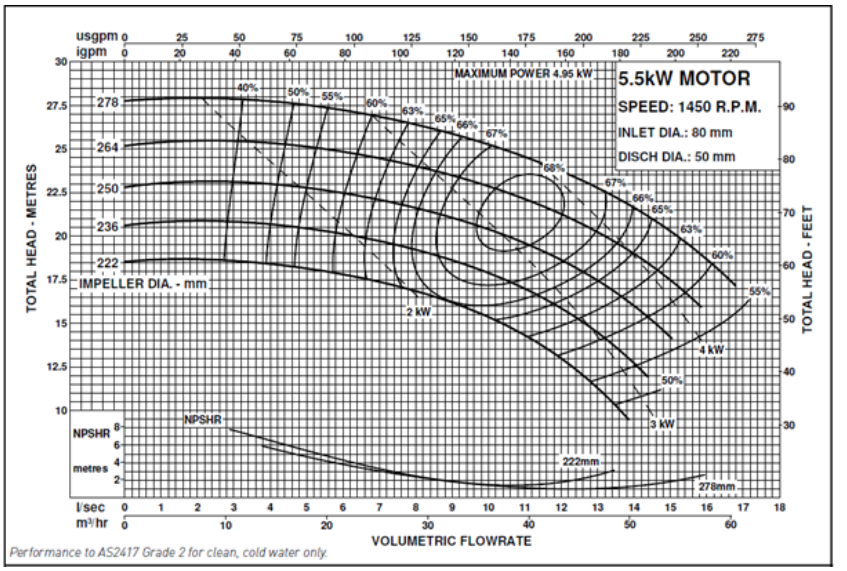

Figure 3: Pump curve of the 80 x 50 - 250 5.5 kW motor model [9]

Another design decision that ultimately saves a lot of energy is the selection of the filters. The POC swimming pool filters are BRE Tier 110 Quadruple Filters. These stainless-steel filters use multiple filter beds placed vertically over each other within a relatively small stainless-steel shell, as shown in Figure 4 [10]. After discussion with the pool consultant, in comparison to the conventional flatbed filter, such as the MICRON Horizontal M5000 filter used in Berakas Camp, schematic shown in Figure 5, these are more hydraulically efficient [11, 12]. Each compartment within the stainless-steel filter holds a bed of sand which effectively filter in parallel so that the effective filtering area is equal to the sum of the areas of the open tops of the containers despite the fact that the floor space occupied is little more than that of a filter with an effective filtration area of only one of the filters using the conventional design [10].

The stainless-steel filters are also more efficiently backwashed. When sand filters need to be regenerated, they need to be backwashed, and water flows from (9) in Figure 4 to enter the compartments (4), from pipe (8), filling them up and dislodging the trapped particulates such that the particulates can exit the compartments and be carried on the gravitational downstream within the shell (2), to be collected and carried out in pipe (3) [11]. The use of the gravitational downstream reduces the energy required to accumulate the unwanted particulates at the outlet, as opposed to in the conventional horizontal flatbed filter, where the particulates depend on the turbulent flow of backwash water to travel the length of the filter and be transported to the outlet [11]. There is little dependence on a gravitational downstream, and this leads to experiential backwash times of around 5-10 minutes, compared to the claimed 2-3 minutes with the stainless-steel filters [11].

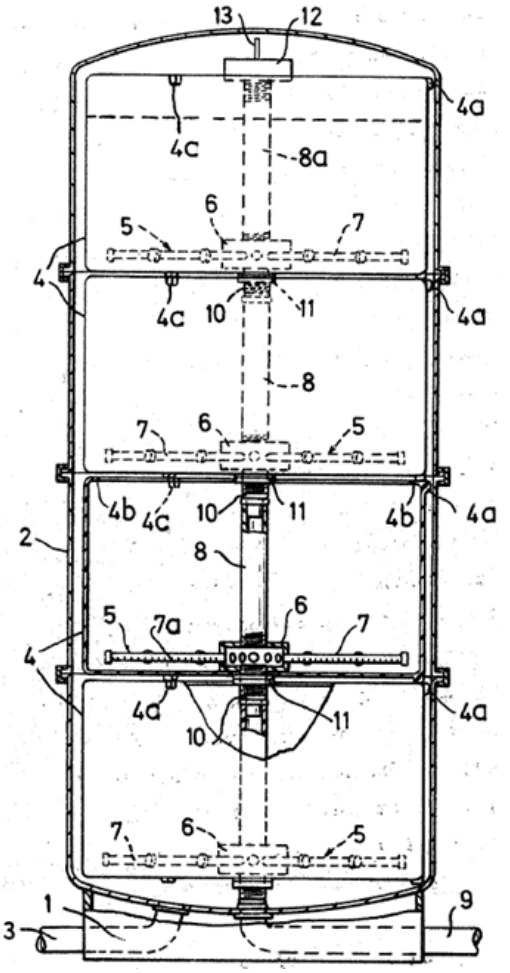

Figure 4: Stainless steel filter schematic [10]

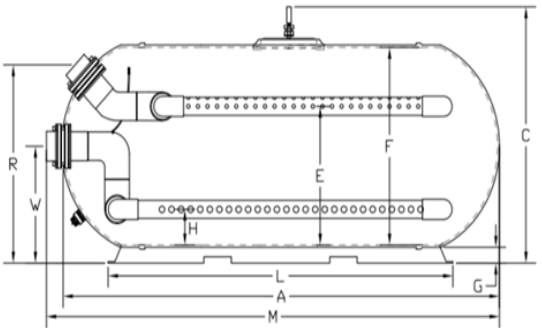

Figure 5: Fibreglass horizontal filter schematic [12]

The quicker backwash means that less water is wasted, as backwash water is immediately sent to the drain, and this becomes increasingly vital in heated pools, such as the one at the POC. When less water is wasted, less energy is required to heat up the new water brought in from the water supply, resulting in a decrease in energy consumption. Also, less energy is spent on backwashing, which serves to regenerate the filters but otherwise does not contribute to the function of the swimming pool.

On the topic of recharging filters, the stainless-steel filters also have a more economical cradle-to-grave cycle. Being relatively smaller than conventional filters, the initial transport of these filters is significantly cheaper. The required space for these filters and the piping required to transport water to them is also reduced, an added advantage that is vital in infrastructure where space is limited. This means that pump rooms do not have to be large structures to accommodate larger filters, cutting down on concrete and transport costs. The stainless-steel filters are also made of entirely recyclable material, compared to say, the conventional flatbed filter discussed here, which uses a fibreglass shell that, at the end of its service life, is a total write-off. Therefore, while the stainless-steel filters are more expensive, their cradle-to-grave cycle is more economical, and ultimately saves more energy.

Conclusions

While all the pools within MINDEF are different, even serving different purposes from fitness and operations training to recreation and rehabilitation, it is always a challenge to achieve maximum energy efficiency, as there are several factors that must be considered as well when designing a swimming pool. A pool could be recreational, which requires shorter turnover times, or solely for training, which lengthen acceptable turnover times. Pools such as the one in POC Bolkiah Garrison would need heater units for when the water needs to be heated, or alternative cleaning units when chlorine is unacceptable, whereas salt-water pools or deep-diving pools may have salt-injection units so that the pool water replicated the properties of sea water. The end users' requirements will determine the function of the pool, which affects the initial design of the pool and ultimately the energy efficiency of the pool, as more complex functions would have a snowball effect on a pool's efficiency, not least the pool's dimensions or even the distance between the pool and the pump room.

Certainly, there are possible policies that may be implemented that would increase the energy efficiency of the pool, and retro-fitting an inefficient pool would solve issues that were overlooked during the design, however, we cannot discount the fact that decisions in the design phase of a swimming pool will significantly contribute to the pool's power consumption, not just during the normal running of the pool but also during the build of the pool, therefore also saving on the energy expenditure of a retrofit. It is however, important to keep in mind the trade-offs that may have to be made when attempting to prioritise energy efficiency. It is hoped that these findings will lend more insight into future pool designs and help suggest recommendations towards the policies that may be implemented to decrease energy consumption within MINDEF.

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Recommendations on Physical Training during Ramadan Fasting for Royal Brunei Armed Forces Soldiers

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ABSTRACT

Fasting during the ninth month of the Hijrah calendar, i.e. Ramadan, is mandatory for all able-bodied Muslim. During this fasting month, soldiers who fast will face challenges in maintaining their optimum fitness level due to restrictions on food and fluid intake including alteration in physical activities and sleep patterns. This article will provide strategies and suggestions that can assist Royal Brunei Armed Forces (RBAF) personnel to continue and maintain their physical activities during Ramadan. Recommendations provided in this article will cover all different aspects of performance such as training, which looks at the ideal time-of-day to train, nutrition by providing guidelines on food intake, timings for meal consumption and type of nutrients, hydration strategies to minimize fluid loss during training and cooling techniques, rest and recovery such as planned naps during the day and sleep schedule and lastly, cognitive and mental preparations and performance of soldiers. This article will act as a useful guide for trainers and soldiers to plan their training program strategically in order to circumvent the challenges of training whilst fasting and obtain the most optimal level of fitness performance during Ramadan.

Introduction

Ramadan is the ninth month of the Hijrah calendar and considered the most sacred period of the year in Islam. During Ramadan, Muslims refrain from drinking, eating and smoking from dawn (sahur) until sunset (iftar), although persons may eat during the remaining hours. Daily fasting duration depend on the prevailing daylight hours for example; summer season (in the northern hemisphere) daylight hours are longer; therefore Muslims living in this region can fast up to 18 h per day. However in Brunei, Muslims fast consistently around 13 hours throughout.

During the Ramadan month, in predominantly Muslim societies such as countries in the Middle East region, Ramadan fasting and its associated activities become the primary focus and much of the daily activities and routines revolve around the act of fasting. For example, the start of the working day is delayed and working hours are shortened. Sporting activities such as football league matches are played after iftar, and the period between this meal and the competition is generally two to three hours. However, in other contemporary societies, this is clearly not the case and thus Muslim individuals in these countries will have to adapt and suit their behaviour to the majority of society accordingly. International competitions or major sports events scheduling do not take Ramadan into account and many Muslim athletes perform the expected challenging physical requirements during these events [1,2]. Similarly, for military personnel, operations continue throughout the Ramadan month and, the duration operations are varying.

Perturbations that are commonly associated with Ramadan fasting such as dehydration, substrate limitation, sleep deficit, mood swings and feeling of lethargy could influence optimal cognitive and physical performances [3]. Behavioural modifications include meal re-scheduling and disturbances in sleep patterns could be deemed as additional stress imposed on the athletes/soldiers. This may also lead to drastic shift in the individual diurnal circadian rhythm resulting in a negative impact on an athlete/soldier's physiology and lifestyles [4]. Thus, perturbations associated with fasting could negatively impact optimal performance and training-induced adaptations in the military personnel who is fasting. Previous studies have shown that exercise performance is likely to be poorer during the initial first week of Ramadan month.

Military personnel are required to maintain their fitness levels and continue their training regime despite observing the month of Ramadan. Physical activities are reduced during the month of Ramadan and following the Eid festivals due to other events or functions, leading to a possible decline in their physical fitness levels.

Military personnel are required to maintain their fitness levels and continue their training regime despite observing the month of Ramadan [4]. Physical activities are reduced during the month of Ramadan and following the Eid festivals due to other events or functions, leading to a possible decline in their physical fitness levels.

There are many studies that have been carried out to show that health and physical performances does not necessarily decline during Ramadan. Hence, the Performance Optimisation Centre (POC), supported by experts from Singapore Sports Institute and Universiti Sains Malaysia, has organized a two days seminar, titled "Physical Training during Ramadan Fasting for Royal Brunei Armed Forces Soldiers" aimed at creating awareness and educating RBAF personnel on the optimal and most efficient way to conduct training during this Holy month. Some of the topics presented during the seminar focused on the effects of Ramadan fasting on exercise and military performance, impact of fasting on psychological and mental strength, physiological stress on exercise training during fasting and recommendations for optimal and effective training during Ramadan.

There are many strategies and suggestions that can help RBAF's personnel continue their physical activities during Ramadan that was highlighted during the seminar. Thus, this document intends to share the recommendations suggested for optimal training during Ramadan month and provide guidance for Muslim athletes/soldiers on how to overcome and/or circumvent the challenges of Ramadan fasting whilst training and carry out military operations at the same time.

Document Overview

This paper aims to provide the reader with guidelines on recommended methods of physical training for Muslim athletes/soldiers during Ramadan month. It addresses modifications that will need to be performed on existing training programme while taking into consideration of variation seen during fasting in terms of performance parameters, in order to maintain operational effectiveness and to ensure optimum performance and readiness. This document is based on a review e-book Chapter titled "Recommendations for Optimal Competitive Exercise Performance and Effective Training-Induced Adaptations when Ramadan fasting" published in an e-book titled "Effects of Ramadan fasting on

Health and Athletic Performance", edited by Dr Hamdi Chtourou and published by Omics eBooks Group on June, 2015 [3].

The objectives of this paper are to provide guidance for RBAF Training Officers and Instructors when planning and organising physical training programme during Ramadan fasting and for future development of Ramadan physical fitness training policy. The outline of the paper are as stated below:

Modifications to Training describes ways to reduce the unfavourable impact of Ramadan fasting and improving or maintaining exercise performance by modifications on training variables such as time-of-day training, the FITT (i.e. Frequency, Intensity, Time and Type) principles of exercise, warm-ups protocols, training environment and organisation including pre-Ramadan training initiatives.

Modifications to Nutrition provides recommendations that athletes/soldiers will need to take into account in terms of the type, amount and time of day of food ingestion by applying the same FITT principled used in training.

Modifications to Hydration explains the FITT principles of hydration that needs to be taken into considerations when trying to optimize the exercise performance of athletes/soldiers during training in Ramadan.

Rest and Recovery describes steps or behavioral patterns that athletes can adopt to enhance their overall rest and recovery situation during Ramadan.

Psychological and Cognitive Impact provides recommendations on how to improve the cognitive and mental performance of athletes/soldiers during Ramadan.

Modifications to Training

Training variables can be modified to improve or maintain exercise performance during the month of Ramadan through modifications on the time-of-day of training, FITT (i.e. Frequency, Intensity, Time and Type) principles of exercise, warm-ups protocols and training environment. This section will explain further on the specific recommendations for each component.

1. Time-of-day:

The available options to schedule training sessions are: 2-3 h after sahur, 1-2 h just before iftar, and 2-3 h after iftar.

a. Training session after sahur:
(i) Prior to this session, the athlete/soldier would have just consumed their sahur meals early in the morning i.e. 1-2 h before commencing the training. Therefore, he/she would be food and fluid filled.
(ii) While in theory, the quality of the session may not be compromised, the training-induced adaptations of the session are not really ideal since post-exercise food and fluid can only be consumed >6-8 h (or longer depending on the duration of the day's fast) later at iftar. Indeed, research has shown that there is no effective recovery from training until nutrients are ingested by the athlete/soldier [5].
(iii) Training in the morning could also lead to poorer and less than optimal quality of effort since the soldier may likely to "pace" himself during the session to conserve energy.
(iv) Thus, physically low-to-moderate intensities exercises, such as specific skills, tactics and techniques, are usually recommended.

b. Training session just before iftar:
(i) Advantageous since high level of motor coordination and other physical measures such as strength tend to peak around late afternoon or early evening period and arousal levels are closer to optimum level for exercise performance [6].
(ii) Due to the prolonged absence of food and fluid during the day prior to exercise, the athlete/soldier may experience sleepiness, early onset of fatigue and may face a heightened risk to injury [7].
(iii) Quality of training might be compromised but the cellular effects of the mechanical work done may be advantageous [8].
(iv) Session must end just prior to the breaking of the day's fast to allow ingestion of food and fluid within the ideal window to optimise cellular training-induced adaptations [8,9].

c. Training session after iftar:
(i) The major advantage conducted 2-3h after breaking of fast provides the best opportunity to fuel and hydrate before, during and after exercise without restrictions.
(ii) However, high-intensity exercises performed 1-2h before bedtime can negatively affect sleep quality [10], and may further be exacerbated with the need to wake up early to consume sahur meal. With this sleeping pattern repeated over days, there will be accumulated sleep debt that could be debilitating to the fasted individual [11].

d. Based on all of the recommendations stated above, the table below presents two proposed model for a twice-a-day training session for Muslim athletes/soldiers during Ramadan at different times.

Table 1: Model A for a suggested twice-a-day training sessions [42].

Time	Daylight					Darkness			
	A.M.			Noon	P.M.	P.M.			P.M./ A.M.
	05:00–05:30h	06:00–08:00h	08:00h–10:00h	11:00–12:00h	12:00–17:30h	17:30–19:15h	19:15–20:00h	20:30–22:00h	23:00–05:00h
Activity	Eat & Drink (***Sahur*** *Meal*)	Sleep/ Rest	Train (non-physically challenging /technical exercise session)	Day nap	Rest	Rest	Eat & drink (***Iftar*** meal)	Train (high-intensity exercise) and Eat & drink	Sleep

Table 2: Model B for a suggested twice-a-day training sessions [42].

Time	Daylight						Darkness		
	A.M.			Noon	P. M.		P.M.		P.M. /A.M.
	05:00–05:30h	06:00–08:00h	08:00h–10:00h	11:00–12:00h	12:00–17:30h	17:30–19:15h	19:15–20:00h	20:30–22:00h	23:00–05:00h
Activity	Eat & Drink (***Sahur*** *Meal*)	Sleep/ Rest	Train (non-physically challenging /technical exercise session)	Day nap	Rest	Train (high-intensity exercise)	Eat & drink (***Iftar*** meal)	Rest and/or Eat & drink	Sleep

Nonetheless, it is still ideal that training sessions are conducted at the same time-of-day as their competition event time, regardless of the optimal time for training during Ramadan as this will condition the body to perform at its best at that specific time [12].

2. FITT principle for training

a. Frequency: If twice a day of training session needs to be carried out, the first session of training needs to be a low-to-moderate intensity or a tactical session or an "indoor training" such as video analysis, psychological counselling, education or career talks.

b. Intensity:
(i) It is suggested that athlete/soldiers train at relatively lower training load or intensity with reduced duration of the beginning of Ramadan to dissipate accumulated fatigue and maximise adaptation, and subsequently progressively increasing the training load towards the later part of Ramadan [13].
(ii) Another strategy is to commence the act of fasting (or at least partial fasting) in a stepwise manner over a few days or up to two weeks prior to the official start of Ramadan. This is similar to the method used in anticipation of major change in time zone where people slowly adapt by changing their major sleep period over a course of a week prior to international travel.
(iii) In summary, it is emphasised that athlete/ soldiers should maintain the training intensity or load during Ramadan equivalent to that before Ramadan, after progressively increase the training load towards the later part of Ramadan [13,14].

c. Time (or duration of exercise):
(i) Regardless of intensity, it is important that sessions during the daytime in Ramadan do not last longer than 75 min (including warmup and cool-down phases). Such duration usually means that hypoglycemia does not develop in fasted subjects, and more importantly, endogenous muscle glycogen will not deplete and limits exercise capacity [15].
(ii) Performance and capacity during moderate –to high- intensity exercises that are longer than 90min tended to be limited by both liver and muscle glycogen [16] and possibly dehydration as well, which can lead to poor thermoregulatory processes.
(iii) More frequent rest periods must be allowed during training sessions, and physical training sessions should be kept as short as possible, without compromising the objective of the session.

d. Type of exercise performed:
(i) If two training sessions are conducted in a day, it is best to convert the first session to a less physically taxing session.
(ii) It is also important to schedule some of strength or resistance session, at least once a week in order to reduce total protein loss and preserve muscle mass [17].

3. Warm-ups protocols:

a. Warm-up is important during Ramadan sessions as it helps reduce "sleep inertia" in fasting athletes/soldiers who are planning to exercise soon after waking up from their daytime naps.

b. Too much or excessive warm-up can lead to accumulative fatigue and too long a duration will increase heat exposure and sweat loss; all of which could compromise the fasted individual's thermoregulation processes later during the session, especially when exercising in a hot and humid environment.

c. Warm-up session should be of appropriate intensity between ~60 – 70% VO2max (maximum volume of oxygen an individual can use at maximum levels of intense aerobic exercise) but short duration of 10min or less, followed by several minutes of recovery [18].

4. Training environment

Training sessions should preferably be carried out in a cool, shaded place as much and often as possible, which will help reduce the debilitating effects of heat on physiological and perceptual responses, which are factors that could lead to poorer exercise performance [19,20].

Modifications to Nutrition

During Ramadan fasting, the absence of nutrients for a prolonged period of time can result in hypoglycemia and lowers the amount of endogenous glycogen concentration. Thus, an athlete/soldier will need to take into account the type, amount and the time of day of food ingestion in order to optimize the endogenous substrates storage for future use during exercise. Therefore, the FITT principle will be applied to the modifications of dietary intake during Ramadan.

1. FITT principle for nutrition

a. Frequency: It is recommended that Ramadan's sahur meal to be matched with the normal lunch; Ramadan's iftar meal to dinner; and Ramadan night's snack with the typical morning breakfast [20]. This will ensure that athletes/ soldiers will likely consume sufficient amount of calories over the 24h period during Ramadan.

b. Intensity (or amount):
(i) It is recommended that the total energy intake is able to support the energy requirement for performance and recovery as well as satisfy the overall needs for food and fluid for the day.
(ii) Sahur is the last opportunity for fasting athletes/ soldiers to be able to put nutrients in their body and hence, the individual who is planning to fast should take full advantage of this meal.

c. Timing:
(i) Sahur meal should be consumed as close as possible to sunrise just before the commencement of the day's fast while iftar to be taken immediately at sunset once allowable to break from fasting [20]. This strategy will ensure that the body is in the 'fasted state' for the shortest period possible.
(ii) It is well established that the best time to consume food and fluid for recovery is the period immediately after exercise, especially heavy training, for higher rates of glycogen storage during first 2-4h post exercise [9]. Therefore, if heavy training is to be conducted during the day time in Ramadan, the session should be timed such that it ends just prior to the breaking of the day's fast to allow unrestricted ingestion of food and fluid for enhanced post-exercise recovery [9].

d. Type:
(i) There are 3 types of nutrients the physical body needs on a daily basis: carbohydrates, proteins and fats.
(ii) Food taken by athletes/soldiers for iftar and sahur should contain predominantly nutrients of carbohydrate and protein.
(iii) It has recently been shown that the date fruit is an advantageous nutrient because

it is a low GI (Glycaemic Index) food and it is caloric-dense [21]. Milk contains a high amount of protein and recent studies have indicated that adding a small amount of protein to carbohydrate clearly has been shown to further enhance absorption of carbohydrate and thus storage of muscle glycogen [22]. Additionally, the ingested protein will promote amino acid re-synthesis and muscle re-building [23].
(iv) It is recommended that consumption of a combination of low GI meal and protein (i.e., dates and milk) as to provide the best mixed meal during iftar, although scientific experimental studies are required to confirm this assertion [3].

2. Balanced meal

a. Macronutrients are the energy-giving components of our food intake and they help our body to function properly. The total daily calories required by a soldier depends on the body size, activity level and environment he/she is in. Men and women generally should have 3,250 to 4,600 and 2,300 to 3,150 calories, respectively, per day, which will fluctuate based on the factors stated.
(i) Carbohydrates: It provides fuel for the brain, central nervous system and kidneys, and are found in grain foods such as bread, rice, quinoa, pasta, potatoes, crackers and barley. It should contain 45 – 65% of your total daily calories.
(ii) Protein: It is the building block for brain cells, muscle, skin, hair and nails, and is found in meat and plant-based foods like legumes, seeds and grains. It should contain 10 – 35% of your total daily calories.
(iii) Fats: It is vital to healthy body function. Healthy fat is important for absorption of fat soluble vitamins, and is found in foods such as flaxseed, nuts, avocadoes and hummus. It should contain 20 – 35% of your total daily calories.

b. Micronutrients, on the other hand, are the essential vitamins, minerals, antioxidants and phytochemicals within these micronutrients. They are vital to the proper functioning of all the body's systems. The micronutrients that our body needs can be found in foods such as nuts, whole grains, leafy green vegetables and colourful fruits.

Modifications to Hydration

Athletes/soldiers' are unable to ingest fluid many hours before exercise during Ramadan fasting which can lead them to a hypohydrated state pre-exercise. This state is made worse during exercise in the daytime during Ramadan, and cause acute dehydration [24]. Research has shown that pre-exercise hypohydration as little as ~1-2% of body mass can reduce performance of short duration, high-intensity exercises [19]. It is reasonable to argue that for the Ramadan fasted individual, the lack of acute fluid intake before and during exercise will result in greater physiological consequence than that of food intake, especially if the exercise is performed in a hot and humid environment.

The main aim of the hydration strategies during Ramadan is to minimize pre-exercise hypohydration and fluid loss (i.e., dehydration) during exercise session. Additionally, the trainer and athlete/soldier need to be aware of the different environmental conditions that can exacerbate the effects of hypo- and de-hydration during exercise, and take these into considerations when planning for the volume of fluid to be ingested, prior to the start of day's fast. Similar to previous modifications and recommendations, the FITT principles of hydration is taken into consideration for optimizing the exercise performance during Ramadan including monitoring hydrations status, cooling techniques to be applied and mouth-rinsing strategy.

1. FIIT principle for hydration

a. Frequency:
(i) It is recommended that athletes/soldiers hyper-hydrate themselves during the permissible period between iftar and sahur. During this period, fluid intake should be spread out throughout the available time, with frequent small amounts of drinks rather than ingesting large volumes in a single seating. This "grazing" pattern of fluid intake will help retain greater fluid and reduce necessary urine losses.
(ii) Fluid consumption should be paced at a rate of ~200 ml for every 30 min [20].
(iii) Fluid retention is further enhanced when sodium salts are added to the ingested food and drinks [25].
(iv) Another possibility of increasing fluid retention is to consume fluid together with glycerol, which is a masking agent for hyper-hydrating and helps to retain the fluid in the body [25]. This method however, is deemed as illegal for competitive athletes as stated by the World Anti-Doping Agency (WADA).

b. Intensity (or amount):
(i) The European Food Safety Authority recommended that the total water intake over 24 h is 2.5 L per day for adult individuals living in temperate climate [26]. There is no suggested value for individuals in equatorial region, but a volume of ~3.0 L per day seems reasonable, and probably Ramadan fasted athletes/soldiers may require a slightly higher volume [20].
(ii) To individualized fluid requirement over the 24 h period during Ramadan, the athlete/soldier can simply weigh himself before and after a typical training session to obtain the estimated amount of fluid loss from sweating

during exercise (this should be trialed out in the non-Ramadan period). The formula is as follows:

Sweat loss = Change in body mass + Fluid intake during exercise – Urine output [27].

This calculated fluid requirement can be used to determine the individual's total volume for the day during Ramadan.

c. Timing: Similar to the nutritional strategy, the athlete is encouraged to ingest fluid as soon as permissible and also to ingest as much as possible throughout the nocturnal period until the commencement of the day's fast, using the above-mentioned grazing technique.

d. Type:
(i) While plain water is acceptable, it is unlikely that many athletes/soldiers would want to consume only water throughout the period between iftar and sahur. To promote voluntary consumption, the fluid should be of varying flavours.
(ii) Athletes/soldiers should consume only a small amount of coffee and tea since they are diuretic which promote fluid excretion rather than retention.

2. Hydration status monitoring: Urine frequency and colour can be used as simple markers to monitor hydration status on a daily basis. A normal dehydrated individual will have a light yellow urine colour, whilst a darker yellow urine colour implies a greater state of hypo-hydration [28].

3. Mouth-rinsing strategy: Anecdotal evidence indicated that the mouth-rinsing strategy seems to provide subjective relief, albeit only temporary. This view is supported by a recent study showing that mouth- rinsing with either carbohydrate or water at every 10 min intervals during a ~55 min time-trial cycling performance in the Ramadan fasted state led to a better endurance performance when compared to no-mouth rinsing exercise trial [31].

4. Cooling techniques:

a. External cooling techniques such as ice baths, cold towels, plunge pools and ice vests can be used before, during and after exercise to reduce the impact of heat generated and hence attenuate thermoregulatory concerns [29, 30].

b. Trainer and athletes/soldiers should also choose appropriate clothing that allows better dissipation of sweat produced and promotes cooling during exercise in the Ramadan fasted state [19].

Modifications to Rest and Recovery

During Ramadan, Muslims usually wake up early at pre-dawn and with the added social and religious activities that take place after sunset, can lead to ~1-2 h of sleep lost per day [11]. When this acute sleep debt occurs over consecutive days, the accumulation of sleep loss will eventually lead to chronic sleep deprivation, which in turn could affect physical and mental performance directly or indirectly via mood swings or feelings of lethargy [32]. Hence, rest and recovery gain greater importance in the athlete/soldier's overall training program during Ramadan. Below are additional steps or behavioural patterns that athletes/soldiers can adopt to enhance their overall rest and recovery situation during Ramadan:

1. Minimising uneventful physical exertion during daytime:

a. To limit the use of precious available endogenous resources such as muscle and liver glycogen, and blood glucose.

b. To prevent occurrence of accumulative physical fatigue, which could hamper exercise during the later part of the day.

2. Afternoon and/or planned naps:

a. Non-Ramadan studies showed that daytime naps increased acute alertness and neurobehavioral functions [33].

b. Sprint performance was also enhanced following a 30min afternoon nap [34].

c. It is advised to best avoid prolonged (>60min) daytime naps and/or naps close to bedtime as it will tend to disturb nocturnal sleep and make it more difficult for the individuals to adjust to the changing biological clock [35].

3. Sleep quantity and quality:

a. Encouraged to take daytime naps to compensate for the shorter nocturnal sleep hours.

b. Need to plan a fixed sleep schedule to ensure that sleep hours are maintained throughout the fasting month [19].

Psychological and Cognitive Impact

One of the fundamental factors that helps athletes/soldiers in concentration; learning and remembering new skills; reacting appropriately to stimuli; solving problems or decision-makings; is optimal cognitive functioning and these are useful in many sports and activities. Therefore, impairment to the cognitive function can affect the athlete/soldier's performance and result in injury [36]. Physical and mental performance, including cognitive function, fluctuates across the day during Ramadan due to changes in the circadian rhythm of the body [19]. Several recommendations are compiled to help improve cognitive and mental performance of athletes/soldiers during Ramadan.

1. Support from coaches/instructors and non-Muslim teammates:

a. Coaches/instructors and non-Muslim teammates should try to provide every support possible to Muslim athletes/soldiers who are fasting. Emotional support from non-Muslim teammates and coaches is very important for a more cohesive team dynamics.

b. Non-Muslim coaches/instructors can make some effort to appreciate and understand why the Muslims fast, and what the Muslim athletes are going through [37]. This may help them to plan and organize the athlete/soldier's training program to better suit the fasting Ramadan regime [37]. Furthermore, knowing that the coach/instructor is fully supportive of his decision will strengthen the fasted athlete/soldier's conviction to do his best and maximize his effort in training and competition.

2. Ramadan fasting as a coping strategy for stress:

a. It has been reported that fasting athletes actually experienced less stress during Ramadan [1]. This could be due to the athlete's personal spiritual belief and the act of Ramadan fasting itself, where a Muslim individual is expected to engage in daily prayers, and self-control, which can lead to a positive state of mind.

b. Fasting athletes should be encouraged to regulate and mobilize their emotions and psychological resources towards a more positive approach, which can enhance his sporting performance. Additionally, there were reports stating that Muslim athletes felt much stronger or "more powerful" when competing in the Ramadan fasted state [38]. Apparently, these fasting athletes became more determined, i.e., mentally stronger or possessed a greater level of motivation to do well and perform their best during training or competition whilst in the Ramadan fasted state [4]. Thus, athletes are recommended to maintain an overall positive mental perspective of the Ramadan fast in order to help them cope with the rigors of training during fasting.

3. Coaches/instructors awareness on the perturbations of circadian system during Ramadan fasting:

a. The human circadian system provides coordination of many endogenous physiological and behavioral systems, such as core body temperature and sleep-wake pattern, with each other and with the external environment. The circadian system is entrained to the 24 h day via exposure to the Earth's 24 h light-dark cycle, and some of the peaking of these variables are parallel with peaking in exercise performances [39]. A delay in evening sleep times and early or delayed awake times can significantly alter the natural circadian rhythm and this drastic shift has been touted as one of the contributing factors for the observed impact of fasting on exercise performance during Ramadan [19, 6]. For example, the athlete may always perform his best in the late afternoon or early evening in non-Ramadan period, but this "top" performance may be delayed to the late evening period during Ramadan due to the drastic shift in his circadian rhythm [40].

b. Coaches and athletes should be aware of such disturbances that can cause much variability in their performance and/or capability when planning the athlete's training programs [19].

4. Mental preparation strategies throughout Ramadan fasting:

a. Athlete's mood and motivation can also be severely affected during Ramadan. Therefore, it is recommended for the athletes to practice some mental preparation strategies such as task focused concentration, positive expectations, correct execution of task and emotional control, throughout Ramadan. This is to develop proactive coping strategies for improving general resources required to reduce or attenuate the discomfort of fasting during Ramadan [1].

b. In line with the teachings of Islam, the athlete/soldier is reminded to adopt a more patient approach in their dealings with any stressful or conflicting situations during Ramadan. This will clearly help the athletes/soldiers to cope better when fasting and training at the same time. Coaches/instructors should also be aware of the variability in performance capacity and/or capability over the day when planning or modifying their training programs [19].

5. Ways to assess athletes/soldiers exercise performance during Ramadan fasting:

a. Previous studies have also assessed the fasted individuals' ability to train, alertness and concentration and other variables as indicators of the fasted individuals' fatigue levels [10,41,42]. These studies have used psychological instruments tests such as the Profile Mood of State to determine the individuals' mood levels prior to exercise.

6. Previous Ramadan fasting and exercise studies have shown two consistent findings:

a. Exercise performance is likely to be poorer during the initial first week of Ramadan month.

b. Performance tends to be better (albeit still lower than during non-Ramadan days) as Ramadan progresses.

These findings suggest that Muslim individuals are able to cope with the negative perturbations of Ramadan, if given time to adjust. Thus, in situations where the athlete needs to compete during the first few days of Ramadan, there is clearly a need for the athletes to "familiarize" themselves to exercising in the fasted state. The coach may need to organize simulated matches that compel the athletes to compete or exercise in the "simulated" Ramadan fasted state, in preparation to competitions held during the early part of the fasting month.

Summary

In summary, the paper has provided Muslim athletes/soldiers with guidelines on recommended methods or strategies for optimal training during Ramadan month. Recommendations were provided looking at all different aspects of performance such as training, nutrition, hydration, rest and recovery and lastly, psychological and cognitive impact.

For training variables, some of the recommendations that were provided looked the time-of-day of training, where it is recommended for trainings of high-intensity to be conducted before or after iftar. Ideally training sessions should also be conducted at the same time-of-day as their competition event time in order to allow the body to condition at that specific time. Trainings can also be carried out twice a day depending on the intensity of session and this intensity or load can be progressively increased towards the later part of Ramadan and should be equivalent to that of before Ramadan. Trainings should also be conducted at a cool, shaded area as much as possible and not longer than 75 mins during daytime with frequent rest periods are recommended. Warm-up sessions are also recommended to be conducted at a duration of 10 mins of less with intensity of 60% to 70% VO2max.

In terms of nutrition, it is recommended that an athlete consume three meals during Ramadan which is during sahur, iftar and night snack. The amount of food intake should also be able to support the energy requirement for performance and recovery for the day. Timings for meal consumption is also important where sahur meal must be consumed as close as possible to sunrise and iftar meal to be taken immediately at the allowed break time. If heavy training is conducted during the day time, the session should end just prior to breaking the day's fast for enhanced post-exercise recovery. The type of nutrients to be consumed is also important for improving the performance of athletes/ soldiers during Ramadan. It is recommended that food taken for iftar and sahur should contain predominantly carbohydrates and protein, with iftar meals preferably a combination of low GI meal and protein.

There are also several hydration strategies that can be considered during Ramadan in order to minimize fluid loss during training. It is recommended that athletes/soldiers hyper-hydrate themselves between iftar and sahur time, where fluid intake should be spread out with frequent small amounts. Ideally, the amount of fluid to be consumed in a day is according to the calculated amount of fluid loss from sweating during exercise. Athlete/ soldiers are also encouraged to ingest fluid immediately after iftar and coffee or tea should only be consume at a small amount as it promote fluid excretion. Other strategies such as monitoring hydration status, performing various cooling techniques and mouth-rinsing strategy are also vital in order to maintain and improve performance during Ramadan fasting.

Rest and recovery are also of great importance for athlete/soldier's overall training program during Ramadan. Some of the recommendations that have been stated is to minimise uneventful physical exertion during daytime, afternoon and/or planned naps during the day and to plan a fixed sleep schedule to ensure that sleep hours are maintained throughout the fasting month.

Lastly, there are also several recommendations on how to improve cognitive and mental performance of athletes/soldiers during Ramadan. Support from coaches and non-Muslim teammates are important for a more cohesive team dynamics such as better understanding and appreciation on why Muslims fast and what the Muslim athletes are going through.

Ramadan fasting can also reduce stress through their personal spiritual belief and the act of Ramadan fasting itself which can lead to a positive state of mind. It is also helpful if coaches or instructors are aware on the perturbations of circadian system during Ramadan fasting when planning training programs as this can cause variability in their performance. Mental preparation strategies throughout Ramadan is also useful as proactive coping strategies and there are ways for coaches or instructors to determine their athletes/soldiers mood levels prior to exercise. Muslim individuals are able to cope with the effects of Ramadan if given time to adjust and if the recommended steps stated in this paper are followed accordingly, performance of Muslim athletes/soldiers can be maintained or further improved during Ramadan fasting.

Conclusions

Ramadan fasting can influence an athlete/ soldier's exercise performance evident from their training and competitions outcomes. However through a unison of several strategies, as explained in the paper, Ramadan can have a non-detrimental effect on performance. This includes implementing or applying different aspects of frequency, intensity (amount or volume), timing and types of training, nutrition, sleep, rest, and even personal lifestyle and social behavioral strategies. Hence with this document, the guidelines provided can lead to the development of effective and optimal training programme for soldiers and thus, improve and maintain their physical fitness and performance during Ramadan. This will also assist in maintaining the overall operational performance and capabilities of the RBAF throughout the year and can eventually lead to the development of a fitness training policy for Ramadan month including creating more opportunities to conduct research on this particular subject matter.

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