KDUiRC
INTERNATIONAL RESEARCH CONFERENCE

14TH INTERNATIONAL RESEARCH CONFERENCE

" Security, Stability and National Development in the New Normal "

09TH - 10TH SEPTEMBER 2021

BASIC AND APPLIED SCIENCES

PROCEEDINGS

GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

14TH INTERNATIONAL RESEARCH CONFERENCE

SECURITY, STABILITY AND NATIONAL DEVELOPMENT IN THE NEW NORMAL

Basic and Applied Sciences

PROCEEDINGS

General Sir John Kotelawala Defence University

Ratmalana, Sri Lanka

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Vice Chancellor, General Sir John Kotelawala Defence University

Keynote Speaker, Mr. Lalith Weeratunga Principal Advisor to H.E. President Gotabaya Rajapaksa, Secretary to the Ministry of Defence, General (Retd.) Kamal Gunaratne, DVC Administration and Defense, Brigadier Wipula Chandrasiri, DVC Academic, Prof Sanath Dhammika, Deans of the respective faculties, Centre Directors, Academics, Senior Military Officers, Administrative Staff, Students and all distinguished guests who are connected with us in the cyber space.
Good Morning to you all!

It is indeed with a great sense of responsibility that I deliver the welcome address at this 14th consecutive international research conference of General Sir John Kotelawala Defence University held on the timely theme, 'Security, Stability and National Development in the New Normal", at one of the most crucial times of our history.

To begin with, let me very warmly welcome our chief guest and keynote speaker, Mr. Lalith Weeratunga, the principal advisor to HE the President Gotabhaya Rajapakse. Of course, Mr. Lalith Weeratunga is not at all a stranger to KDU. He is one of the great personalities who clearly understands the role played by KDU for the betterment of the nation and who has long been assisting us in numerous ways to develop this institution to what it is today. As I remember Mr. Lalith Weeratunga was the keynote speaker of our 6th research conference in 2013. Sir, your keynote on our theme, "Sri Lanka as a Hub in Asia: the Way Foreword" still reverberate in our minds even after 8 long years.

And it is a remarkable coincidence that I welcome you once again to deliver the keynote address on our current theme, 'Security, Stability and National Development in the New Normal", which highlights the importance of stability created by the development and security nexus in the context of emerging new threats to national, human, and global security. Sir, we are looking forward to listening to your words of wisdom today as well.

Mr Weeratunga, it is also remarkable that eight years ago, you were accompanied by the Secretary Defence during that time, who has been destined to be President of our country today, H.E. Gotabaya Rajapaksa, and today you are accompanied by the present Secretary Defence and the Chairman of our Board of Management, General (Retd.) Kamal Gunarathne, and I am indeed honoured to welcome General Kamal to this conference as the Guest of Honour because he has been a tower of strength for KDU at this crucial time of its history.

Let me also welcome all distinguished invitees including the Tri-Service Commanders and other BOM members including the Chairman of the UGC, distinguished members of the diplomatic corps, Vice Chancellors and academics from other universities, senior tri-service and police officers, and national and international participants joining this event on line.

Ladies and gentlemen, this year's conference is significant to us at KDU on several accounts. First, 2021 is the year in which we mark the 40th year of KDU's existence in the higher education landscape of Sri Lanka, and we are proud of the role we have been playing therein, whilst continuously growing in its stature as a national university doing its call of

duty towards the nation with fullest commitment and dedication.

Secondly, this year's conference is the one that we hold under the most trying circumstances in our history. Last year too, we conducted our research conference in a hybrid mode due to the first wave of the COVID 19 pandemic that took us all by surprise.

But we hoped that we would be able to conduct the 2021 conference freely and in the usual glamour. But this year, it turned out to be even a worse scenario with the third wave of the pandemic hitting us harder. So we consider that this is a more challenging test of our resilience as the nation's defence university.

Ladies and gentlemen, we always believe in the dictum that a quitter never wins and a winner never quits. So we were determined to challenge the challenges, how hard they may be. And we ensure the continuity of the conference adjusting and amending the circumstances, while taking the highest precautions against the pandemic scenario. We were able to slowly but steadily accept the prevailing danger, assess the situation realistically, and to see the best options for the best interest of our University. Therefore, we finally decided that this year's conference will a hybrid one with a major virtual orientation.

Ladies and gentlemen, the reason why we conduct this conference somehow or the other is because of our belief that we need to set an example for the nation to stand on its feet at times of crises. We as a nation cannot afford to continue to play the waiting game for ever. As our theme highlights, we need to find ways to ensure security and national development in the new normal adjusting ourselves to the new normal conditions sooner than later.

And thirdly, we believe that this is the time in which a nation's intellectual community must come forward to engage in serious and meaningful research to help overcome innumerable issues and problems that crop up in diverse fields such as defence and security, economics, science, technology and engineering, medicine and health services, management, social sciences and humanities, law and so on and so forth. It is the responsibility of a university to create the necessary environment and enabling grounds for important research outcomes, which the nation yearns for.

Ladies and gentlemen, we are glad that the intellectual community of the country has very positively responded to our initiative. Despite some adverse comments and criticisms of KDU and its role in higher education in Sri Lanka from certain quarters in recent times, the large majority of fair thinking academics, professionals and ordinary people are with us fully, and that is evident from the large number of research papers submitted by researchers from all over the country representing various higher educational institutions.

Despite the difficulties in adjusting to the online mode, the organizers of the KDU international research conference have done their best to maintain the quality of the conference in the highest level. They intend to set the tone to initiate more collaborative research to face new global challenges. As I always point out these types of research conferences are ideal platforms to make connections nationally and internationally for mutual benefit.

I hope that authors of KDU and various other local and international universities will take the opportunity to interact and develop friendly relationships, establish networks, and explore opportunities to embark on productive research collaborations.

While assuring our commitment to providing best opportunities for research collaborations, I wish all the very best for the presenters and hope you will enjoy every moment of this academic fusion. Thank you.

Keynote Address

Mr Lalith Weeratunga

Principal Advisor to His Excellency the President of Sri Lanka

Secretary, Ministry of Defence, Chief of Defence Staff and Commander of the Army, Commander of the Air Force, Vice Chancellor of the KDU, Distinguished academics, Honoured guests, Friends, *Ayubowan!*

Once again, I am delighted to be with you this morning at this research conference. It gives me much pleasure to be at the KDU because it is one of the best universities we have in Sri Lanka. Since of late, there have been much attack on and criticism of the KDU. That's because the KDU is doing well and has brooked no nonsense. With a village background, my mind goes back to a famous Sinhala saying, which means "only those mango trees that have sweet fruits are attacked."

The entire world is undergoing a massive reorganization with the COVID-19 pandemic, and the traditional themes and arguments in security seems rather irrelevant in the present context. "Security, Stability, National Development in the New Normal" is a timely theme, giving us much food for thought in terms of the advancement of a country like Sri Lanka. If you take the first component, security, the bottom line of security is survival. *Survival,* is based on a number of factors. Barry Buzan, the veteran in international security rejected the practice of restricting security to just one sector and defined it as "a particular type of politics applicable to a wide range of issues."

As eminent representatives of the security sector, you are aware that the concept of security can somewhat vary from one country to another. When Mexico's major national security threat has remained to be organized crime for quite some time, Afghanistan's has been religious extremism. For a country like Somalia, it is the inbuilt corruption into their governance. For some countries, it might change abruptly. A few days ago, we all saw corruption and mismanagement which was the major security threat of the African nation Guinea, getting substituted by another – an armed unrest. In spite of these differences, almost all countries in the world have developed a commonality during the past year, where the health insecurity assumed a major role over and above all others.

The COVID-19 pandemic has caused the entire world to assume a 'new normal' to fight this common insecurity that is caused by a tiny, microscopic virus. Even during the new normal, however, certain fundamental features of the modern-day security have not changed. Security in the 21st Century was, to a great extent, focused on internal factors of a country, rather than external ones. The organization of the threat factor has changed from state militaries to terrorist organizations to even pirates. The underlying motivation for creating insecurities has shifted from being political to one that is economic.

Targets have shifted from soldiers to civilians. The distinction between 'high profiles' of national security and 'low profiles' of economic and social interactions have softened. This has given rise to new sources of global insecurity in the 21st Century which are essentially 'soft' in nature.

The 21st Century has continued to witness these new sources throughout its first two decades. Donald Rumsfeld, the onetime Defence Secretary of the United States said at a key decision-making point in the history of his country, "there are known knowns; the things we know we know, we also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns—the ones we don't know we don't know." Although stated in relation to a completely different scenario, when recalling this statement, I see that it resonates with the pandemic that we are facing now. In 'security

terms', COVID-19 is a 'wild card', an 'unknown unknown'. It is a security threat without a passport. It caused the 'health security' to assume the prime position in the security landscape of the modern day, surpassing the food security, water security and all other soft securities.

When we view the modern-day threats, we see that none of these is of a purely military nature, as those perhaps were, during the cold-war period. As a result, they also cannot be tackled by purely military means. There is another factor that contributes to the restriction of military means as a response to insecurities. In today's security landscape, States do not have the monopoly that they used to enjoy. Human beings have assumed that role. When the individual is considered as the central point in security rather than the 'State' as before, it gives a new insight into all our security related concerns. This helps us to understand the present-day global vulnerabilities with a new eye.

When the centre of focus in security becomes the individual, it changes the state-centric understanding of national, regional as well as global security. When a pandemic, which cannot be controlled by military means is plaguing the world, the human-centric understanding of security becomes vital to address it in order to ensure development of any country. This is why the 'soft component' of security, or the 'human security' gains more prominence over the 'hard component' of security during this new normal, created by the worst health pandemic in the recent history of the world.

The pandemic has given rise to a number of human security threats. To mention a few, the threat to economic security through unemployment, to health security through the deadly infectious virus and to environmental security through the mass accumulation of the waste generated in the health sector. It has also given a signal on food security as well, which is precisely when the Government declared essential services and appointed an authority to manage the situation in Sri Lanka. So you see, security in the new normal is connected with the stability of a country, but in a different way from how it did with conventional security under the normal conditions.

National development, as we all know, is an all-encompassing term. It includes both the individual and the nation. Therefore, national development can be considered as the process of development and reconstruction of all dimensions of the nation, along with the development of the individual. This concept is essentially linked with both the growth and the change where *change* can be socio-cultural or economic, tangible or intangible. National development involves activities through a planned national economy, application of modern technology in agriculture to enhance production, application of science and technology in the production sector, improving the human resource and providing education for all among many others.

During a disaster such as the COVID pandemic, it also includes providing facilities and assistance to the poorest segments of the society. In theory, addressing the security needs, especially those of soft security and implementing broad array of the previously mentioned key activities in national development ensures the stability of the country during the new normal. This theory is in practice in Sri Lanka today, in different sectors to different degrees.

Let us consider the vaccination drive for example. Two months ago, Sri Lanka was struggling with the inadequate human resource in the civilian component of the health sector to conduct the vaccination programme at its full length. Health sector employees were getting exhausted with the enhancing demand for services. At this point, the Government employed its military health professionals to assist their civilian component. That accelerated our vaccination drive to such an extent that Sri Lanka became the first country in the world to have the fastest vaccination drive to its population.

H.E. the President had first-hand supervision of this process, at times acting as a 'vaccination planner', which contributed to the success of the

whole programme. This measure addresses our health security, and at the same time contributes to our national development by making the workforce resistant to the pandemic. Together, the two outcomes contribute to enhancing the stability of the country during this new normal.

Now let us consider a few of the numerous initiatives that the Government has introduced to ensure food security. The Government recently decided to take a transition from inorganic agriculture to organic agriculture, in keeping with pledge given to our people by the President, H.E Gotabaya Rajapaksa, in his policy document, 'Vistas of Prosperity and Splendour." The primary aim was to safeguard the public, and especially the future generations from non-communicable diseases including renal diseases, again ensuring the health security. This also gave an added advantage where the imports of chemical fertilizers became minimal and that saved a considerable amount of money to our Treasury. This also resulted in enhancing organic and bio fertilizer production within the country, opening up new employment opportunities.

Linked with these two activities, the Government also launched 'Wari Saubhagya', a programme to rehabilitate 1000 small tanks across the country. This was to provide water for both irrigation and drinking purposes. These projects ensured irrigation water to a greater area of paddy and other field crop cultivations and also created additional employment opportunities within the country. Overall, those made a noteworthy contribution to the national development as well as to the soft security of the country during the new normal.

National development not only involves the infrastructure development, but also the human development. A developed human resource is a shield against certain soft threats. The programme 'connect Sri Lanka' was launched during the new normal, initially providing four remote areas with 4G connectivity. We are planning to expand it into all 9 provinces.

The pandemic period where schools had to be closed was also used to plan education reforms aiming at producing future generations that are better equipped with battling their way through the ever-changing global order. These enhance opportunities for the public, especially the children to gain access to knowledge that is amply available to children and citizens of many developed countries, and also to equip themselves better to assist with development initiatives of the Government.

Fruits of this labour will be reaped only in the future, where our country will continue to have a learned, open minded younger generations, and through them, smarter work forces. The activities that the Government has started today contribute to national development in the future on the one hand, security on the other, and to stability of the country, overall.

The last example that I wish to draw has a direct connection with all institutions in the public as well as the private sector, electricity. The Government spent over US$ 2.3 Bln for oil imports in 2020. We all know that a considerable amount of this is spent for generating electricity. This is an unbearable amount for a developing country like Sri Lanka, to be spent notwithstanding the prevailing health pandemic. It is also a waste of funds considering the vast and untapped potential that Sri Lanka has for renewable energy.

The Government gave due consideration to both these when establishing 'Thambapawani' the first wind power station owned by the Government of Sri Lanka. Another similar plant has been launched in Pooneryn. Use of solar power has been introduced to households. A waste-to-power plant was also declared open at Kerawalapitiya. It is not an easy task for a developing country like Sri Lanka to manage this shift while battling with a pandemic, but amidst all, the Government plans to increase the renewable energy component to 70% of the total consumption of the country by 2030. It Is an ambitious target, but it helps the country to reach a higher status in self-sufficiency and also prepares the country to face worse calamities than the present one that might arise in the future. The 'failure to prepare' as the old saying

goes, is 'preparation for failure'. We intend to avoid it.

Moving back to the concept of security with these examples, with special emphasis on human security, it is evident that the national development and security are inter-linked. These cannot be achieved separately. This is probably what caused the formerly known definition of security, 'freedom from fear', to be redefined as 'freedom from want', indicating the link between security and development. Human security, as we all know, is an integral part of State security, which in turn, has an equally strong connection with national development. This is why if you have a closer look at Sustainable Development Goals, you will see that all 17 goals are connected to human security.

In this context, I believe there is something vital that we all need to understand about security, development and the stability that those bring about. The new normal caused by the COVID-19 pandemic is calling us to re-think our actions, plans and concepts on security and development both.

Is it not high time for us to re-think our national security and national development?

Is this not the best time for us to redefine our development-security nexus?

Let me conclude by bringing back to your memory, extracts from a famous speech delivered by Robert F. Kennedy during his run for the Democratic nomination for the Presidency of the United States. Over 50 years later, his remarks about the measurements of development resonate with something that we need to re-discover with experience we had during this new normal. He said, and I quote,

"… the gross national product does not allow for the health of our children, the quality of their education or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages, the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage, neither our wisdom nor our learning, neither our compassion nor our devotion to our country, it measures everything in short, except that which makes life worthwhile."

Distinguished scholars, ladies and gentlemen, let us try to fathom the lesson that this global pandemic and the new normal is trying to teach us. Let us acknowledge the all-encompassing nature of national development and pay attention to the vital fact that has evaded our comprehension thus far – the fact that the individual, the human has assumed the central focus in security as well as in national development. Let us use that understanding to re-define our development-security nexus and bring a lasting stability to our country during the new normal.

Stay safe and take care of yourselves.

Thank you.

Address by Secretary, Ministry of Defence, Sri Lanka

General Kamal Gunaratne (Retd) WWV RWP RSP USP ndc psc MPhil

Secretary, Ministry of Defence, Sri Lanka

Chief Guest and Keynote Speaker of the 14th International Research Conference of KDU, Principal Advisor to the President Mr. Lalith Weerathunga, Ambassadors and High Commissioners, Foreign Secretary Professor Jayanath Kolombage, Chancellor of KDU General Jerry De Silva (Retd), Chief of Defence Staff and Commander of Army General Shavendra Silva, Commander of the Navy Vice Admiral Nishantha Ulugetenne, Chairman of University Grants Commison Professor Sampath Amarathunga, Vice Chancellors of other Universities, Vice Chancellor of KDU, Chief of Staff of Air Force, Director General at Institute of National Security Studies Professor Rohan Gunarathna, Deputy Vice chancellors, All Deans and Directors, former Chancellors and Commanders at KDU, Eminent Scholars, Senior Officers of the Armed forces and Police, distinguished guests joining us virtually from Sri Lanka and Overseas, Ladies and Gentlemen;

I consider it as a great pleasure and a privilege to be present here today at the inauguration ceremony of General Sir John Kotelawala Defense University's International Research Conference which is taking place for the 14th consecutive year and I would like to thank the Vice Chancellor and the conference organizers for the invitation extended for me to be present here to participate in this event. The International Research Conference of KDU is providing the opportunity for academics, professional researchers and practitioners to share their research findings and expertise addressing the mutual challenges in their fields. Therefore, this event has gained tremendous recognition among all interested parties around the world. Further, the provision of a wider interaction and networking with national and international scholars in respective fields would be absolutely beneficial for all the participants to broaden their horizons of knowledge through intellectual discussions. However, due to the global pandemic situation in effect, most participants may join the event through a virtual platform for this conference as same as the last year. Yet, I'm sure we will be able to achieve the desired objectives in a state amidst this pandemic situation.

Furthermore, I'm extremely pleased that the theme selected by the KDU for the conference this year security, stability, and the national development in the new normal is a timely theme capable of augmenting the significance and focus of the subject of strategic national importance. Further, I firmly believe that the endeavor towards warranting the national development and ensuring national security becomes further from achievement by undermining the routine activities due to the ill effects of the pandemic but becomes attainable by ensuring the adaptability to the new normal as widely accepted by all the countries in the world, today which is implied by the theme that you have selected. In fact, as comprehensively illustrated by the keynote speaker Mr. Lalith Weerathunga it is quite imperative that all of us understand and pursue the ways and means of adopting the circumstances embedded with the new normal. in order to coexist with the Covid 19 pandemic which has not shown any expiry date as of yet.

Ladies and Gentlemen in a context of globalization and further economic integration, in recent decades the relationship between national development and national security of a country has become increasingly

interlinked for Sri Lanka. These connections represent both opportunities and potential threats to the country's national security. The open and interconnected Sri Lankan economy creates vulnerabilities from potential international and external threats. Against this backdrop, national development has emerged as an important strategic priority for the Sri Lankan government with the connection between development and national security which will be orchestrated upon the vistas of prosperity and splendor, the national policy framework of our government headed by his excellency the president Gotabhaya Rajapaksha.

Ladies and gentlemen, the development generally depend on the stability of a country which should be achieved by ensuring national security. Sri Lanka being a country endangered by ruthless terrorism for almost three decades has experienced a lot of hardships during the past and was in the stage of eyeing its development in the last decade. Even though we were able to relieve the country from the menace of terrorism we have found another security threat in the form of a pandemic which has posed a greater threat to the entire world. The threat that we face today is progressing in its second continuous year without any indication of a possible termination we are yet to find a permanent solution for the same. However, we must always work towards reaching our development goals without letting our country at peril. In such a context our endeavor here as Sri Lankans should be to seek possibilities to find ways and means to steer the country towards development goals amidst said difficulties. Sri Lankan government is at the threshold of trying all possible methods to meet its economic growth and objectives yet with lots of empidements while ensuring human security. When the domestic affairs of a country are affected it is extremely difficult for a country to reach its desired end state. Sri Lanka is no exception in this, regard being a developing country Sri Lanka cannot accept any economic standstills for a protacted time frame. However, any plans to expedite the economic gains should never be at the expense of human lives. Therefore, his excellency the president himself has expressed his keenness on this aspect to see and inspire all possibilities available to ensure the maintenance of momentum in the economic sphere.

On the contrary, we should also note the other contemporary security concerns such as violent extremism, terrorism, piracy, drug, and human trafficking, smuggling, cybercrimes, and other organized crimes and natural disasters pose a grave threat to the stability of a country. Sri Lanka's geostrategic location is susceptible to such threats as it is located in the main sea routes in the Indian ocean. The same geopolitical significance has given a greater recoginition to the country, thus it has gained greater demand from the rest of the world. In such an instance, the possibility of Sri Lanka becoming susceptible to threats posed from violent extremism and organized crimes is very high and present the government has initiated several steps to curtail such illegal activities and such measures taken such as the demarcation of maximum security prisons concept and highly effective maritime domination programs launched by the Sri Lankan Navy which have become very effective in restricting such threats. However, the effects of such activities pose a moderate level threat to the stability of our country.

Ladies and gentlemen, a government alone cannot afford to force all these threats that are in concert ruining the stability of a country. Therefore, as responsible citizens, it is our bounded duty to provide novel ideas, suggestions, and proposals to consider in regaining our country's stability and development. I hope the academic events of this nature will undoubtedly serve this national requirement. Such efforts are

arranged to address emerging challenges. Promoting more research and development becomes a task of topmost priority for all of us.

Fortunately, as the Secretary of Defense, I feel tremendously proud and content to say that the Kotelawala Defence University is at the forefront of researching the development of security-related problems in the new normal. The approach adopted by the Kotelawala Defense University to understand the contempaty complex situations concerning the bigger picture rather than dwelling on the narrow passages will become far more effective in resolving the emerging complexity of future challenges. Therefore, I'm well certain that the faculties of General Sir John Kotelawela Defence University with their interest, commitment, dedication, and knowledge in diverse academic disciplines and outside rich researches inputs would contribute immensely to this year's conference theme. The knowledge that you are going to unearth and share during this conference would be of immense benefit not only to the academic community but to the entire humankind to make their lives better.

In conclusion ladies and gentlemen, I should express my most sincere appreciation to the Vice Chancellor and the organizers of the General Sir John Kotelawala Defense University's 14th International Research Conference 2021 for organizing this timely important event amidst the covid 19 pandemic concerns and I wish this event be successful in all way imaginable. Ladies and Gentlemen thank you very much for your patience, thank you.

Vote of Thanks

Dr Harinda Vidanage

Conference Chair, 14th International Research Conference, General Sir John Kotelawala Defence University

Mr Lalith Weeratunga, Principal Advisor to HE the President of Sri Lanka, Secretary to the Ministry of Defence, General Kamal Gunaratne, Vice Chancellor – Maj Gen Milind Peiris, Deputy Vice Chancellor (Defence & Administration), Deputy Vice Chancellor (Academics), Rector – Southern Campus, Senior Professors, Deans and Directors, Senior officers representing Tri Forces and Police, Distinguished guests, colleagues, Ladies & Gentlemen, Good morning!

In its 40th Anniversary since its inception the flagship academic conference of the KDU, the international research conference progresses to 14 years of continuity. I stand here to reflect and provide my gratitude to a team of individuals who despite every challenge in the form of material and the forces of nature has confronted us with, have managed to successfully bring us to where we are today.

Since 2019, the country has witnessed unprecedented upheavals from violent extremism to microbial threats that have forced a drastic rethinking of every aspect of social life. These challenges have made all of us believe in a reality that long established norms, traditions, beliefs do have their limits and if we are to survive and thrive in the new normal, we must adapt, adopt and innovate. The core fundamentals driving this year's IRC is based on this conviction and that the KDU as a leading force of defiance and a beacon of hope amidst such calamities.

On behalf of KDU, I would first and foremost like to extend a heartfelt appreciation to our Chief Guest and Keynote Speaker, Mr Lalith Weeratunga the Principal advisor to H E President Gotabaya Rajapaksa. Your presence today is a blessing to us as an institution and to the IRC as a process and your observations made at the keynote enriched us with knowledge and perspective. Your wise words of wisdom will have a bearing on the deliberations of all academic communities within and well beyond this conference. I also would like to thank Secretary to the Ministry of Defence, General Kamal Gunaratne for his presence, his insights and his towering leadership that has seen KDU through fair weather and through some rough storms.

I would like to highlight and appreciate the visionary leadership of the Vice Chancellor, Maj Gen Milinda Peiris and his belief in maintaining continuity of this apex academic event of the KDU. I must then appreciate the critical roles played by Deputy Vice Chancellor (Defence & Administration) Brigadier Wipula Chandrasiri in ensuring that the IRC will take place and in providing the administrative leadership towards the materializing of the conference. The support and blessing of the Deputy Vice Chancellor (Academic) Professor KAS Dhammika is highly appreciated, along with the support of all Deans of faculties who came together to make this event a success.

Even at a time when every institution is careful about its purse, our sponsors have stood by us, let me profoundly thank and appreciate the generosity of our Gold Sponsors, the Bank of Ceylon and the People's Bank and with Huawei Sri Lanka and National lotteries board being our silver partners. There are many more who have chipped in and do not want their names mentioned and a big thank you for all.

I must mention that this year it is the first time the faculty of Defense and Strategic Studies have been tasked with the overall IRC and holds the chair. I must with gratitude mention the hard work of my colleagues in both departments of Defense and Strategic Studies under the leadership of Col Enoj Herath the Dean of the faculty. The FDSS represents the tip of the Spear of the KDU and bears

testimony to the perfect convergence of civic-military relations.

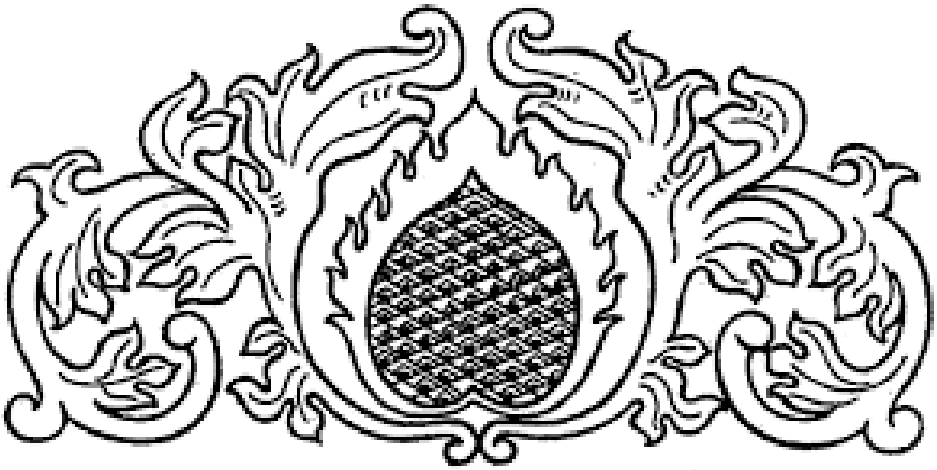
Towards the buildup to the conference the shutdowns became lockdowns and lockdowns became enforced quarantined curfews, yet the main committee of the IRC 2021 managed to work tirelessly around the clock. We knew it was all for a greater cause and I must appreciate the gargantuan task that was handled by the secretary of the IRC committee Ms Lihini De Silva who virtually was my prime buffer and the tremendous work done by the three co secretaries, Maj Ranushka Ferdinandesz, Ms Isuri Uwanthika and Captain Abeetha Athukorala. We were all supported by the dynamic team of faculty coordinators who labored hard and were endowed with patience.

It is with sincere gratitude I appreciate the services of Mr Kithsiri Amaratunga the president of the Editorial committee and Dr Faiz Marikar the deputy editor. I also want to mention the prudent actions taken by Commander Bogahawatte, the president of the publication committee. I would like to thank all committee presidents, committee members, faculty committees, the office of Bursar, Registrar, Adjutant and C/O Admin and the staff at the Vice Chancellor's office.

New normal pushed us to the limits, yet we managed to overcome as we functioned as a collective team. Yet, finally the work would be incomplete if not for the researchers who had put faith in us and submitted papers and reviewers who filtered them. This year's IRC is the most decentralized event out of all IRCs, facilitating intellectual deliberations of this scale is no easy task. To keep this grid alive and robust the contributions made by Director IT and his team needs a special word.

We have truly embraced the new normal. We have not run away from it, instead we have transcended it. Thank you all for accepting and believing in us. We shall prevail and we shall overcome.
Thank you very much!

BASIC AND APPLIED SCIENCES



PLENARY SESSION

Establishment of Sharing System of Mouse Resources Using Reproductive Technology

Professor Toru Takeo

Division of Reproductive Engineering, Center for Animal Resources and Development (CARD), Institute of Resource Development and Analysis, Kumamoto University, Japan

Genetically engineered mice are a powerful tool as human disease model in biomedical research. Previously, researchers had to develop suitable mouse models before their experiments, which was a critical limitation to start their research. To overcome this problem, we established a mouse bank which provides logistics over mouse research. This system is very simple. Mouse bank archives useful mouse models and supply mice for researchers. This helps to quickly start the experiments for the researchers and also quickly establish their collaborations. In this lecture, I will introduce our activities in mouse bank and the development of mouse reproductive technology.

Why we focus on mice? Mice lead us to very new discoveries. Many researchers who won Nobel Prizes used mice to find new discoveries and mice are also useful in education and creating new drugs. Why are the mice useful? We share 98% of our gene with mice. So, mouse gene has helped us to understand the human gene. To understand our gene functions, we produce Knockout mice or Knockin mice. We will also use the mouse as dieses model mouse. There is an international project named Knockout Mouse Project (KOMP). Since 2006, scientists around the world have been working together to generate knockout mice for every gene. The KOMP project brought to international mouse phenotyping consortium (IMPC). This builds the first truly comprehensive, functional catalogue of a mammalian genome. In IMPC we systematically examine the phenotypes of 20,000 knockout mice, one for each gene. This is a project of international collaboration of mouse bank called the International Mouse Strain Resource (IMSR). IMSR produced mutant mice archived in mouse bank and published the data of the mice on their website. Any scientist can obtain mice from this mouse bank. IMSR contains 77,302 strains of genetically engineered mice.

Center for Animal Resources and Development (CARD) is also a member of IMSR, and it is the first mouse bank in Japan. It is also the hub research center for Medical and Life Sciences using genetically modified mice. CARD has two animal facilities and has the ability to breed 50,000 mice under specific pathogen free environment with automatic water supply system and ventilated cage system. CARD supplies genetically engineered mice for researchers. In CARD mouse bank we cryogenically preserve embryo and sperms of 4609 strains. We can identify couple of advantages of mouse banks including resource availability, reproducibility, sustainability, avoidance of redundancy and animal welfare. Reproductive technology is necessary for mouse bank system. This technology helps storage (cryopreservation of sperms and embryos), production (superovulation, in-vitro fertilization, embryo transfer) and shipment (cold storage of sperms and embryos). Until now we produced various reproductive technologies and published 90 papers on reproductive technologies. In our study we found useful compounds to improve reproductive technology. First, we improve the fertility of cryopreserved sperm. We observed low fertility of frozen-thawed C57BL/6 sperm. To overcome this issue, we developed a cryoprotectant from Raffinose/ skim milk L-glutamine which recovers motility. However, the fertility of the sperms was not good. To recover the fertility, we investigated a sperm activator. Fortunately, we found cyclodextrin show strong activity to capacitation. Cyclodextrin is a very unique compound as they can bind lipids in the hydrophobic cavity. Especially, Methyl-beta-cyclodextrin remove cholesterol from sperm membrane. Removal of cholesterol is very important to activate the sperm. Next, we invented Oocyte fertilizer. We Focused on the structure of Zona Pellucida. Oocyte is surrounded by Zona Pellucida. Zona Pellucida is composed of ZP1, ZP2 and ZP3 proteins. We saw that if we can cut the network the sperm can easily enter the Zona Pellucida. So, we used chemical scissors to cut the network. Reduced glutathione (GSH) was used as the scissors as they break the disulfide bonds in ZP. We established CARD IVF protocol with sperm cryopreservation, sperm preincubation and fertilization medium to obtain higher fertilization rate. The next important fact is the

increase of the number of ovulated oocytes. Previously, we used classic methods of superovulation, eCG-hCG method which is less efficient. To improve the efficiency, we invented superovulation technique Inhibin Antiserum. Inhibin is a peptide hormone discovered in 1970s. It has two isoforms Inhibin A and B. Inhibin is a down regulator of FSH production and regulate the ovarian folliculogenesis. Inhibin Antiserum inhibit the Inhibin produced by the ovary and increase the production of FSH by the pituitary gland. Hence, improves the follicular development. Next, transport of fresh sperm and embryos at 4 °C will be discussed. Shipment of live animals is getting difficult. To overcome this problem, we developed transport techniques of cold-stored embryos and sperms. In this technique the cold storage medium is important. Adding N-acetyl cysteine prolongs the survival period of embryos at 4 °C for 4 days. In the technique of the shipment of cold-stored mouse sperms, Cauda epididymis used. This is an organ to store matured sperm. We transport the epididymis to the researching facility, where they perform IVF and the embryo transfer.

We share our mouse production technology over publication, protocol and workshops. We have held hands-on workshops on mouse reproductive technology to educate students, technicians, and scientists worldwide since 2000. In addition, we published online manual for mouse reproductive technology. As a suggestion, if you are interested in animal experiments, we recommend establishing a mouse bank in Sri Lanka and that research network will promote science as mouse banks support international collaborations.

How to Commercialize University Research Output

Prof RMG Rajapakse

Senior Professor, Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka

Universities in Sri Lanka create numerous inventions each year. However, almost all of them are confined to scientific research publications and higher degree theses. This can be evident by the number of high impact journal publications produced by Sri Lankan scientists during the period of 01st December 2019 through 30th November 2020. A total of 60 can be found for Physical Sciences (1 in Advanced Functional Materials, 13 in European Physical Journal C, 34 in Journal of High Energy Physics, 1 in Nature Communications, 11 in Physical Review Letters), 6 in life sciences (1 in Cell Host and Microbe, 1 in Molecular Psychiatry, 1 in Nature, 1 in Nature Medicine, 1 in Proc. National Academy of Sciences USA, 1 in Science Advances) and 4 in Earth and Environmental Sciences (1 in Environmental Science and Technology, 2 in J. Geophysical Research: Solid Earth, 1 in Nature). Such high impact research outcomes have gone unattended and hardly incorporated in the commercialization for improving national economy. Therefore, the time has come to address the question of converting the important research outcomes leading to new inventions into commercial products.

This process involves a couple of steps. Usually, the inventions are made by the research done under laboratory scale. Once the proof of concept has been made on the discovery which led to the valuable product the next strategy is to carry out the proto typing. Then the scaling up will be carried out if the prototyping is successful. In the meantime, it would be an added advantage to make the relevant state sector organizations/ ministries aware about the social impact of the invention being made. In the current context of Sri Lanka these ministries are State Ministry of Skills Development, Vocational Education, Research and Innovations. Application for a local patent from the National Intellectual Property Organization (NIPO) is also important. Getting state sponsorship for the invention is also a key step in the process of converting the novel invention to a commercial product. Becoming partnered with a relevant industry (public or private) is of paramount importance in order to carry out the scaling up of the research successfully. In this step, market research based on cost calculations, feasibility studies, available local and foreign markets should be thoroughly studied. When integrating with an industrial flow process, it will be necessary to change conditions, procedures and even materials used to suit to manufacturing processes. The proof of non-toxicity, non-hazardousness, biocompatibility and other requirements such as eco-friendliness, biodegradability of the materials is also essential for a product that would have direct application on human/animal body and also for direct application in the environment. The aesthetic properties of the device/material are also an important factor to be considered. Cooperation with the Ministry of Trade is important in designing the product and investigating markets. The general public should then be educated on the product/material and this could be done through public awareness programs including press conferences, television and radio programs and through social media. The quality of the product should be assured for each batch and each lot. There should not be quality variations within different batches of the device/material. Keeping all the records of analyses and getting them verified from independent accredited organizations is also important.

In this Plenary talk, all these essential steps will be highlighted through research studies carried out by the author and his collaborators and research students using practical examples. Even if the research output may have an enormous input to the society and prototypes proven, the invention may not end up as a successful commercialized product if any one or more steps in the above chain is/are missing. Examples will be taken to highlight both unsuccessful and successful stories.

Experimental Pharmaceutical Agents for Breast Cancers

Dr Tracey Bradshaw

Assistant Professor, Biodiscovery Institute, School of Pharmacy, Faculty of Science, University of Nottingham, UK

Natural products have been investigated since ancient times to treat many diseases including cancer. At present more than 50 % of drugs used in cancer chemotherapy are natural products, natural-product derived or natural product inspired. Hence, it is important to pursue natural product drug discovery to identify novel molecules from various natural sources such as rainforests that may possess anticancer activity. Success in this field has led to the use of microtubule targeting agents in cancer chemotherapy. Agents such as vincristine and vinblastine, isolated from *Catharanthus roseus*, and taxol, isolated from the Pacific Yew, *Taxus brevifolia*, remain integral to the treatment of intractable cancers. Paclitaxel stabilises and inhibits depolymerisation of microtubules and is widely used in the treatment of breast and ovarian carcinomas while, vincristine, binds to tubulin dimers and destabilises and inhibits the assembly of microtubules and is used to treat number of blood cancers. The cell cycle is governed by a rigorous system of checkpoints that consists of cyclin-dependent kinase (CDK)-cyclin complexes that allow progression from one cell cycle phase to the next. Taxanes and vinca alkaloids are able to arrest cell cycle at G2/M, affecting levels of cyclin B1. In 2008, seven novel Aspidosperma indole alkaloids were isolated, jerantinines A–G, from a leaf extract of Malayan plant *Tabernaemontana corymbosa.* As such with colleagues at the University of Nottingham, Malaysia, Dr. Bradshaw has investigated in detail the rich biodiversity of the Malaysian rainforest for novel molecules that may represent drug-leads for treatment of cancer.

Dr. Bradshaw and her research group in Nottingham, has found that the natural alkaloid Jerantinine A (JA), isolated from *Tabernaemontana corymbosa,* and its acetate derivative (JAa) elicit potent, broad-spectrum antitumor activity. For example, GI_{50} values between 0.14 and 0.38 μM had been achieved against breast cancer cell lines irrespective of receptor status. They have found that, JAa targets tubulin, disrupting microtubule dynamics. Also, it inhibits polo-like kinase 1 and generates reactive oxygen species. These mechanisms and molecular targets, although pertinent to tumorigenesis, are not cancer-specific, therefore, adverse, systemic toxicities may pose a risk in the clinic. By exploiting cancer cells upregulated transferrin receptor-1 (TfR1) expression, and TfR1-recognition of apoferritin (AFt), JAa has been encapsulated within AFt to enhance tumor-targeting, reduce systemic toxicity, and also to circumvent putative drug-resistance mechanisms in the clinic. Ferritin is a natural iron storage protein which plays an important role in iron homeostasis in many organisms, including humans and other mammals, plants, fungi and bacteria. AFt refers to the iron-free form of the protein where molecules could be trapped into the cavity. Around 120 JAa molecules had been encapsulated within the Aft cavity by exploiting the AFt's disassembly/reassembly method. Dynamic light scattering (DLS) and native PAGE have corroborated AFt-integrity post successful JAa-encapsulation. Western blot and flow cytometry experiments have demonstrated TfR1 expression by cancer cells, with TfR1 levels below detection in non-tumorigenic MRC-5 lung fibroblast cells. Interestingly, enhanced internalization of human-AFtin SKBR3 and MDA-MB-231 breast cancer cells had been observed, compared to MRC5 fibroblasts. Accordingly, significantly greater intracellular JAa levels followed exposure of SKBR3 and MDA-MB-231 cells to AFt-encapsulated-compared to free JAa (0.2 μM). Furthermore, profound cell cycle perturbation including G2/M arrest, greater reduction in cell numbers and increased apoptosis compared to free agent (0.2 μM JAa; $p<.01$) had been observed in breast cancer cells. Thus, in summary this study showed that AFt represents a biocompatible vehicle for targeted delivery of JAa which is a potent drug lead, offering potential to minimise toxicity and enhance JAa activity in TfR1-expressing cancers.

Food and Health

Dr Vijay Pal Singh

Veterinarian and Assistant Professor, Council of Scientific and Industrial (CSIR) Institute of Genomics and Integrative Biology, India

While the world has experienced a rapid economic growth and development, there are still lagging problems with food safety, sustainability, and food security. With the increasing incidence of diabetes and obesity, the burden of foodborne diseases and lifestyle disease on one hand whereas triple burden of malnutrition, wasting and hunger on another side is a complex situation to handle for humanity. Food is the single strongest factor for human health and environmental sustainability. However, food is currently threatening both people and the planet. And the biggest challenge is to provide safe food from a sustainable food system to the burgeoning world population. Nearly 820 million people still lack sufficient food and others are either consuming low or too much. An unhealthy diet puts greater risk than unsafe sex, alcohol, drug, and tobacco use combined. Global food production has consequences on climate stability and ecosystem resilience. In this plenary talk, I will further discuss the issue and possible transformative change in the food system approach.

There is a great acceleration in global food system. Now we see CO_2 emissions, ocean acidification, energy use, tropical forest loss, water usage and fertilizer usage are going high over the past years. We are not yet bending the curves on unhealthy and unsustainable food system. The scale of the challenge is 2 billion people lack key micronutrients like iron and vitamin A, 41 million children are overweight and nearly 52 million children are wasted and so on. To overcome this problem, we need to achieve planetary healthy diets for nearly 10 billion people by 2050. Healthy diet includes whole grain, tubers or starchy vegetables, vegetables, fruits, dairy foods, protein sources, added fats and added sugars. In a healthy diet majority should cover with fruit and vegetables and minor intake on scratchy, dairy and added sugars. However, if we compare the current intake with the reference diet you can see for example in North America the consumption of red meat is extremely high whereas the consumption of fruits, vegetables and legumes are considerably low. In Asia, consumption of starchy vegetables is so high but fruits, legumes, whole grain and nuts are really low. How to overcome this problem through five strategies of great food transformation? First strategy is to seek international and national commitment to shift towards healthy and sustainable diets. Next is the reorienting agriculture priorities from producing high quantities of food to producing healthy food. Thirdly, sustainably intensify food production to increase high-quality output. Strong and coordinated governance of land and oceans as the fourth strategy. Finally, at least halve food losses and waste, in line UN sustainable development goals.

What are we doing in India as an attempt to change the conservation of food and nutrition to bend the curve? We started a program called “Eat Right India” unveiling a new language in food and nutrition. There pillars have been identified in the Eat right India movement. Those are Eat safe, Eat right and Eat sustainably. Rich content, outreach programs, partnerships with all the Bollywood actors and cricketers who can make this program going forward. The ultimate goal is to provide healthy and sustainable food systems to achieve planetary healthy diets for people.

Training Excellence in Translational Neuroscience by International Collaborations

Prof Harry Steinbusch

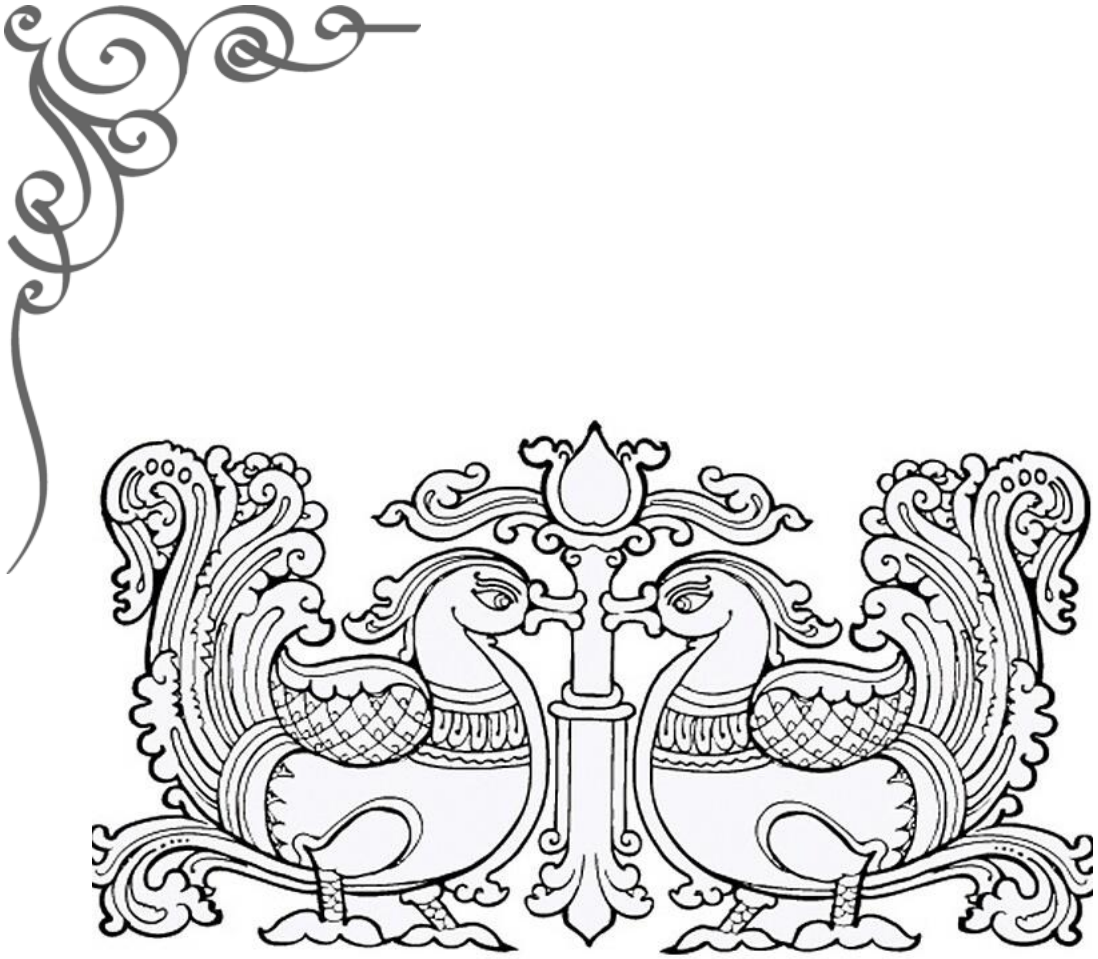
Professor in Cellular and Translational Neuroscience, Department of Cellular Neuroscience, Faculty of Health, Medicine & Life Sciences, Maastricht University, The Netherlands

Networking for early-stage researchers is an important area for PhD students. Most scientists know that networking is important for success, whether in their research or career, but many still find the mere word off-putting. These days, very few aspects of science are done in isolation. Many projects are conducted in collaboration with researchers in other disciplines, and new ideas are frequently sparked by conversations with other scientists. Moreover, finding a job in academia is often helped by knowing people who have a position to fill, or who can point you to those who do. And when venturing outside academia, meeting people who can give you valuable information about how to enter a new work sector is crucial. But it doesn't need to be that way—and to be effective, it shouldn't be. It often takes skill, and practice, to start enjoying and reaping the benefits of networking.

Maastricht University and i.e., EURON – the European Graduate School of Neurosciences – have worked for more than 10 years together with Sri Lanka leading neuroscientist Prof. R. De Silva to build a network for educating PhD students and work towards Double Doctoral degrees. The first Double Doctoral degree was awarded in 25th August 2020 from Maastricht University (World University ranking 121) which was the first time in Sri Lanka where two more Double Doctoral degrees are currently ongoing. This collaboration could be established due to utilization of the Sri Lanka Brain bank and DNA/serum bio-bank, which provides valuable material for molecular diagnostics, biomarker discovery, neuropathological and epidemiological studies. The uphill task of establishing the Sri Lanka Brain bank and DNA/serum bio-bank and linking with the west has been jointly published as a benchmark article in the Lancet Neurology; 1st ranked among the Clinical Neurology journals with an impact factor of 44.

This co-operation will be developed further in a multidisciplinary foreign collaborative research and academic programmes leading to postgraduate degrees in MSc, PhD. degrees in Neuroscience between The European Union (EU) and General Sir John Kotelawala Defence University (KDU) while utilizing resources from Sri Lanka, under the following aspects: a) Development of MSc program in Neuroscience and collaborative research between the two institutions leading to PhD; b) PhD Training Programs and c) Exchange programmes for PhD/MSc Faculty and students between EURON and KDU. The common theme will be to bridge the gap between fundamental neuroscience and clinical, cognitive, and behavioral neuroscience and attempts to understand (dys)function of brain and behavior from a translational perspective.

The PhD students from Sri Lanka could further target for a EURON certificate based on the cumulative impact factor of their publications, which would add a value to the local PhDs. Europe's efforts to cope with the ever-growing problems of ageing of the European population heavily depend on creative contributions of young well-trained researchers. Exchanges and integration of different areas in neuroscience are necessary to create an integrated approach between industrial and academic disciplines. Therefore, our collaboration will provide insight into the pathophysiological mechanisms of neurodegenerative disorders to increase the development of new therapeutic strategies to stimulate central plasticity against neurodegenerative processes.



TECHNICAL SESSIONS

Analyzing the Service Performance of a Post Office in Kurunegala District: A Case Study

MAN Perera, BMMT Bandaranayake, KHMSD Goonatillake, MASD Premarathne and BMAM Balasooriya#

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Abstract - The postal service is an essential service organization that provides a quality service leading to customer satisfaction. However, long queues were observed at a post office in the Kurunegala district. Since it affects the service quality, this study aims to suggest an improved configuration for the selected post office by analyzing its queuing performance. This study collected 300 data from two counters in the post office during three hours from 10.00 am on two consecutive weekdays. The system was modelled using the Rockwell ARENA 16 software. The queues for the observed registered post and speed post counters were named queue 01 and queue 02, respectively. The existing system resulted in 19.03 and 18.43 minutes of waiting time in queues 01 and 02. The number waiting in queues 01 and 02 were 25 and 24. The percentage of customers served by the system was 58.23 percent. Since the existing system showed a low performance rate, the study recommended doubling the staff at the counters. Therefore, three models were suggested as models 01, 02, and 03. The suggestions were to double the resources at counter 1, double the resources at counter 2, and double the resources at both counters. Compared to models 01 and 02, model 03 shows less waiting time and number waiting. Therefore, the study recommends model 03 as the best-fitted model. It reduced waiting times to 3.52 and 1.27 minutes, and the numbers waiting to 6 and 2 in queues 01 and 02. Moreover, the proposed system could increase its performance by 33.72 percent.

Keywords: computer-based, simulation model, post office, service quality

I. INTRODUCTION

The postal service is a major service of the central government that meets every citizen on a daily basis. It has done a great service from ancient times to the present (Crew & Kleindorfer, 1992). The service-providing organizations should provide quality customer service to survive in the field (Zalatar, 2012). Providing better services to the customers leads to high customer satisfaction and makes customers more loyal to the organization (Chen, 2008; Chou & Kim, 2009).

Moreover, services play a significant role in the economy of the country. Despite the technological advancements, the postal service is still vital in the transport sector. However, one of the reasons for the customers' dissatisfaction is the presence of more waiting time to obtain the service. Therefore, based on the necessity of the improvements in the postal service, modeling and simulation can be applied to regulate the service process and eliminate the complications.

Modeling and simulation are comprehensive concepts absorbed in engineering applications and other social sciences scenarios. The essence of the simulation method's contribution is capturing the dynamic side of the system and complicated probabilistic relationships (Achimsk, 2019). The simulation consists of knowledge-based dynamic modeling, real-time computer-aided simulation, online and offline identification of engineering systems (Mohamed, 2010). Moreover, simulation helps to create a real image of the organization's process with a dynamic analysis (Jun et al., 1999). This study provides the reader instances of using the simulation method to enrich the queuing system of a Post Office in the Kurunegala district.

The majority of people visit the post office to send postal goods through registered post and courier services. When observing the post office, it was found that the registered mail counter and the speed post counter have a long waiting line compared to other counters, and it has badly affected the overall performance of the post office. Therefore, to enhance the performance of the post

office, a well-managed system should be executed for the two counters mentioned above. The psychological nature of the waiting time in the system has a high impact on customer satisfaction levels.

As per the author's knowledge, a performance evaluation study of a post office using Rockwell Arena has not been published for the Sri Lankan context. Therefore, the study's main objective is to minimize customer waiting time in queues and optimize the performance of a post office in the Kurunegala district by modeling a project to simulate the queues at the two observed counters. It is considered to describe that modeling and simulation satisfy the proposed project when tested with the real. Rockwell Arena software is capable of generating great deal of models through providing analytical models and graphic simulation patterns (Kelton et al., 2008). In this study, reduction of customer waiting time is specified as an effective method to increase productivity and efficiency of the post office.

II. METHODOLOGY

A. Theoretical Model

Determining the various waiting times and queue sizes for certain system components helps the management make judgments on how the system should proceed to have an improved configuration.

The average length of the queue (L) can be broken down as the average number of customers waiting in the queue (L_q) and the average number of customers waiting in the queuing system (L_s). In addition, the average time a customer spends in the system (W) can be broken down as the average amount of time spent in the queue (W_q) and the average amount of time spent in the queuing system (W_s).

According to Little's rule,

$$L = \lambda W$$

$$L_q = \lambda W_q$$

$$L_s = \lambda W_s$$

Here, λ is the arrival rate of units to the system.

According to Kendall's notation, a system that has exponential inter-arrival times, exponential service times, and one server can be written as (M/M/1) : (GD/∞/∞). Here, M stands for Markov, and GD stands for General Discipline.

$$\lambda_j = \lambda \text{ for } (j = 0.\ 1,\ 2,\ldots.)$$

$$\mu_j = \mu \text{ for } (j = 0.\ 1,\ 2,\ldots.)$$

Then the steady-state probability can be written as,

$$\pi_j = \lambda^j \pi_0 \ / \ \mu^j$$

The traffic intensity of the system can be written as,

$$p = \lambda \ / \ \mu$$

Since the sum of all the steady state probabilities is equal to one, the equation can be written as,

$$\pi_0(1 + p + p^2 + \ldots + p^j) = 1$$

Assuming $0 \le p \le 1$ and $S = (1 + p + p^2 + \ldots + p^j)$,

$$S = \frac{1}{1-p}\ ,\ \pi_0 = (1- p)$$

This provides $\pi_0 = p^j\ (1- p)$ as the steady-state probability of state j.

With the steady-state probability of the system, the average number of customers in the system (L) can be represented by,

$$L = \sum_{j=0}^{\infty} j\pi_j = (1 - p) \sum_{j=0}^{\infty} jp^j \qquad (1)$$

Let $S = \sum_{j=0}^{\infty} = p + 2p^2 + 3p^3 + \ldots.$

Then $pS = p^2 + 2p^3 + 3p^4 + \ldots.$

By substracting them,

$$S - pS = p + p^2 + p^3 \ldots = \frac{p}{1-p}$$

$$S = \frac{p}{(1-p)^2} \qquad (2)$$

Substituting equation 2 to equation 1,

$$L = (1 - p)\ \frac{p}{(1-p)^2} = \frac{p}{1-p} = \frac{\lambda}{\mu - \lambda}$$

To calculate L_s, the number of customers in service should be identified at any given moment. There will be only one customer in service except for when there are no customers in the queuing system. Therefore, the formula can be written as,

$L_s = 0\pi_0 + 1(\pi_1 + \pi_2 + \pi_3 + \ldots)$

$= 1 - \pi_0 = 1 - (1 - p) = p$

Since, $L = L_q + L_s$,

$$L_q = \frac{p^2}{1-p}$$

Using Little's rule, the formulas for W, W_s, W_q can also be derived.

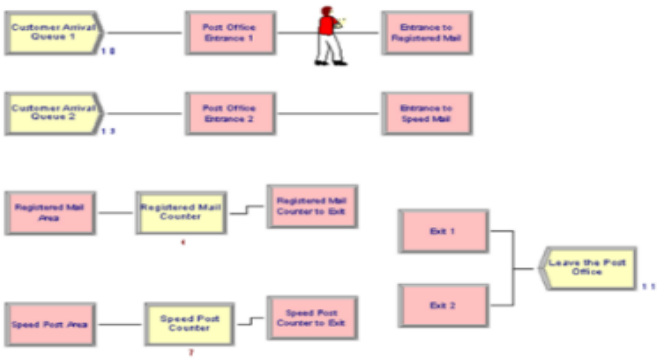
B. Survey Design

When observing the functionaries of a Post Office in Kurunegala district, it was found that two counters have more workload compared to other counters. Also, there were long waiting lines due to the heavy workload. Therefore, this study was done using those two counters of the Post Office. The registered mail counter and the speed post counter were the two observed counters of the Post Office. The study's sample size is 300, while the population is the customers who visit the Post Office. The population size was infinite, and queues were served on a First In First Out (FIFO) basis. The time period was considered as experienced by the post office functionaries.

Table 1. Identified Statistical Distributions

	Distribution	Expression
Customer Arrival Rate- Queue 1	Erlang	-0.001 + ERLA (22.3, 2)
Customer Arrival Rate- Queue 2	Erlang	-0.001 + ERLA (22.3, 2)
Service Rate (Counter 1)	Erlang	39 + ERLA (22.3, 2)
Service Rate (Counter 2)	Erlang	23 + ERLA (22.3, 2)

Source. Author's Calculations



Customer arrival time, service start time, and service end time were recorded as the data of the study. The inter-arrival time and the service time needed to build up the model were calculated using customer arrival time, service start time, and service end time. The data were recorded in seconds. The fitted statistical distributions for the inter-arrival rate and the service rate identified using the Arena Input Analyzer are shown in Table 01.

The identified statistical distributions were used as the input data of the model. The Rockwell ARENA software was used in modeling the study. The developed model was based on several assumptions, including the customer attaining each counter with equal probability, availability of identical counters, no work shifts between the workers, and no customer leaving the queue until the service is completed. Subsequently, the conceptual model of the post office was developed, as shown in Figure 01.

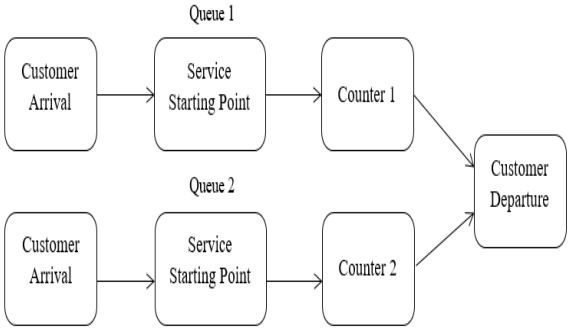


Figure 1. Conceptual Model for the Existing System

Source. Author's Calculations

III. DISCUSSION AND ANALYSIS

The results of the existing and proposed models are shown in Table 2. Observations suggested further

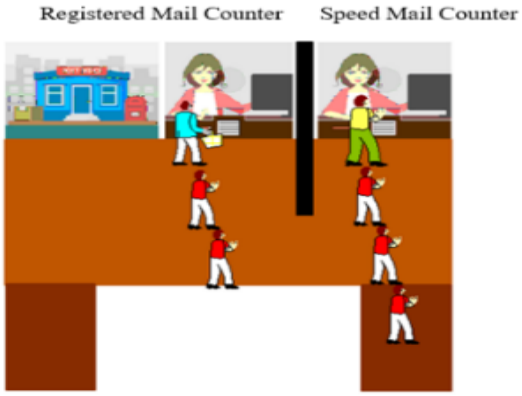


Figure 2. Animated ARENA Model for the Existing System

Source. Author's Calculations

developments for its optimal. The waiting time of the existing model was 19.03 minutes and 18.43 minutes for queue 1 and queue 2, respectively.

The study aimed to reduce the waiting time in queues. Accordingly, Model 01 and Model 03 of the proposed systems minimize customer waiting time

compared to the existing system. Moreover, Proposed Model 01 and Model 03 reduced the number of waiting customers in queue 1 and queue 2 to 4 and 15, 6, and 2, respectively. However, in the Proposed Model 02, the waiting time and number waiting in queue 2 were reduced compared to the existing system and the other two proposed models while increasing the waiting time and number waiting in queue 1 considerably.

Table 2. Results of Existing and Modified Systems

	Existing Model		Proposed Models					
			Model 1		Model 2		Model 3	
Counter No:								
Waiting Time (min)	19.03	18.43	2.67	11.48	20.17	0.36	3.52	1.27
Number Waiting (min)	24.48	23.55	3.62	14.73	25.81	0.47	5.20	1.84
Number In	237		242		238		261	
Number Out	138		196		181		240	
Percentage of Customers Served	58.23		80.99		76.05		91.95	

Model 1 – Resources were doubled in registered mail counter (1)

Model 2 – Resources were doubled in speed post counter (2)

Model 3 – Resources were doubled in both counters

Source. Author's Calculations

This shows that when doubling the resources, the waiting time and number waiting decreases substantially in the respective counter.

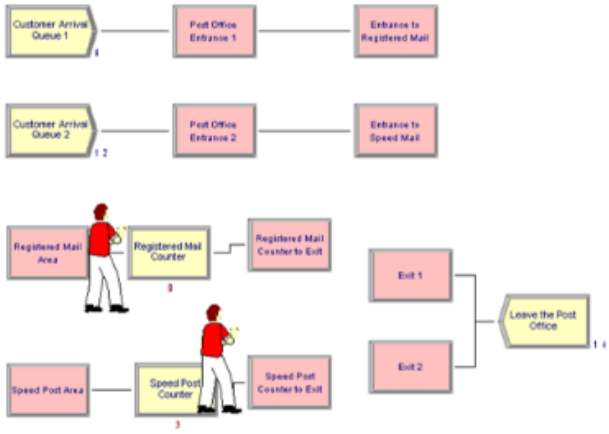


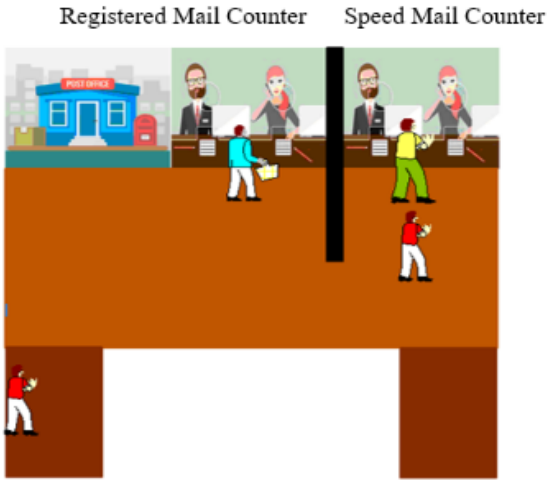
Figure 3. Animated ARENA Model for Proposed Model 03

Source. Author's Calculations

Moreover, it highlights that division of the workload among two staff members reduces the queue length of the two counters while increasing the system's overall performance. In addition, the customer served percentage of all the three proposed models was comparably higher than the existing model. However, this study aimed not to reduce the waiting time of one queue but for both queues in a counter.

IV. CONCLUSION

The study results concluded that the proposed Model 03 is the best-fitted model for the study requirements. Since the other two proposed models have high waiting times and number waiting atleast in one counter, compared to Model 03, Model 03 is the best-fitted model for the system. This adequate model displayed lower waiting time and number of waiting (queue size) in both counters. It decreased the waiting time in queue 01 and 02 to 3.52 and 1.27 minutes and decreased the number waiting in queue 01 and 02 to 6 and 2, respectively. Therefore,



assigning two employees to each counter optimizes the process of the Post Office.

Limited time caused to collect only 300 amount of data. The data were collected only on two weekdays. Since analyzing more data increases the accuracy of the results, this can also be considered a limitation of the study.

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Determine Reference Intervals for Selected Clinical Chemistry Parameters Using Selected Healthy Adult Population in Sri Lanka

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Abstract - This study was aimed to determine the reference interval values for selected clinical chemistry parameters: Full Blood Count, ESR, TSH, blood sugars, liver function test, lipid profile test, and renal profile test using selected healthy adult population of Colombo city, Sri Lanka. Data was collected from March 2019 - October 2019 using a selected total of 991 healthy adults (656 males and 335 females)population in the Nawaloka Hospital laboratory database. Descriptive statistics were used to calculate mean, median, 2.5^{th} – 97.5^{th} percentiles range, 95% CI, maximum, and minimum using Minitab 17.3,1 software. Data were statistically analyzed using the paired sample T-test and one-way ANOVA to see the association between age and gender. There was a significant difference (p<0.05) between gender and the levels of eosinophil, basophils, haemoglobin, PCV, MCHC, RBC, MCH, MCV, platelet count, specific gravity, TSH, ESR, Albumin, Globulin, Bilirubin, ALT, GGT, AST, Triglyceride, HDL, Total HDL ratio, VLDL, Urea, Creatine, Uric acid Calcium and Phosphorus. Further, there was a significant difference in the values of WBC, Hemoglobin, PCV, RBC, MCH, MCV, platelet count, TSH and ESR, ALT, total cholesterol, triglycerides, HDL, LDL, Total HDL ratio, VLDL, Chloride, Creatine, Phosphorus, FBS and PPBS (p<0.05) according to the age groups.

Keywords: reference interval, biochemical investigation, liver function test

I. INTRODUCTION

Reference interval is crucial for disease screening, diagnosis, monitoring, progression and treatment efficacy. Due to lack of locally derived reference values for the parameters, RI derived from western population is widely used in most of the laboratories (Edvardsson et al., 2017) (Longmore et al.,2014). However studies conducted in different countries have shown differences between locally and western derived RI values (Concordet et al., 2009). Therefore, strict adherence tothe reference values generated in developed countries could lead to inappropriate diagnosis and treatment of patients.

Different studies also indicated considerable variation in clinical chemistry RIs by several variables such as age, sex, geographical location, environment, lifestyle and genetic variation. (Rustad et al., 2004) (Ozarda et al., 2013). RI values for clinical chemistry parameters are vital for assessment of the health status of human population as they are used as baseline data in clinical trials. In Sri Lanka, American Standards are used as the RI values but the values have not been checked for the healthy Sri Lankan individuals. These clinical parameters may vary with the other factors like age and sex. Therefore, this study is aimed to determine the RI values for selected clinical chemistry parameters and determine the variation with age and gender using selected healthy adult population. This may be the first private sector study to establish RIs using Sri Lankan population considering age and gender.

II. METHODOLOGY

A. Reference Population

In this cross-sectional study, conveniently sampled, clinical records of healthy adults living in Colombo, the main city of Sri Lanka, were selected from existing database of Nawaloka Hospital Laboratory for 8 months period starting from March 2019 through October2019. Based on inclusion exclusion criteria 1054 individual records were ultimately selected in the study.

Briefly, the inclusion criteria included: male and female elders between 18 and 80 years old. Conversely, individuals with the following conditions were excluded: Age <=18 years, adults with common intestinal parasitic infections, hemoparasite, HIV, HCV, HBV positives and HCG

positive (for females), hospitalized persons, chronic diseases, cardiovascular diseases, kidney diseases, medication and acutely ill as per the recommendations were excluded from this study.

B. Sample Size

Sample size calculation based on WINPEPI (Version 11.48) comparison of proportions of two groups, (p=0.05, Power 80%). Assumed proportional difference of two groups is 10%.Ratio of sample size B: A=1. Therefore, need minimum of 336patients for the study (Tang, 2014). In this study, population stratification was based on sex and age.

C. Variables

Reference intervals of common clinical chemistry parameters were the dependent variable with receptively sex and age.

D. Operational Definitions

Healthy Adults: Individuals (adults) with age >=18 years andwithout disease or disabilities based on clinical sign and symptom plus laboratory investigations.

Reference Intervals: the range between, and including two reference values defined by a specific percentage (usually 95%) for common clinical chemistry parameters of healthy individuals.

95th percentile ranges: It is the range between, and including the 2.5th percentile and the 97.5th percentile.

E. Method of Data Collection

Bio-chemical investigations data from existing data base in the Nawaloka Hospital Laboratory in Sri Lanka was collected.

F. Data Management and Statistical Analysis

All statistical calculations were performed on the Minitab version 17.3.1 software. Descriptive statistics was used to determine the mean, median, 95%CI, minimum, maximum and 2.5th -97.5th percentile range of each parameter. Independent sample T-test and one-way ANOVA were employed to see the association between variables. All statistical tests were two tailed, and p-value < 0.05 considered as statistically significant.

G. Ethical clearance

Ethical clearance was obtained from the Nawaloka Hospital Research and Education Foundation.

III. RESULTS AND DISCUSSION

A. Screening Results

Table 1 describes the characteristics of the study participants. After carefully screening of 1621 records, complete data records of 1054 (670males and 384 females) were included for analysis.

Table 1 - Demographic Characteristics of Study Population

Variable	Frequency (number)	Percent
Gender		
Male	670	63.56
Female	384	36.43
Age (in years)		
18 – 24	163	16.66
25 – 34	210	21.51
35 – 44	210	21.51
45 – 54	205	21.00
55 – 64	130	13.31
>= 65	60	6.14
Biochemical Investigations		
Full Blood Count (FBC)	790	74.95
Urine Full Report (UFR)	921	87.38
Erythrocyte Sedimentation Rate (ESR)	581	55.12
Thyroid Stimulating Hormone (TSH)	353	33.49
Liver Function Test (LFT)	371	35.19
Lipid Profile Test (LPT)	607	57.59
Renal Profile Test (RPT)	316	29.18
Hemoglobin A1C (HbA1C)	241	22.86
Glucose Post Prandial Blood Sugar	240	22.77

B. Demographic characteristics

In table 1 the mean age of both the study participants at the study entry period was 40.921 years. The mean age of the females and males were 42.727 and 39.924 years respectively.

C. Clinical Chemistry Reference Intervals

The calculated mean, median, 95% CI for mean, 2.5th – 97.5th percentile range values of clinical

chemistry parameters based on gender and age were summarized in tables 2 and 3 respectively. The overall mean value of WBC, Neutrophil, Lymphocytes, Eosinophil, Monocytes and Basophil of participants were 7161.8 (*10^9/l), 51.1 (*10^9/l), 37.2 (*10^9/l), 4.0 (*10^9/l), 6.7 (*10^9/l), and 0.4 (*10^9/l), respectively. Males had reference intervals of WBC of 3806 – 10407 (*10^9/l) against females of 3877 – 10663 (*10^9/l), Neutrophil values of 35.14 – 67.25 (*10^9/l) against female of 36.11 – 68.37 (*10^9/l), Lymphocytes of 21.66 – 52.94 (*10^9/l) against females of 21.31 – 52.72 (*10^9/l), Eosinophil of (-1.19) – 9.68 (*10^9/l) against females of (-1.53) – 9.00 (*10^9/l), Monocytes of 2.30 – 11.31 (*10^9/l) against females of 2.75 – 10.49 (*10^9/l) and Basophile of (-0.14) – 1.05 (*10^9/l) against females of (- 0.24) – 1.05 (*10^9/l). Males had significantly different ($p<0.05$) higher 2.5th – 97.5th percentile ranges of Eosinophil and Basophiles than females. The mean values of Eosinophil and Basophils were significantly different ($p<0.05$) between males and females. However, significant difference in gender was not observed in the mean values of WBC, Neutrophils, Lymphocytes and Monocytes.

As shown in table 2 participants had overall mean value of Hemoglobin of 14.19 (g/dl), PCV of 42.44 (*10^9/l), MCHC of 33.42 (g/dl), RBC of 4.97 (*10^9/l), MCH of 28.35 (pg) and MCV of 84.77 (fl). Males had reference intervals of Hemoglobin 12.48 – 17.44 (g/dl) against females of 10.45 – 14.94 (g/dl), PCV of 37.65 – 51.25 (*10^9/l) against females of 32.39 – 44.67 (*10^9/l), MCHC of 30.23 – 37.13 (g/dl) against females of 30.67 – 35.19 (g/dl), RBC of 4.25 – 6.17 (*10^9/l) against females of 3.68 – 5.30 (*10^9/l), MCH of 23.75 – 33.28 (p g) against females of 23.83 – 32.26 (pg) and MCV of 73.05 – 96.14 (fl) against females of 74.62 – 95.60 (fl). Males had significant ($p<0.05$) higher 2.5^{th} – 97.5^{th} percentile ranges of Hemoglobin, PCV, MCHC, RBC, MCH and MCV.

The overall mean values of platelet count, specific gravity, pH, TSH and ESR of participants were 286675 (*10^9/l), 1.02, 5.86, 2.38 (micro Iu/ml) and 12.65 (mm) respectively. Males had reference intervals of platelet count of 162189 – 393073 (*10^9/l) against females of 179960 – 428684 (*10^9/l), specific gravity of 1.01 – 1.03 against females of 1.01 – 1.03, pH of 4.75 – 6.94 against femalesof 4.73 – 7.08, TSH of (-1.32) – 5.39 (micro Iu/ml) against females of (-1.46) – 6.96 (micro Iu/ml) and ESR of (-11.68) – 28.27 (mm) against females of (-4.50) – 44.44 (mm). Males had significantly ($p<0.05$) higher 2.5^{th} – 97.5^{th} percentile ranges of platelet count, specific gravity, TSH and ESR.

As shown in above table the difference in the 2.5^{th} – 97.5^{th} percentile range of pH were not statistically significant between males and females ($p>0.05$). The means values of platelet count, specific gravity, TSH and ESR were significantly different between males and females ($p<0.05$), whereas significant gender difference was not observed in the mean value of pH ($p>0.05$)

Table 2 - Biochemical Parameters of Full Blood Count, ESR and TSH according to the Gender

	Male		Female		Combined		p- Value
Parameters	2.5^{th}– 97.5^{th} percentile range	95% CI for mean	2.5^{th}– 97.5^{th} percentile range	95% CI for mean	2.5^{th}– 97.5^{th} percentile range	95% CI for mean	
WBC (*10^9/l)	3806– 10407	6961.70- 7251.00	3877– 10663	7062-7479	3828– 10495	7043.00- 7280.60	0.204
Neutrophils(*10^9/l)	35.10– 67.20	50.40- 51.80	36.10– 68.30	36.60- 37.70	35.40– 67.60	50.90- 52.10	0.091
Lymphocytes(*10^9/l)	21.60– 52.90	36.60- 37.90	21.30– 52.70	36.00- 37.90	21.50– 52.80	36.60- 37.70	0.635
Eosinophil(*10^9/l)	(-1.10)– 9.60	4.00- 4.40	(-1.50)– 9.00	3.40- 4.00	(-1.30)– 9.40	3.80- 4.20	0.014
Monocytes(*10^9/l)	2.30– 11.30	6.60- 7.00	2.70– 10.40	6.30- 6.80	2.40– 11.00	6.50- 6.80	0.245
Basophils(*10^9/l)	(-0.10)– 1.00	0.40- 0.40	(-0.20)– 1.00	0.30- 0.40	(-0.10)– 1.00	0.40- 0.40	0.026
Hemoglobin(g/dl)	12.40– 17.40	14.80- 15.00	10.40– 14.90	12.50- 12.80	11.00– 17.30	14.00- 14.30	0.000

PCV(*10⁹/l)	37.60– 51.20	44.1- 44.70	32.30– 44.60	38.10- 38.90	33.80– 51.00	42.10- 42.70	0.000
MCHC(g/dl)	30.20– 37.10	33.50- 33.80	30.60– 35.10	32.70- 33.00	30.20– 36.60	33.30- 33.50	0.000
RBC(*10⁹/l)	4.20– 6.10	5.10- 5.20	3.60– 5.30	4.40- 4.50	3.80– 6.10	4.90- 5.00	0.000
MCH(pg)	23.70– 33.20	28.30- 28.70	23.80– 32.20	27.70- 28.30	23.70– 32.90	28.10- 28.50	0.000
MCV(fl)	73.00– 96.10	84.00- 85.10	74.60– 95.60	84.40- 85.70	73.50– 95.90	84.30- 85.10	0.000
Platelet Count (*10⁹/l)	162189– 393073	272562- 282701	179960– 428684	296677- 311968	165651– 407699	282357- 290993	0.000
Specific Gravity	1.00– 1.00	1.00- 1.00	1.00– 1.00	1.00- 1.00	1.00– 1.00	1.00- 1.00	0.005
PH	4.70– 6.90	5.80- 5.80	4.70– 7.00	5.80- 5.90	4.70– 6.90	5.80- 5.90	0.139
TSH(micro Iu/ml)	(-1.30)– 5.30	1.70- 2.20	(-1.40)– 6.90	2.40- 3.00	(-1.40)– 6.20	2.10- 2.50	0.001
ESR(mm)	(-11.60)– 28.20	7.20- 9.30	(-4.50)– 44.40	18.20- 21.60	(-11.70)– 37.00	11.60- 13.60	0.000

As shown in table 3, the values of Neutrophils, Lymphocytes, Eosinophils, Monocytes, Basophiles, MCHC, specific gravity and pH across all age groups of participants were similar ($p>0.05$). However, there was significant difference in the values of WBC, Hemoglobin, PCV, RBC, MCH, MCV, platelet count, TSH and ESR ($p<0.05$).

Table 3 - Biochemical Parameters of Full Blood Count, ESR and TSH according to the Age

Parameters		Age group						p-Value
		18-24	25-34	35-44	45-54	55-64	>= 65	
WBC (*10⁹/l)	Mean	7530	7294	7177	6938	6872	7069	0.038
	Median	7105	7240	6900	6770	6850	7060	
	2.5th– 97.5th percentile range	3424- 11636	43.97- 10191	3871- 10483	3473-10403	4057-9687	3457-10681	
	95% CI for mean	7130-4930	7063-7526	6916-7437	6667- 7210	6590- 7154	6464-7675	
Neutrophils (*10⁹/l)	Mean	52.71	50.84	50.73	51.12	52.15	53.80	0.111
	Median	52.10	50.90	50.70	50.80	50.75	54.60	
	2.5th– 97.5th percentile range	34.56- 70.87	34.68- 67.00	35.46- 66.01	33.65- 68.59	37.57-66.74	42.41-64.20	
	95% CI for mean	50.94- 54.48	49.54- 52.13	49.53- 52.49	49.75-52.49	50.69- 53.61	52.06-55.55	
Lymphocytes (*10⁹/l)	Mean	36.32	38.00	37.88	37.40	36.89	35.17	0.255
	Median	36.35	37.70	37.20	37.50	37.20	34.95	
	2.5th– 97.5th percentile range	19.83– 52.82	21.66– 54.35	23.35– 52.41	20.15– 54.66	22.10– 51.68	23.02– 47.32	
	95% CI for mean	34.71- 37.93	36.69- 39.31	36.73- 39.02	36.05-38.75	35.41- 38.37	33.13- 37.21	
Eosinophil (*10⁹/l)	Mean	3.77	3.98	4.21	4.17	4.10	3.36	0.483
	Median	3.15	3.40	3.40	3.70	3.60	2.30	
	2.5th– 97.5th percentile range	(-1.2)– 8.77	(-1.10)- 9.06	(-2.05)- 10.47	(-1.26)–9.61	(-0.25)– 8.45	(-2.19)– 8.91	
	95% CI for mean	3.29- 4.26	3.57- 4.38	3.71- 4.70	3.74- 4.60	3.66- 4.53	2.43- 4.29	
Monocytes (*10⁹/l)	Mean	6.76	6.74	6.74	6.82	6.43	7.28	0.494
	Median	7.35	7.00	7.10	7.00	6.90	8.00	
	2.5th– 97.5th percentile range	1.96– 11.56	2.69– 10.79	2.49– 10.99	2.80– 10.84	1.65– 11.21	2.11– 12.45	
	95% CI for mean	6.29- 7.23	6.41- 7.06	6.40- 7.08	6.50- 7.13	5.95- 6.91	6.41- 8.15	
Basophils (*10⁹/l)	Mean	0.41	0.45	0.42	0.47	0.41	0.39	0.394
	Median	0.40	0.40	0.40	0.40	0.40	0.30	
	2.5th– 97.5th percentile range	(-0.18)- 1.01	(-0.35)– 1.25	(-0.09) – 0.93	(-0.08) – 1.04	(-0.17) – 1.00	(-0.22) – 1.01	
	95% CI for mean	0.35- 0.47	0.38- 0.51	0.38- 0.46	0.43- 0.52	0.35- 0.47	0.29- 0.49	
Hemoglobin (g/dl)	Mean	14.69	14.43	14.42	13.99	13.87	12.92	0.000
	Median	15.00	14.75	14.60	14.20	13.70	12.80	
	2.5th– 97.5th percentile range	11.93– 17.46	11.35– 17.52	11.27– 17.58	10.73– 17.25	10.71– 17.03	10.32– 15.54	

	95% CI for mean	14.426-14.965	14.185-14.680	14.172-14.671	13.737-14.249	13.554-14.187	12.491-13.367	
PCV ($*10^9$/l)	Mean	43.97	43.36	42.92	41.79	41.56	39.17	0.000
	Median	44.40	43.70	43.35	42.00	41.30	39.00	
	2.5th– 97.5th percentile range	36.66–51.29	34.74–51.99	34.53–51.32	33.55–50.03	33.05– 50.08	31.67– 46.69	
	95% CI for mean	43.26-44.68	42.67-44.05	42.26-43.59	41.14-42.43	40.71- 42.41	37.92-40.43	
MCHC (g/dl)	Mean	33.40	33.35	33.57	33.43	33.34	32.96	0.459
	Median	33.40	33.60	33.40	33.50	33.30	33.00	
	2.5th– 97.5th percentile range	31.22–35.59	28.02–36.69	31.35–35.80	30.92–35.96	30.88– 35.81	30.58– 35.35	
	95% CI for mean	33.18-33.61	32.92-33.78	33.39-33.74	33.24-33.63	33.09- 33.59	32.56-33.36	
RBC ($*10^9$/l)	Mean	5.21	5.10	5.03	4.90	4.79	4.39	0.000
	Median	5.30	5.10	5.10	4.90	4.70	4.40	
	2.5th– 97.5th percentile range	4.13– 6.29	3.98– 6.22	3.92– 6.15	3.95– 5.85	3.71– 5.87	3.39– 5.38	
	95% CI for mean	5.11- 5.32	5.01- 5.19	4.95- 5.12	4.82- 4.97	4.68- 4.90	4.22- 4.55	
MCH (pg)	Mean	28.01	28.19	28.43	28.17	28.72	29.20	0.049
	Median	28.30	28.60	28.65	28.70	28.90	29.00	
	2.5th– 97.5th percentile range	24.36–31.68	23.51–32.88	24.67–32.19	21.85–34.51	24.26– 33.20	26.59– 31.82	
	95% CI for mean	27.66-28.37	27.82-28.57	28.13-28.72	27.68-28.67	28.28- 29.17	28.76-29.64	
MCV (fl)	Mean	83.95	84.18	84.66	84.70	86.10	88.04	0.000
	Median	84.50	84.20	85.20	85.40	85.90	88.40	
	2.5th– 97.5th percentile range	74.36–93.54	73.57–94.80	75.17–94.17	72.36–97.01	75.43– 96.79	78.52– 97.57	
	95% CI for mean	83.01-84.88	83.33-85.03	83.91-85.41	83.73-85.66	85.03- 87.17	86.44-89.64	
Platelet count ($*10^9$/l)	Mean	296778	299127	291852	274964	277167	251579	0.000
	Median	289500	293000	290000	278000	268500	250500	
	2.5th– 97.5th percentile range	171613–421943	182495–415759	179948–403756	156810–393118	135767–418567	161593–341565	
	95% CI for mean	284596-308960	289776-308477	282993-300710	265697-284230	262996-291337	236488-266670	
Specific Gravity	Mean	1.02	1.02	1.02	1.02	1.02	1.02	0.336
	Median	1.02	1.02	1.02	1.02	1.02	1.02	
	2.5th– 97.5th percentile range	1.01- 1.03	1.01– 1.03	1.01– 1.03	1.01– 1.03	1.01– 1.03	1.01– 1.03	
	95% CI for mean	1.02- 1.02	1.02- 1.02	1.02- 1.02	1.02- 1.02	1.02- 1.02	1.02- 1.02	
pH	Mean	5.88	5.91	5.85	5.84	5.77	5.96	0.329
	Median	5.50	6.00	5.50	5.50	5.50	5.50	
	2.5th– 97.5th percentile range	4.87– 6.88	4.56– 7.26	4.80– 6.90	4.78– 6.90	4.79– 6.75	4.60– 7.31	
	95% CI for mean	5.79- 5.96	5.81- 6.01	5.77- 5.93	5.76- 5.91	5.67- 5.87	5.76- 6.15	
TSH (micro Iu/ml)	Mean	1.41	2.20	2.05	2.39	2.64	3.61	0.004
	Median	1.05	1.87	1.52	1.67	2.14	2.54	
	2.5th– 97.5th percentile range	(-0.29)–3.11	(-0.19)–4.60	(-1.34)–5.46	(-1.63)–6.42	(-1.57)– 6.87	(-2.07)– 9.29	
	95% CI for mean	0.60- 2.21	1.88- 2.51	1.69- 2.42	1.94- 2.83	2.08- 3.21	2.52- 4.69	
ESR (mm)	Mean	6.29	9.78	9.74	12.95	19.00	26.23	0.000
	Median	4.00	7.00	6.00	11.00	12.50	26.00	
	2.5th– 97.5th percentile range	(-6.36)–18.96	(-6.89)–26.45	(-5.84)–25.34	(-7.02)–32.93	(-14.71)–52.71	(-18.16)–70.62	
	95% CI for mean	4.53- 8.05	8.16-11.39	8.35-11.14	11.18-14.72	15.36- 22.64	17.92-34.53	

Table 5 Biochemical Investigations of Blood Sugar Level according to Age group

Parameters		Age group						p-Value
		18-24	25-34	35-44	45-54	55-64	>= 65	
Fasting Blood Sugar (FBS)(mg/dl)	Mean	93.47	95.75	109.70	122.66	133.09	121.71	0.000
	Median	93.50	92.00	95.00	104.00	107.00	106.00	
	2.5^{th}– 97.5^{th} percentile range	69.05-117.90	53.31-133.20	19.86-199.50	33.66-211.70	6.90-259.30	41.55-201.90	
	95% CI for mean	90.54-96.40	92.06-99.45	101.84-117.56	114.78-130.54	120.57-145.61	109.42-134.00	
Hemoglobin A1C (HbA1C)	Mean	8.95	7.55	6.89	7.30	7.53	6.88	0.272
	Median	8.95	7.20	5.90	6.50	6.80	6.70	
	2.5^{th}– 97.5^{th} percentile range	8.25-9.64	3.27-11.84	2.93-10.85	3.43-11.18	3.72-11.36	4.61- 9.16	
	95% CI for mean	5.77-12.12	6.17-8.94	6.35-7.43	6.83- 7.78	7.00- 8.07	6.46- 7.30	
Glucose post prandial Blood Sugar (PPBS)(mg/dl)	Mean	112.00	108.70	134.64	164.40	219.60	160.60	0.000
	Median	99.00	92.00	105.00	151.00	205.50	153.50	
	2.5^{th}– 97.5^{th} percentile range	(-2.46)-226.50	31.38-186.0	(-11.20)-280.50	11.13-317.70	78.47-360.70	39.08-282.10	
	95% CI for mean	58.00-166.00	96.56-120.84	118.19-151.00	143.50-185.40	187.60-251.50	127.60-193.70	

Table 4 Biochemical Investigations of Blood Sugar, according to gender

Parameters	Male		Female		Combined		p-Value
	2.5^{th}– 97.5^{th} percentile range	95% CI for mean	2.5^{th}– 97.5^{th} percentile range	95% CI for mean	2.5^{th}– 97.5^{th} percentile range	95% CI for mean	
Fasting Blood Sugar (FBS) (mg/dl)	25.27–203.3	109.56-118.98	24.17–197.5	105.56-116.12	24.79–200.8	109.29-116.30	0.340
Hemoglobin A1C (HbA1C)	(-10.20)–26.54	6.70- 9.63	3.24 – 11.29	6.81-7.72	(-7.28)–23.02	6.88-8.84	0.244
Glucose post prandial Blood Sugar (PPBS) (mg/dl)	5.32 – 305.4	142.97-167.76	(-5.32)–276.7	120.71-150.68	0.31– 295.5	138.33-157.48	0.299

The calculated mean, median, 95% CI for mean, 2.5^{th} – 97.5^{th} percentile range values of Blood sugar parameters based on sex and age are shown in table 4 and 5 respectively. As shown in table 4, participants had overall mean value of FBS of 112.79 (mg/dl), HbA1C of 7.867, PPBS of 147.90 (mg/dl). Males had reference intervals of FBS 25.27 – 203.3 (mg/dl) against females of 24.17 – 197.5 (mg/dl), HbA1C of (-7.289) – 26.54 against females of 3.244 – 11.29, PPBS of 5.325 – 305.4 (mg/dl) against females of (-5.329) – 276.7 (mg/dl). The values of FBS, HbA1C and PPBS were not significantly difference between males and females. As shown in table 5, the values of FBS and PPBS across all age groups of participants were significantly different (P<0.05)

Table 6 Biochemical investigations of lipid, liver, renal according to the Gender

Parameters	Male				Female				Combined				p-Value
	Mean	Median	2.5^{th}–97.5^{th} percentile	95% CI for mean	Mean	Median	2.5^{th}–97.5^{th} percentile	95% CI for mean	Mean	Median	2.5^{th}–97.5^{th} percentile range	95% CI for mean	

			range				range						
Total Protein (g/dl)	7.50	7.50	0.60	7.44-7.55	7.38	7.40	0.60	7.28-7.49	7.45	7.50	0.50	7.39-7.50	0.066
Albumin (g/dl)	4.38	4.40	0.50	4.33-4.43	4.11	4.20	0.60	4.06-4.17	4.27	4.30	0.50	4.23-4.31	0.000
Globulin (g/dl)	3.11	3.00	0.80	3.04-3.18	3.31	3.20	0.80	3.22-3.39	3.19	3.10	0.80	3.14-3.25	0.000
Albumin/ Globulin Ratio (g/dl)	1.45	1.40	0.50	1.41-1.50	1.34	1.30	0.40	1.23-1.45	1.40	1.40	0.50	1.35-1.46	0.059
Bilirubin (mg/dl)	0.76	0.66	0.43	0.70-0.82	0.56	0.51	0.30	0.52-0.60	0.67	0.57	0.41	0.63-0.71	0.000
Alanine aminotransferase (ALT) (u/l)	45.54	40.50	30.00	42.77 - 48.30	32.61	28.00	20.00	29.85 - 35.36	39.96	33.00	26.75	37.93 - 42.00	0.000
Gamma-glutamyltransferase (GGT) (u/l)	52.39	38.00	29.50	46.74 - 58.04	35.02	26.00	20.25	30.68 - 39.36	45.35	34.00	26.00	41.48 - 49.23	0.000
Alkaline phosphatase (ALP) (u/l)	76.01	75.00	27.00	73.18 - 78.85	75.85	73.00	28.00	71.99 - 79.70	75.94	74.00	25.25	73.65 - 78.24	0.945
Aspartate aminotransferase (AST) (u/l)	28.15	25.00	13.00	26.34 - 29.96	24.12	21.00	10.00	22.51 - 25.73	26.54	23.00	13.00	25.27 - 27.81	0.001
Cholesterol, Total (mg/dl)	194.07	193.00	57.00	189.37-198.76	195.94	193.50	56.50	190.42-201.46	194.81	193.00	56.00	191.23-198.38	0.612
Triglyceride (mg/dl)	146.84	125.00	95.00	137.85-155.83	109.52	103.00	64.75	102.75-116.30	131.91	115.00	82.50	125.69-138.14	0.000
High Density Lipoprotein (HDL)(mg/dl)	45.75	43.00	14.00	44.23 - 47.28	52.90	51.00	13.25	50.90 - 54.90	48.62	46.00	16.00	47.37 - 49.86	0.000
Low Density Lipoprotein (LDL)(mg/dl)	119.18	119.00	55.00	114.42-123.95	119.10	115.00	55.50	113.38-124.81	119.15	117.00	56.00	115.50-122.80	0.981
Total/ HDL Ratio	4.49	4.30	1.80	4.32-4.67	3.87	3.70	1.30	3.70-4.05	4.25	4.00	1.80	4.12-4.37	0.000
Very Low Density Lipoprotein (VLDL) (mg/dl)	29.59	25.00	18.50	27.42 - 31.77	22.64	20.00	11.00	20.68 - 24.59	26.86	23.00	16.00	25.40 - 28.57	0.000
Non-HDL (mg/dl)	143.94	147.00	63.00	137.03-150.84	137.79	127.00	45.00	124.06-151.53	141.65	139.00	55.25	134.98-148.31	0.430

Sodium (mmol/l)	138.99	139.00	133.10–144.90	138.53-139.44	143.49	140.00	133.70–153.30	135.30-151.68	141.05	140.00	134.40-147.70	137.30-144.81	0.280
Potassium (mmol/l)	4.39	4.40	3.61–5.17	4.33-4.45	4.35	4.40	3.52–5.18	4.28-4.42	4.37	4.40	3.57–5.17	4.33-4.42	0.440
Chloride (mmol/l)	99.32	99.00	94.72-103.90	98.97 - 99.68	99.08	100.00	82.00 – 116.20	97.65 - 100.51	99.21	100.00	87.17 – 111.30	98.53 - 99.89	0.743
Urea (mg/dl)	25.49	25.00	8.71–42.28	24.20 - 26.78	21.91	21.00	8.44–35.39	20.78 - 23.04	23.85	23.00	8.13–39.58	22.97 - 24.74	0.000
Creatinine (mg/dl)	1.01	0.93	(-0.38) – 2.41	0.92-1.09	0.76	0.69	(-0.48) – 2.01	0.68-0.85	0.90	0.81	(-0.45)–2.26	0.84-0.96	0.000
Uric Acid (mg/dl)	5.51	5.70	3.01–8.00	5.32-5.70	4.35	4.40	2.30–6.40	4.18-4.52	4.98	5.00	2.42–7.54	4.84-5.12	0.000
Calcium (mg/dl)	9.16	9.20	8.43–9.90	9.10-9.22	9.02	9.00	8.35–9.69	8.97-9.08	9.10	9.10	8.38–9.81	9.06-9.14	0.001
Phosphorus (mg/dl)	3.36	3.30	2.67–4.65	3.29-3.43	3.66	3.70	-	3.57-3.74	3.49	3.50	2.48–4.29	3.44-3.55	0.000

As shown in above table 6, there were significant difference (P<0.05) between males and females in the levels of Albumin, Globulin, Bilirubin, ALT, GGT, AST, Triglyceride, HDL, Total HDL ratio, VLDL, Urea, Creatinine, Uric acid Calcium and Phosphorus. The reference intervals of Total protein, Albumin/Globulin ratio, ALP, Total cholesterol, LDL, Non- HDL, Sodium, Potassium and Chloride were not significantly different between the two sex groups (P>0.05).

Table 7 Biochemical investigation of Lipid, liver, Renal According to Age group

Parameters		Age group						P-Value
		18-24	25-34	35-44	45-54	55-64	>= 65	
Total Protein (g/dl)	Mean	7.82	7.49	7.41	7.4790	7.4219	7.393	0.257
	Median	8.00	7.50	7.50	7.5000	7.4000	7.300	
	2.5th– 97.5th percentile range	7.06–8.59	6.67–8.31	5.87-8.96	6.768-8.190	6.605-8.239	6.239-8.547	
	95% CI for mean	7.56-8.08	7.38-7.60	7.25-7.57	6.76- 8.19	7.32-7.51	7.16-7.61	
Albumin (g/dl)	Mean	4.31	4.32	4.29	4.28	4.25	4.10	0.200
	Median	4.30	4.40	4.40	4.30	4.30	4.30	
	2.5th– 97.5th percentile range	3.62-5.01	3.58–5.06	3.52-5.06	6.60– 4.96	3.45-5.06	3.24–4.96	
	95% CI for mean	4.08-4.55	4.22-4.42	4.21-4.37	4.20- 4.35	4.16-4.35	3.93-4.27	
Globulin (g/dl)	Mean	3.50	3.17	3.18	3.19	3.16	3.29	0.417
	Median	3.70	3.10	3.10	3.20	3.00	3.30	
	2.5th– 97.5th percentile range	2.47–4.54	2.12–4.22	2.17–4.20	2.20– 4.18	2.01–4.31	2.11–4.47	
	95% CI for mean	3.15-3.86	3.03-3.31	3.08-3.29	3.08- 3.30	3.02-3.29	3.06-3.52	
Albumin/Globulin Ratio (g/dl)	Mean	1.28	1.41	1.47	1.38	1.38	1.30	0.591
	Median	1.10	1.40	1.40	1.30	1.40	1.20	
	2.5th– 97.5th percentile range	0.56–1.99	0.76–2.06	(-0.76)–3.12	0.78– 1.99	0.67–2.10	0.64–1.95	
	95% CI for mean	1.03-1.52	1.32-1.50	1.30-1.64	1.31- 1.45	1.31-1.46	1.17-1.42	
Bilirubin	Mean	0.64	0.71	0.72	0.66	0.64	0.64	0.767

(mg/dl)	Median	0.62	0.68	0.59	0.56	0.54	0.57	
	2.5th– 97.5th percentile range	0.30– 0.98	0.49– 1.38	(-0.07)– 1.52	0.02– 1.31	(-0.22)- 1.52	(-0.03)– 1.31	
	95% CI for mean	0.50- 0.79	0.61- 0.81	0.63- 0.80	0.5965- 0.7425	0.543- 0.7538	0.50-0.77	
Alanine aminotransferase (ALT) (u/l)	Mean	34.63	42.44	44.25	44.43	34.48	30.29	0.000
	Median	27.00	33.00	37.50	41.00	33.00	30.00	
	2.5th– 97.5th percentile range	(-18.45)- 87.71	(-7.48)– 92.36	(-11.28)– 99.78	(-4.922)– 93.78	4.453– 64.51	4.281– 56.30	
	95% CI for mean	27.75- 41.51	36.94- 47.93	39.18- 49.33	40.03- 48.83	31.45- 37.50	26.15- 34.42	
Gamma-glutamyltransferase (GGT) (u/l)	Mean	35.17	45.07	41.59	49.40	51.04	38.55	0.284
	Median	31.00	29.00	35.00	38.50	35.00	27.00	
	2.5th– 97.5th percentile range	1.57– 66.76	(- 47.32)– 137.50	(-8.36)– 91.55	(-21.71)– 120.50	(-50.62)– 152.70	(-40.20)– 117.30	
	95% CI for mean	28.77- 41.57	32.89- 57.24	36.36- 46.81	41.43- 57.37	38.85- 36.23	23.27- 53.84	
Alkaline phosphatase (ALP) (u/l)	Mean	78.50	73.05	74.67	74.90	78.62	77.55	0.730
	Median	76.00	74.00	73.50	68.00	76.00	71.00	
	2.5th– 97.5th percentile range	36.69– 120.30	32.54– 113.60	26.93– 122.40	24.23– 125.60	43.32– 113.90	38.86– 116.20	
	95% CI for mean	64.94- 92.06	67.80- 78.30	69.73- 79.60	69.19- 80.62	74.45- 82.80	70.04- 85.06	
Aspartate aminotransferase (AST) (u/l)	Mean	26.67	25.68	26.19	27.64	27.32	25.38	0.911
	Median	21.00	21.00	24.00	25.00	24.00	23.00	
	2.5th– 97.5th percentile range	2.05– 51.29	(-0.17)– 51.53	4.787– 47.59	0.4945– 54.79	(-10.47)– 65.11	3.918– 46.84	
	95% CI for mean	18.68- 34.65	22.48- 28.87	24.15- 28.22	25.06- 30.22	23.32- 31.31	21.87- 28.88	
Cholesterol, Total (mg/dl)	Mean	187.28	202.86	203.26	197.56	186.63	173.67	0.000
	Median	189.50	199.00	198.00	192.00	194.00	173.00	
	2.5th– 97.5th percentile range	128.00– 246.60	114.20- 291.50	113.70– 292.90	112.00– 283.10	95.20– 278.10	83.22– 264.10	
	95% CI for mean	178.68- 195.88	193.74- 211.97	195.62- 210.90	190.13- 204.99	177.28- 195.98	159.80- 187.53	
Triglyceride (mg/dl)	Mean	95.50	146.20	130.37	130.37	141.57	104.98	0.013
	Median	72.00	119.00	115.50	115.50	120.50	92.00	
	2.5th– 97.5th percentile range	(-5.43)- 196.40	(-39.80)- 332.20	(-14.98)- 275.70	(-14.98)- 275.70	(-6.388)- 289.50	15.66– 194.30	
	95% CI for mean	70.60- 120.30	124.30- 168.00	117.30- 143.45	117.30- 143.45	126.44- 156.71	91.29- 118.67	
High Density Lipoprotein (HDL) (mg/dl)	Mean	42.42	48.46	47.78	48.25	48.05	56.18	0.007
	Median	42.00	45.00	47.00	47.00	47.00	52.00	
	2.5th– 97.5th percentile range	-	13.25	17.00	16.00	18.00	27.00	
	95% CI for mean	37.93- 46.91	44.27- 52.65	45.14- 50.42	45.92- 50.57	45.77- 50.33	50.64- 61.72	
Low Density Lipoprotein (LDL) (mg/dl)	Mean	131.16	125.84	127.56	119.66	111.64	96.67	0.000
	Median	138.00	130.00	124.00	115.00	111.00	96.00	
	2.5th– 97.5th percentile range	47.00	53.00	50.50	49.50	61.00	58.50	
	95% CI for mean	115.48- 146.84	115.38- 136.30	119.96- 135.15	112.51- 126.80	103.16- 120.12	85.72- 107.61	
Total/ HDL Ratio	Mean	4.76	4.55	4.56	4.28	3.99	3.27	0.000
	Median	4.80	4.40	4.15	3.90	4.10	3.00	
	2.5th– 97.5th percentile range	2.10	1.30	2.10	1.80	1.75	1.05	
	95% CI for mean	4.06- 5.47	4.18- 4.92	4.26- 4.85	4.02- 4.53	3.76- 4.22	2.96- 3.57	
Very Low Density Lipoprotein (VLDL) (mg/dl)	Mean	21.33	29.37	25.76	26.94	31.18	19.41	0.005
	Median	18.00	25.00	22.00	23.00	25.00	17.00	
	2.5th– 97.5th	24.00	19.00	12.00	13.00	18.00	12.00	

	percentile range							
	95% CI for mean	9.45-33.22	25.03-33.70	22.41-29.11	24.17-29.72	26.95-35.41	16.58-22.24	
Non-HDL (mg/dl)	Mean	134.00	153.90	142.64	140.86	137.15	141.00	0.814
	Median	130.00	153.00	139.00	140.50	141.00	113.00	
	2.5th– 97.5th percentile range	13.00	53.50	62.25	46.25	68.00	66.00	
	95% CI for mean	99.10-168.90	139.24-168.57	131.37-153.91	132.71-149.01	125.38-148.91	86.60-195.30	
Sodium (mmol/l)	Mean	139.86	152.70	139.39	139.39	138.88	138.29	0.344
	Median	140.00	139.00	140.00	140.00	140.00	139.00	
	2.5th– 97.5th percentile range	5.00	3.00	3.00	3.50	4.00	7.00	
	95% CI for mean	137.69-142.02	125.20-180.20	138.82-139.96	138.65-140.12	137.88-139.88	136.51-140.05	
Potassium (mmol/l)	Mean	4.22	4.29	4.37	4.31	4.47	4.47	0.060
	Median	4.20	4.30	4.40	4.30	4.40	4.45	
	2.5th– 97.5th percentile range	0.80	0.50	0.50	0.40	0.50	0.40	
	95% CI for mean	3.81-4.63	4.17-4.41	4.28-4.45	4.22- 4.40	4.37-4.58	4.31-4.64	
Chloride (mmol/l)	Mean	99.28	99.25	99.79	99.61	99.62	95.11	0.022
	Median	100.00	99.00	100.00	100.00	100.00	99.00	
	2.5th– 97.5th percentile range	2.00	2.50	2.00	2.00	4.00	4.75	
	95% CI for mean	97.70-100.86	98.75-99.74	99.34-100.25	99.08-100.14	98.80-100.45	87.76-102.46	
Urea (mg/dl)	Mean	26.38	22.59	22.53	24.81	24.55	25.54	0.243
	Median	26.00	22.00	22.00	25.00	24.00	25.00	
	2.5th– 97.5th percentile range	7.75	10.00	10.00	12.25	11.00	16.50	
	95% CI for mean	22.53-30.22	20.39-24.79	21.02-24.03	23.10-26.25	22.67-26.42	20.11-30.96	
Creatinine (mg/dl)	Mean	1.41	0.78	0.95	0.83	0.96	0.93	0.040
	Median	0.86	0.75	0.87	0.80	0.80	0.79	
	2.5th– 97.5th percentile range	0.18	0.26	0.29	0.28	0.26	0.41	
	95% CI for mean	0.20-2.62	0.74-0.82	0.79-1.10	0.80- 0.86	0.77-1.14	0.82-1.05	
Uric Acid (mg/dl)	Mean	4.83	5.17	5.12	5.01	4.93	4.54	0.413
	Median	5.30	4.90	5.30	5.00	4.90	4.40	
	2.5th– 97.5th percentile range	2.15	2.10	1.80	1.85	1.72	1.47	
	95% CI for mean	3.40-6.26	4.73-5.60	4.84-5.40	4.68- 5.33	4.63-5.22	4.06-5.02	
Calcium (mg/dl)	Mean	9.04	9.10	9.05	9.10	9.18	9.014	0.267
	Median	9.20	9.10	9.10	9.10	9.10	9.05	
	2.5th– 97.5th percentile range	0.40	0.45	0.50	0.40	0.40	0.70	
	95% CI for mean	8.71-9.37	8.98-9.22	8.96-9.14	9.02- 9.18	9.10-9.26	8.86-9.16	
Phosphorus (mg/dl)	Mean	3.68	3.45	3.37	3.44	3.61	3.67	0.020
	Median	3.55	3.50	3.40	3.40	3.70	3.40	
	2.5th– 97.5th percentile range	0.70	0.67	0.40	0.70	0.80	0.90	
	95% CI for mean	3.37-4.00	3.29-3.60	3.28-3.45	3.30- 3.57	3.48-3.74	3.40-3.93	

As shown in table 7, the analyzed data of total protein, Albumin, Globulin, Albumin/Globulin ratio, Bilirubin, GGT, ALP, AST, Non-HDL, Sodium, Potassium, Urea, Uric acid and Calcium

across all age groups of participants were similar ($p>0.05$), but, there was a significant difference in the values of ALT, total cholesterol, Triglycerides, HDL, LDL, Total HDL ratio, VLDL, Chloride, Creatine and Phosphorus ($p<0.05$)

IV. CONCLUSION

In the current study, some of the calculated reference intervals of clinical chemistry parameters were significantly different according to the age and gender. Therefore, there is a possibility of inappropriate diagnosis of some clinical conditions in healthy adults. However, further studies are required to establish unique reference intervals for Sri Lankan population.

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