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PREVALENCE OF OVERWEIGHT, OBESITY AND HYPOTHYROIDISM AMONG HYPERTENSIVE PATIENTS AT TEACHING HOSPITAL BATTICALOA

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ABSTRACT

The aim of the study was to determine the prevalence of overweight, obesity and hypothyroidism among hypertensive patients. It was a descriptive study on 50 patients (28% were males and 72% were females) who follow the medical clinic at teaching hospital Batticaloa. Overweight and obesity were defined according to the cut-off values of body mass index (BMI) for Asian population. Thyroid stimulating hormone (TSH) level was used to assess the functional status of thyroid gland. Results showed, 8% were underweight, 28% were normal weight, 36% were overweight and 28% were obese among the hypertensive patients. 94% of the hypertensive patients had normal thyroid functions. 4% and 2% of the total population had hypothyroidism and hyperthyroidism respectively. Those patients with overweight, obesity and abnormal thyroid functions were reassessed clinically and further investigations and management were implemented. In conclusion the BMI distribution of the population sample revealed more people that is 36% were predominantly overweight. Approximately 2/3 of the total population is above the target BMI, which is overweight or obese. Furthermore, 94% hypertensive patients had normal thyroid functions. Only 6% of the population sample was abnormal in their thyroid status and only 4% had hypothyroidism, which was not clinically significant. Therefore routine screening of

hypertensive patients to assess their BMI is an important step as majority are above the target BMI. However routine screening of TSH is not recommended to all the hypertensive patients. Thyroid functions should be done only if clinically indicated.

Key words: Overweight, Obesity, Hypothyroidism and Hyperthyroidism

INTRODUCTION

Prevalence of overweight and obesity have been increasing worldwide. These are the risk factors for almost all of the non-communicable and communicable diseases. According to the World Health Organization (WHO), obesity has been tripled worldwide since 1975. Considering the population of more than 18 years of age, 39% and 13% were overweight and obese respectively worldwide¹. Likewise Sri Lanka also significantly affected by overweight and obesity. This was evidenced by a study done by Kalulanta et al showed 25.2% were overweight and 9.2% were obese among the population over 18 years of age in Sri Lanka². It is well known that overweight and obesity are the risk factors for hypertension³.

Studies conducted in Northern Europe, Japan and the USA have found that the prevalence of hypothyroidism ranges in between 0.6 and 12 per 1000 women and between 1.3 and 4.0 per 1000 in men⁴. However there are no much studies on Sri

Lankan adult population about hypothyroidism. As everyone knows hypothyroidism is associated with overweight and obesity. In addition it causes significant metabolic effects, such as hypercholesterolaemia, hypertension and accelerated atherosclerosis, which lead to increased cardiovascular mortality^{3, 5}. At the same time it could be diagnosed and treated very easily when we identify the symptoms early and prevent the metabolic complications⁶. Therefore this project has been design to study about the prevalence of overweight, obesity and hypothyroidism among hypertensive patients.

RESEARCH DESIGN AND METHODOLOGY

It was a descriptive study among hypertensive patients who follow-up the medical clinic at teaching hospital, Batticaloa, Sri Lanka. Ethical clearance for this study was obtained from Ethical Review Committee, Faculty of Health-Care Sciences, Eastern University of Sri Lanka. Total of 50 hypertensive patients were included and the study was conducted from August 2017 to October 2017.

Data collection was done after obtaining informed written consent from the subjects and every other 5th hypertensive patient was selected for this study after careful evaluation with exclusion criteria. The exclusion criteria were anyone on pharmacological treatment for weight reduction and past history of hypothyroidism or on treatment with thyroxin.

The participants' height (in centimetres) and weight (in kilograms) were measured and the body mass index (BMI) was calculated. Overweight and obesity were defined according to the non-communicable disease unit, ministry of health care and nutrition, Sri Lanka's BMI

cut-off values for Asian population as follows⁷.

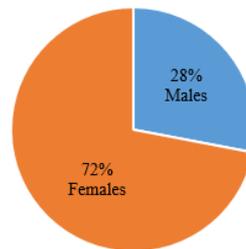
- BMI ≤ 18.4 kg/m² - Under weight
- BMI is 18.5 – 23 kg/m² - Normal
- BMI is 23.1 – 27.5 kg/m² - Over weight
- BMI ≥ 27.6 kg/m² - Obesity

Hypothyroidism had been defined as TSH more than 4.68 mIU/L (this is the upper limit of normal reference range at teaching hospital Batticaloa).

Results of this study were analyzed as per SPSS 19 package.

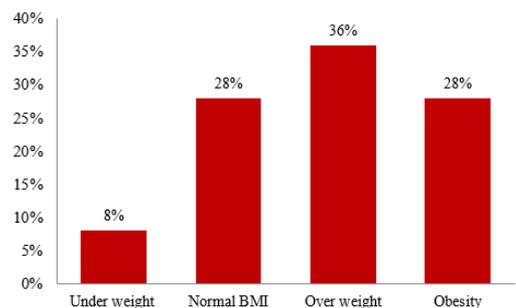
RESULTS

Figure 1 - Sex Distribution



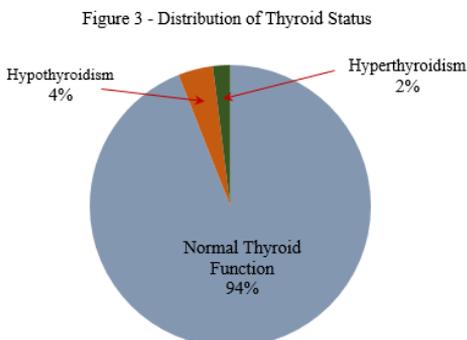
Study population comprised of 50 hypertensive patients and 28% of them were males (14) (Figure 1).

Figure 2 - BMI Distribution



BMI of the study population demonstrated 8% (4) were underweight, 28% (14) were normal BMI, 36% (16) were overweight and 28% (14) were

obese among the hypertensive patients (Figure 2).



Thyroid status of the population showed that 94% (47) of the hypertensive patients had normal thyroid functions. 4% (2) and 2% (1) of the total population had hypothyroidism and hyperthyroidism respectively (Figure 3).

Both hypothyroid patients were under the category of obesity in this study population.

DISCUSSION

The BMI distribution of the population sample revealed that more people that is 36% were predominantly overweight. Approximately 2/3 of the total population (64%) is above the target BMI, which is overweight or obese. These findings are compatible with prevalence of overweight and obesity among adults in Sri Lanka as well as world wide population^{2,1}. Interestingly these proportions are exactly similar to the proportions of the general population, not among hypertensive subjects. This is clearly evident that everyone in the society needs BMI calculations and majority of them need lifestyle modifications to keep the ideal BMI.

Furthermore, 94% hypertensive patients had normal thyroid functions. Only 6% of the population sample was abnormal in their thyroid status and only 4% had

hypothyroidism, which was not clinically significant. There are no much studies in Sri Lanka or globally to compare these findings of prevalence of hypothyroidism among hypertensive patients. Even though hypothyroidism and obesity are the risk factors for hypertension and both increases cardiovascular mortality, no much recommendation to do the routine screening for hypothyroidism among asymptomatic individuals⁸.

Those patients with overweight, obesity and abnormal thyroid functions in our study were reassessed clinically and further investigations and management were implemented.

CONCLUSION

Routine screening of hypertensive patients to assess their BMI is an important step as majority are above the target BMI. However routine screening for hypothyroidism is not recommended to all the hypertensive patients. Thyroid functions should be done only if clinically indicated.

Conflicts of interest

None

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**PHYSICAL ACTIVITY PATTERNS AND ITS ENVIRONMENTAL
ASSOCIATIONS AMONG SCHOOLTEACHERS IN SELECTED SCHOOL
DIVISION IN EASTERN PROVINCE**

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ABSTRACT

It is a well-established fact that prevalence of physical inactivity is rising in global level in all stages of life with significant association for increased non-communicable disease burden. This study was conducted to describe the physical activity (PA) patterns and its environmental associations among schoolteachers in a selected school. A descriptive cross-sectional study was conducted among 392 government schoolteachers selected by multistage cluster sampling method in 2018. Sociodemographic factors, environmental factors and physical activity pattern were assessed by using a validated questionnaire including The International Physical Activity Questionnaire long version and Physical and Social Environment Scale and the level of physical activity was categorized as sufficient an insufficient group. chi-square and Mann- whitney U test were performed at a 5% level of significance. It was found that each participant on average spends 3005.7 (SD±2706.7) MET-minutes total energy per week. The main contributor to the energy expenditure was engaging in home cleaning and gardening [1516.9 (SD±1618.9) MET-minutes per week]. People engaging in job, transport, leisure related activity was less. Majority (85%) of the participants had sufficient level of

PA. Overall physical and social environment was less favorable to engaging PA. Insufficient PA level was significantly associated among young and not having chronic disease teachers. There were not significant association found between PA level and environment. Despite the non- conducive environment, majority of schoolteachers in KED had sufficient level of PA. Young teachers and those who not having chronic disease did not meet the sufficient level of PA. Young teachers should be motivated to engage in PA. The facilities have to be arranged to motivate the teachers to participate job, transport and leisure related activity.

Key words: Physical activity, teachers, physical and social environment.

INTRODUCTION

It is a well-established fact that prevalence of physical inactivity is rising in global level in all stages of life with significant association for increased non-communicable disease (NCD) burden. Sri Lanka is one of countries in South East Asia with nearly 21 million population (1). Sri Lanka experienced epidemiological transition where disease burden of communicable disease shifted to NCD. This caused a huge socio-economic

impact in individual, community and national level. Sri Lanka has formulated its “National Multispectral Action Plan for the Prevention and Control of NCD” with a vision of a country “Free of the avoidable burden of non-communicable diseases”. The target was set to relatively reduce the premature mortality from cardiovascular disease, cancer, diabetes, or chronic respiratory diseases by 25% by 2025(2)

Physical inactivity, consumption of unhealthy diet, tobacco use, and harmful use of alcohol are the four behavioral or modifiable risk factors for most of NCD related disease. Worldwide, 23% of people (men 20% and women 27%) aged more than 18 years were physically inactive in 2010(3). STEPS survey 2015 has shown 22.5% of the males and 38.4% of the females do not engage minimum level of WHO suggested physical activity (PA) and overweight and obese prevalence is almost 29% (95% CI: 27.5-31.1) in adult population with 24.6% men and 34.3% females (4). Sri Lanka aims to achieve 10% relative reduction in prevalence of lack of physical activity targets by 2025. One of the strategic plans to reduce NCD burden is strengthen or establish the PA programmers in workplaces (5). There are many determinants of physical inactivity, namely individual factors are such as age, gender, education level, income, social motivation, environmental factors and personal barriers. Social and physical environments have a close association with PA (6).

Teachers are a large occupational group. According to the report of Ministry of Education, Sri Lanka, there are 241,591 teachers in 10,194 government schools. They are teaching to around 4.1 million students(7). The previous study results highlighted the importance of perceived teacher support to motivation in PA of students in schools (8). Teacher as a positive role model in encouraging PA has been shown in previous literatures (9).

Also, teachers involve in “School Health Promotion Program (SHPP)” which is introduced by Sri Lankan Government with a collaboration of WHO as a part of NCD Prevention. Teachers are also a health resources to local public, especially in rural area in the aspect of sharing health related knowledge and practices. Improvement in health status of schoolteachers contribute not only the present generation but also future generation. Are teachers’ daily activities sufficient? Do the teaching profession and their workplace allow them to be physically active? Therefore, assessing physical activeness of schoolteachers will help for policy makers and health planner to formulate the strategies on school health promotion program as well as it is very important need on improving occupational health promotion program of schoolteachers in workplace and community level. By keeping all these in mind, this study was planned to describe the PA patterns, its environmental associations among schoolteachers in Kattankudy Educational Division.

METHODS

A descriptive cross-sectional study was carried out among government schoolteachers, who has been teaching for more than 6 months in 31 schools in Kattankudy Educational Division (KED). There are 617 schoolteachers in all four types of schools. Teachers who are currently pregnant, unable to do PA due to physical disability and teachers from type 3 schools were excluded. The sample size was calculated with estimated prevalence of physical inactivity was 30.4%(4), 1.96 Z value with 5% precision and 1.2 design effect(10). After adjustment of 5% non-response rate, the calculated sample size was 410 (11). A multistage cluster sampling method with probability proportionate to size (PPS) of the schoolteachers in each school in KED was

used to select the representative study sample. All selected schools were stratified according to the types of schools. A cluster was considered as a group consist of thirty teachers and 14 clusters were calculated. Number of clusters were selected according to probability proportionate to size of each school. Teachers were selected through simple random sampling, if the total number of teachers would more than 30.

Pre-tested, validated, self-administered questionnaire with three sections was used for data collection. Assessment of the PA pattern of participant by International Physical Activity Questionnaire - Long Version, Assessment of the perceived physical and social environment in relation to physical activity by Physical and Social Environment Scale (PASES) for physical activity. Sections 2 and 3 were validated for Sri Lanka in previous studies(12)(13). Data were collected by the principal investigator and trained medical students. PA level was assessed according to the IPAQ scoring guidelines. PA was assessed as metabolic equivalents (METs) and expressed as MET-minutes/week. Total PA was calculated by adding different field specific activity such as job-related, transportation, housework and leisure-time. PA level was categorized into sufficient activity and insufficient activity.

There are 34 factors included in PASES. All these factors were grouped in to 8 separate main factors. This was measured in terms of six physical and two social factors. Physical factors were assessed by residential density, infrastructure for walking, aesthetics facilities for cycling, vehicular traffic safety, access and connectivity, recreational facilities, safety, land use diversity. Social factors were assessed by social cohesion and social acceptance of PA. Participants were asked to rate each item on a five-point Likert scale according to their agreement. Scoring was given

based on ranging from 1-5 using the scoring protocol for PASES. Mean score for each main factor were calculated. If the median score was more than 4, considered as favorable environment to PA. All questions were coded by principle investigator before entering date. Data cleaning were done by manually checking all questionnaires. Data were analyzed by using Statistical Package for Social Sciences (SPSS version 22 package). Extra precaution was taken while entering data and double entry of 5% of the data was done to identify any input errors.

Descriptive statistics were used to describe the PA pattern, its different components. Continuous variables were described using frequency distributions. Cross tabulation was done between two selected variables. Chi-squared test was used to determine associations between categorical variables. When data set showed a non-normal distribution, a non-parametric test (Mann- whitney U) test was used to assess the association between a continues and categorical variable. A probability of < 0.05 evidence significant. Approval for the study was obtained from the Board of Study, Community Medicine of the Postgraduate Institute of Medicine (PGIM), and Colombo. Ethical clearance was obtained from Ethical Review Committee of PGIM. Informed written consent was obtained from the participants. Data collection was done after obtaining permission from relevant authorities.

RESULT

Description of the study sample based on Socio demographic & economical characteristics.

The sample included a total of 392 (76 men and 316 women) participants with the response rate of 95.8%, whose Socio demographic & economical characteristics are reported in Table 1. Majority of the study participant (62%)

belonged to age less than 40 years. Most of the study population were female (80.6%, n=316). Majority (74%, n=290) of them were receiving average monthly income between 20,001 to 40,000 Sri Lankan rupees. Approximately half of the teachers (49.7%, n=195) were trained teachers followed by graduate teachers (40.8%, n=160)). Half of the teachers had

experience of more than 10 years (n=196). Majority of the teachers (75.5%, n= 296) were residing in urban area. Among the participant 20% had at least one chronic disease.

Table 1 Distribution of Socio demographic & economical characteristics (n=392)

Socio demographic & economical characteristics	Number	%
Age (in years)		
< 40	243	62.0
≥ 40	149	38.0
Sex		
Male	76	19.4
Female	316	80.6
Number of children		
No child	54	13.8
≤ 2	201	51.3
≥ 3	137	34.9
Ethnicity		
Tamil	72	18.4
Moor	320	81.6
Religion (n=391)		
Hinduism	65	16.6
Christianity	12	3.1
Islam	314	80.1
Civil status		
Never married	50	12.8
Currently married	335	85.5
Separate / divorced	7	1.8
Average monthly income (in rupees)		
10,000 – 20,000	37	9.4
20,001 – 40,000	290	74.0
> 40,000	65	16.6
Current Employment status (n=391)		
Permanent	361	92.1
Temporary	30	7.7

Qualification of the teachers		
Graduate teacher	160	40.8
Trained teachers	195	49.7
others	37	9.4
Experience (in years)		
< 10	196	50.0
≥ 10	196	50.0
Area of residence		
Urban	296	75.5
Rural	96	24.5
Having at least one Chronic disease		
Yes	75	19.1
No	317	80.9

Assessments of physical activity pattern of study sample.

It was found in this study that each participant on average spend 3005.7 (SD±2706.7) MET-minutes total energy per week. The main contributor to the energy expenditure was engaging in home cleaning or gardening 1516.9 (SD±1618.9) MET-minutes per week (Table 2). It carries the half of the total energy MET-minutes. Study participant spends approximately equal energy MET-minute in job related, leisure time related

and transportation related activities. When considering intensity specific MET-minutes per week for the study participants (Table 2), It showed that according to the intensity of the PA, on average a participant had spent most of the energy in moderate activity [2069.0 (SD±2173.7) MET-minutes per week]

Table 2 Physical activity level according to the domain and the intensity (n=392)

Domain and Intensity specific PA	PA level (MET minutes/week)				
	Mean	%	SD	Median	IQR
Job-related	454.5	15.12	592.6	247.5	0.0 - 742.5
Transportation	498.2	16.58	808.9	231.0	0.0 - 693.0
Housework	1516.9	50.47	1618.9	810.0	270.0 – 2482.5
Leisure-time	536.1	17.84	1077.2	172.0	0.0 – 584.0
Vigorous intensity activity	110.4	3.67	326.3	0.0	0.0 – 0.0
Moderate intensity activity	2069.0	68.84	2173.7	1335.0	400.0 - 3120.0
Walking	826.3	27.49	980.1	495.0	132.0 – 1179.7
Total	3005.7		2706.7	2278.2	1027.1 – 4220.2

Level of Physical activity
Only 15.5% (n=61) were categorized as low level of PA. Most of them were

moderate (48%, n=188) and 36.5% (n=143) were in high category (Figure 1).

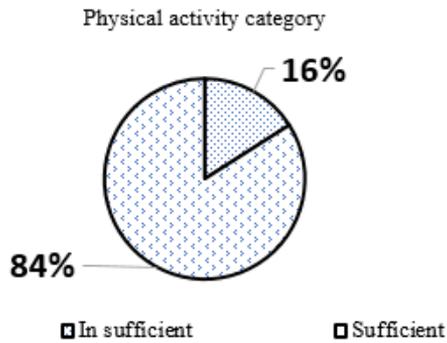


Figure 1 Distribution of study participants according to Physical activity level (n=392)

Association between Physical activity level and environmental factors

Infrastructure for walking (F1), Aesthetics and facilities for cycling(F2), and vehicular traffic safety (F3) were shown the lowest median value indicating least conducive environment for PA in this study population. Overall neighbourhood physical and social environment of study population was less favorable to engaging PA. Overall neighbourhood environment was not significant with sufficient level of PA.

Table 4 Association between Physical activity level and environmental factors

Factors in the PASES			PA level	Mean rank	Sum of rank	Mann-whitny U	z	P value
F1 infrastructure for walking	Mean	2.7	Sufficient	197.83	65481.00	9656.00	-	0.585
	Median	2.7	Insufficient	189.30	11547.00		0.545	
	SD	0.68						
F2 aesthetics and facilities for cycling	Mean	2.7	Sufficient	197.25	65289.50	9847.50	-	0.760
	Median	2.7	Insufficient	192.43	11738.50		0.306	
	SD	0.88						
F3 vehicular traffic safety	Mean	2.4	Sufficient	196.55	65056.50	10080.5	-	0.985
	Median	2.2	Insufficient	196.25	11971.50	0	0.19	
	SD	0.83						
F4 access and connectivity	Mean	3.6	Sufficient	196.97	65197.00	9940.00	-	0.848
	Median	3.6	Insufficient	193.95	11831.00		0.192	
	SD	0.65						
F5 recreational facilities	Mean	3.6	Sufficient	200.03	66209.50	8927.50	-	0.147
	Median	3.6	Insufficient	177.35	10818.50		1.448	
	SD	0.65						
F6 safety	Mean	3.0	Sufficient	197.87	65496.00	9641.00	-	0.574
	Median	3.0	Insufficient	189.05	11532.00		0.562	
	SD	1.00						
F7 social cohesion	Mean	3.5	Sufficient	199.5	66033.50	9103.50	-	0.221
	Median	3.5	Insufficient	180.24	10994.50		1.224	
	SD	0.69						
F8 social acceptance of PA	Mean	3.3	Sufficient	196.98	65202.00	9935.00	-	0.842
	Median	3.3	Insufficient	193.87	11826.00		0.199	
	SD	0.75						
land use diversity	Mean	3.1	Sufficient	195.54	64723.50	9777.50	-	0.696
	Median	3.2	Insufficient	201.71	12304.50		0.391	
	SD	1.19						

DISCUSSION

In this study, it was found that each participant on average spends 3005.7 (SD±2706.7) MET-minutes total energy per week (Table 2). Ozdol et al (14) conducted a study to investigate PA level of 160 teachers working in provincial primary schools of the, Antalya. The authors reported that energy consumption of teachers, on average, was 1608.50 (SD±2026.11) MET-min per week. Previous studies done on general populations showed spectrum of energy expenditure in adult population in Sri Lanka. De Silva Weliange et al(15) conducted a cross sectional study by using the same instrument in 1320 Sri Lankan adult showed total mean energy expenditure was 2039 (SD ±2062) MET – minute. Another community level cross sectional study done among adult showed weekly average energy expenditure was 4473 (SD ±5866) MET-min per week(16). Population-based descriptive cross-sectional survey conducted among 4485 Sri Lankan adults revealed that average energy expenditure of an adult was 4703 (SD ±4369) MET-min per week(17). Comparing with current study, the different may be due to the sample size, socioeconomical background of study population and its behavioral differences.

The main contributor to the energy expenditure in the current study was engaging in home cleaning and gardening (Table 2). Similar finding was observed in the study done by De Silva Weliange et al (15) where study participant was mainly achieved their PA with work inside the home and in the garden. In contrast to current study, STEPS survey 2015 found that work related PA was the major contribution in total PA in Sri Lankan population(4). Study participant spent energy on work, leisure time and transportation related activities was very low. Similar finding was found in previous studies in adult population in Sri Lanka (4)

(18). A study done to determine the PA level in randomly recruited 957 of Italian adult population aged 19-65 years showed that study participant was physically more active in the domestic and garden domain (19). A study done in Bangladesh showed that, People (<3.0%) engaged in leisure-time PA was very low than working and transport related (20). Present study showed based to the intensity of the PA (Table 2), on average a participant had spent most of the energy in moderate intensity activity [mean -2069.0 (SD±2173.7), MET- minutes per week]. This finding was parallel with the study done to describe the pattern of PA among Sri Lankan adults aged 20 to 59 in the district of Colombo(18). There are some similar findings despite of many sociodemographic and methodological differences between current study and above studies may be due to similar nature of study population.

The current study showed that there are 84.4% of the participants categorized to sufficient activity. A previous cross-sectional Study showed that the prevalence of sufficient physical activity in adult population was 82.0% for males and 79.7% for females in Sri Lanka ((18)). A descriptive cross-sectional study among randomly selected 141 secondary school teachers investigated in a in Ibadan, Nigeria in 2012 showed 66.7% of the participants engaged sufficient level physical activity (21). In another study conducted in Turkey, showed that 46% had adequate physical activity level (22). A study done to evaluate the level of PA of teachers aged between 25 and 68 in the public-school system revealed 70% of teachers reached adequate levels of PA(23). A survey conducted among 293 school and university teaching staff in Dohuk city, Iraq reported that 39.5% had sufficient level of PA (24). A study on Italian adults showed that among the participants, 86% were, adhered to the international recommendations that

spending at least 30 minutes of moderate PA on 5 days of the week(19). When comparing the findings of both community setting and teachers' population the current study showed higher proportion of participants were in sufficient category. This could be due to the education level of the study

Current study showed overall physical and social environment was less favorable to engaging PA. Even though, our study results did not show a significant association between PA level and social and physical environment, previous national and international studies showed the significant association. Individual and environmental correlates with PA pattern was assessed in a cross-sectional study among 1320 Sri Lankan adults showed both physical and social environment seen to have influence in leisure related and transportation related PA. It showed the statistically significant between aesthetics and facilities for cycling factors and vehicular traffic safety factors. However, qualitative assessment showed the importance of social environment(25). A cross-sectional study conducted to investigate the performance of PA related to environmental variables among urban population in China was found that there was a positive associated observed between area of residence and transport, leisure related PA(26). Despite of having unfavorable environment to the study participants, majority of them had a sufficient level of PA. Because they involved more in household work and less involvement in transport and leisure related PA. Also, majority of the participants were female who were usually involved in much housework.

CONCLUSION AND RECOMMENDATIONS

Despite the non- conducive physical and social environment, majority of schoolteachers in KED had sufficient level of PA and they had spent most of the energy in moderate activities. Study participant spent energy on work, leisure time and transportation related activities was very low. The facilities have to be arranged to motivate the teachers to participate job, transport and leisure related activity.

Public health implication

Understanding the physical activity patterns of schoolteachers helps to take decisions on promoting healthy lifestyle modification in school environment and community. Also, it helps to strengthen the school health promotion program.

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**DETERMINATION OF ESCHERICHIA COLI IN SPINACIA OLERACEA
(SPINACH) BY CULTURE, BIOCHEMICAL TESTS AND CHROMOGENIC
MEDIA**

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ABSTRACT

The consumption of leafy vegetables such as *Spinacia oleracea* (Spinach) has been expanded in recent years due to the healthy life style recommendations. However, spinach is highly susceptible to cause foodborne diseases as it is usually consumed raw or minimally cooked. To prevent foodborne diseases, it is required to limit bacterial contamination during the pre-harvesting and post-harvesting time periods. This study is mainly focused on detecting the presence of *Escherichia coli* in spinach samples because *E. coli* is the most common bacteria involved for causing wide range of infections. For this study, twenty-one fresh spinach samples were collected from local markets and supermarkets located at Maharagama, Boralesgamuwa, Dehiwala and Nugegoda areas of Sri Lanka. The samples were analysed by culturing on selective McConkey agar and biochemical tests, then cultured on chromogenic media for further confirmation of *E. coli*. As found from this study, 15.91% of *E. coli* were present in the purchased samples of all four regions. The highest *E. coli* percentage was identified from Dehiwala (31%) and *E. coli* were not present in the samples purchased from Nugegoda. Moreover, *Citrobacter* spp. (22.73%), *Klebsiella* spp. (22.73%), *Erwinia* spp. (20.45%), *Enterobacter* spp. (15.91%) and *Serratia* spp. (2.27%) were detected from the samples of all four regions. Although, samples were purchased from local

markets and supermarkets under different storage conditions, significant difference was not observed in bacterial distribution. The hygiene and environmental conditions and handling practices had a direct impact for contaminating spinach with bacteria.

Key words: Spinach, *Escherichia coli*, Culture

INTRODUCTION

The foodborne diseases manifest infectious or toxic nature in the body due to the entering of harmful agents through the ingestion of food or water (Gunasekara, Baumann and Muralitha, 2017). Food borne diseases caused due to the consumption of contaminated vegetables are frequently occur in developing nations like Sri Lanka. However, outbreaks are usually get undetected due to the absence of food borne disease examinations and standard diagnostic measures in Sri Lanka (De Silva, Abayasekara and Dissanayake, 2013). The amount of food borne outbreaks related to vegetables have been expanded in recent years due to healthy life style recommendations. It also influenced by changes in vegetables cultivation and processing practices. Considerable numbers of foodborne disease outbreaks have been aroused due to the consumption of minimally processed fresh leafy vegetables such as

spinach (Smith, Fratamiko and Gunther, 2014).

Spinacia oleracea (spinach) is generally considered as a useful leafy green vegetable due to its different nutritional components, which comprises vitamins, minerals, phytochemicals and bio-actives that provide health benefits beyond the basic nourishment (Roberts and Moreau, 2016). However, spinach is vulnerable to get contaminated with foodborne pathogens due to animal faeces contaminated fertilizer and water suppliers utilized to irrigate crops (Yanamala et al., 2011). Usually spinach is consumed raw or minimally cooked and contain less hindrance against microbial growth as not much amount of salt or food preservatives are added while preparing, thus contaminated spinach is highly susceptible to cause foodborne illnesses (Mritunjay and Kumar, 2015). Considering these reasons, this study will be performed by using *Spinacia oleracea* as the sample to detect certain food borne pathogens including *Escherichia coli*, which is a type of bacteria provide signs of faecal contamination in water and food samples (Hoang, Quy and Chi, 2018).

The *Escherichia coli* was first isolated by the German scientist Theodor Escherich in 1885. It is gram-negative, rod-shaped and lactose fermenting bacterium (Mondal, 2013). *E. coli* is a facultative anaerobic bacterium, but it unable to survive at extreme temperatures and pH levels. These microorganisms benefit its mammalian host by producing vitamin K and vitamin B12 (Blount, 2015). *E. coli* is a major inhabitant of the gastrointestinal tract of humans and animals. Most *E. coli* strains are harmless but few strains are pathogenic and they are causing bacterial infections, including cholecystitis, bacteremia, cholangitis, urinary tract infection, severe diarrhoea, hemorrhagic colitis and hemolytic-uremic syndrome in human beings. Furthermore, *E. coli* is associated with

enterobacteriaceae family and has a close correlation with pathogenic bacteria such as *Klebsiella*, *Enterobacter*, *Serratia* and *Citrobacter* which also referred as coliform bacteria due to shared properties (Guentzel, 1996).

According to the reports, developed countries reflect less mortality rates compared to developing countries (Croxen et al., 2013). The main reason for this could be better food processing practices carried out in developed countries, for example; in most of the developed countries classify spinach cultivars in to three groups as savoy, semi-savoy and flat or smooth leaved based on the varieties in the leaf blade. After that, savoy and semi savoy cultivars are subjected for processing while smooth leaved cultivars are directed to the market due to the simplicity of cleaning, but such categorization or processing is not properly carried out in developing countries such as Sri Lanka (Carder et al., 2010). Despite of maintaining well systematized processing methods, in 2006 and 2010 two major foodborne disease outbreaks were occurred in US due to the consumption of pathogenic *E. coli* contaminated spinach, causing number of hospitalizations and deaths. Hence, there is a higher risk for arising food borne diseases due to the consumption of leafy vegetables in developing countries including Sri Lanka as the processing practices are not efficient to prevent foodborne outbreaks (Grant et al., 2008; Leonard et al., 2015).

This study determines lactose fermenting bacteria by culturing on MacConkey selective media and then suspicious colonies are subjected to series of biochemical tests according to the Bergey's manual to identify *E. coli* and other lactose fermenting bacteria. Finally, the suspected *E. coli* colonies will be cultured on chromogenic media to confirm the presence of *Escherichia coli*.

METHODOLOGY

Sample Collection

Twenty-one *Spinacia oleracea* samples were collected to sterile zip lock bags from different local markets and supermarkets around Colombo (Maharagama, Boralesgamuwa, Nugegoda, Dehiwala), Sri Lanka. The properly sealed *Spinacia oleracea* samples were transported to the laboratory within 24 hours and did the sample preparation in the same day.

All steps were carried out under sterile environment using sterile equipment.

Sample Preparation

A 11.2g of spinach was measured and finely chopped aseptically. Then extract was filtered through muslin cloth and added 100ml of peptone broth, thereby 50ml was added to a labelled falcon tube and incubated at 37°C for 16-18 hours. The same procedure was followed to extract all the samples.

MacConkey Agar Plates Preparation and Streaking

A 500ml of MacConkey agar medium was prepared and autoclaved. The medium was poured in to labelled petri dishes while gently stirring and allowed to solidify. Prior to the streaking, inoculation loop was kept in the flame until red hot. After cooling down, a loop full of extracted sample was taken and quadrant streaking was done on the agar plate. Agar plates were streaked with different extracted spinach samples and incubated at 37°C for 18 hours. After observing bacterial growth, the plates were stored at 4°C.

Subculture in Nutrient Broth

A 5ml of autoclaved nutrient broth was added to twenty-six labelled falcon tubes (15ml). Then one or two dark pink colonies with different morphologies were selected from each petri dish and sub cultured in nutrient broth under sterile conditions and incubated at 37°C for 24 hours.

Biochemical Tests for Lactose Fermenting Bacteria

According to the Bergey's manual isolated pure, lactose fermenting bacterial samples were subjected for following biochemical tests to identify *E. coli* and other bacteria types.

Kovac's Indole Test

A 5ml of autoclaved peptone broth was added to each of twenty-six test tubes. The grown colonies in the nutrient broth were obtained aseptically and respectively introduced into the each labelled test tubes. The samples were incubated at 37°C for 24 hours. As the final step, 1-2ml of Kovac's indole reagent was added to each sample and the results were noted.

Simmon's Citrate Test

A 5ml of autoclaved citrate agar was added to each of twenty-one test tubes and slanted on a support media until get solidified. The inoculation loop was kept in the flame until red hot and allowed to cool. Afterwards, the bottom of the slants was streaked with bacterial samples and incubated at 37°C for 24 hours. The results were observed after the incubation.

Methyl Red and Voges Proskauer (MR-VP) Test

A 5ml of autoclaved MRVP broth was added to each of five test tubes. After that, grown colonies in the nutrient broth were aseptically obtained and respectively introduced into the each labelled test tubes. The samples were incubated at 37°C for 24 hours. Afterwards, 1ml of the broth was removed to separate test tubes for VP testing. Remaining 4ml of the broth were re incubated for an extra two days for the methyl red test. Then, nine drops of 5% α -neophthol reagent was added to 1ml of broth and gently mixed. Afterwards, three drops of 40% potassium hydroxide was added to 1ml of broth and shaken the tube gently for 30 seconds and results were observed.

After 48 hours of incubation, two drops of methyl red were added to 4ml of broth

and shaken gently. The results were interpreted immediately.

Lysine Decarboxylase Test

A 5ml of autoclaved lysine decarboxylase broth was added to a labelled test tube. The bacteria were aseptically obtained from the nutrient broth and introduced to the test tube. Then a thin layer of mineral oil was poured on to the lysine decarboxylase broth and incubated at 37°C for 48 hours. The colour change was observed every 24 hours.

Chromogenic Media Preparation and Streaking

Autoclaved highrome medium was poured aseptically to sterilized petri dishes and left to solidify. The plates were divided to two regions and labelled the sample code and the date. Afterwards, aseptically bacteria were obtained from two citrate negative bacteria samples and streaked on each region according to zigzag pattern. Then, all the plates were incubated at 37°C for 24hours and results were interpreted after the incubation.

RESULTS

Colony Morphology Exhibited on MacConkey Agar



Lactose fermenting bacterial colonies

Figure 1. Colonies formed on MacConkey agar.

Lactose fermenting bacterial colonies appear pink in colour. Different shades of pink colonies with different textures were observed on all the petri plates. When selecting colonies for biochemical tests, priority was given for dark pink coloured, dome shaped colonies as E. coli strains grown on the MacConkey agar usually show bright pink colonies with dome

shaped appearance (Barcella, Barbaro and Rogolino, 2016).

Biochemical Tests

Kovac's Indole Test

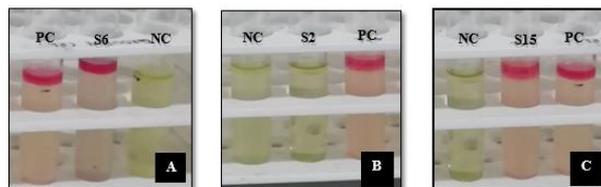


Figure 2. Positive control (PC), negative control (NC) and three samples (A2-S6, B2-S2, C2-15) results of indole test.

The positive control formed a pink colour layer on top of the peptone broth and negative control formed a yellow colour layer on top of the peptone broth upon the addition of Kovac's indole reagent. Therefore, S6 and S15 were positive, S2 was negative.

Simmon's Citrate Test

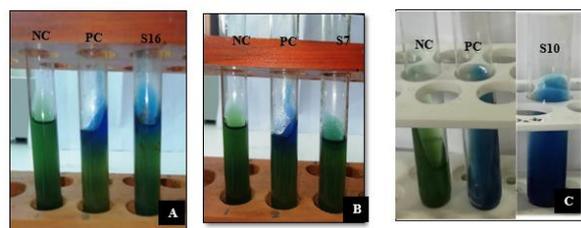


Figure 3. Positive control (PC), negative control (NC) and three samples (A3-S16, B3-S7, C3-S10) results of citrate test.

The slant of the positive control turned to blue colour and the slant remained green colour in the negative control. Therefore, S10 and S16 were positive, S7 was negative.

Voges Proskauer Test

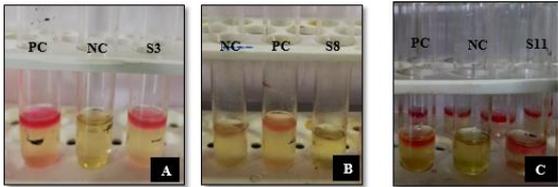


Figure 4. Positive control (PC), negative control (NC) and three samples (A3-S3, B3-S8, C3-S11) results of voges proskauer test.

The positive control formed a pinkish red colour band at the interface and the negative control formed a yellow colour band at the interface. Therefore, S3 and S11 were positive, S8 was negative.

Methyl Red

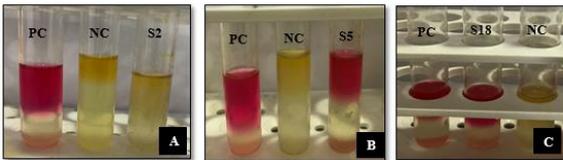


Figure 5. Positive control (PC), negative control (NC) and four samples (A2-S2, B2-S5, C2-18) results of methyl red test .

The positive control formed a bright red colour band at the interface and the negative control formed a yellow colour band at the interface. Therefore, S5 and S18 were positive and S2 was negative.

Lysine Decarboxylase Test

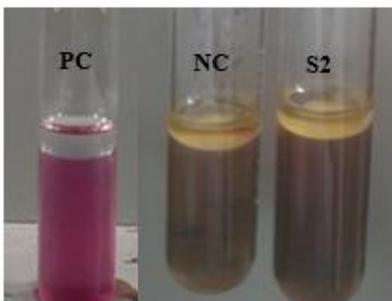


Figure 6. Positive control (PC), negative control (NC) and S2 sample results of lysine decarboxylase test.

The positive control turned to purple color and the negative control turned to brown color upon the incubation. Therefore, S2 was negative.

Chromogenic Media

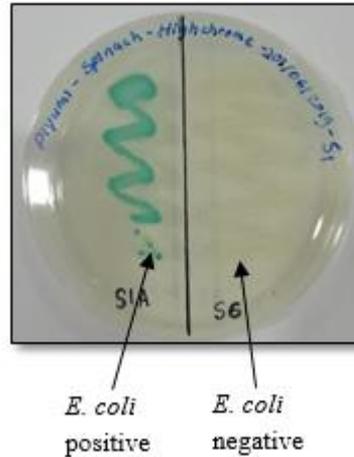


Figure 7. 'A' shows an E. coli positive result on chromogenic media eliciting the presence of green colonies. 'B' shows an E. coli negative result on chromogenic media eliciting the absence of green colonies



Figure 8. The results of few samples which yielded positive results on the chromogenic agar confirming the presence of E. coli in samples S13, S15, S19 and S21.

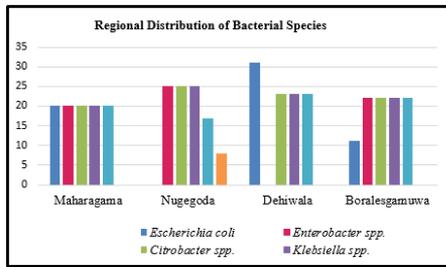


Figure 9. Regional distribution of bacterial contamination in *Spinacia oleracea*.

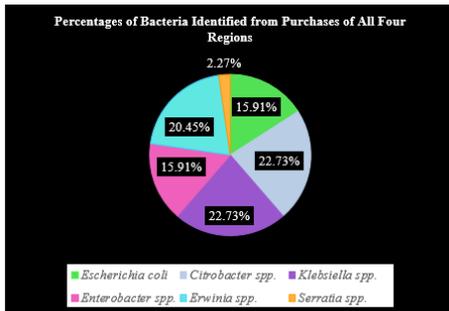


Figure 10. Percentages of bacteria identified from purchases of all four regions.

DISCUSSION

All the spinach samples were collected from the southern part of Colombo metropolitan which is an urbanized environment, but samples were at different storage conditions when purchasing from local markets and supermarkets. Supermarkets are indoors, normally air conditioned to maintain a particular temperature and vegetables are arranged properly in the shelves. Local markets are typical open air markets where food is sold at ambient temperature without covering. As suggested by Sudershan et al., (2012), highly crowded and urbanized areas in developing countries are more prone to bacterial contaminations due to the polluted water and poor hygienic conditions, this was further proven from this study as the bacteria distributions were considerably higher in all four study regions. Moreover, spinach leaves were used for this study because literature suggest that spinach phylloplane (leaf

surface) is more prone to retain microorganisms (Mitra, 2009).

According to this study, different bacteria types were detected from all 21 samples, hence this study emphasises that although the consumption of green leafy vegetables such as spinach is important for healthy life, it could contaminate with different varieties of food-borne pathogens including *E. coli*. As revealed from the study, highest *Escherichia coli* distribution (31%) was identified from the samples purchased from Dehiwala and *Escherichia coli* were not detected from the samples purchased from Nugegoda. Moreover, *Escherichia coli* (15.91%), *Citrobacter spp.* (22.73%), *Klebsiella spp.* (22.73%), *Erwinia spp.* (20.45%), *Enterobacter spp.* (15.91%) and *Serratia spp.* (2.27%) were detected from the purchases of all four regions.

The green leafy vegetables can get contaminated with microorganisms either in pre-harvesting period or post-harvesting period. Pathogenic microorganisms establish on growing crops in the pre-harvesting period, then hazard can be enhanced during the post-harvesting period due to further direct contamination. In the pre-harvesting stage, leafy vegetables can be contaminated due to irrigation water, human handling, contaminated containers and animal waste fertilizers. In the post-harvesting stage, leafy vegetables can be contaminated due to improper storage, post-harvest washing, improper packaging and contaminations from other foods in food preparation area (Mritunjay and Kumar, 2015). Outbreaks were reported in 2002 and 2006 from Salinas and Salleys San Juan valleys of California, United States due to the consumption of *E. coli* 0157 contaminated spinach, through the investigations it was recognised that outbreaks were mainly implicated due to sewage released from the farms in those areas (Cooley et al., 2017).

In Sri Lanka, usually untreated irrigation water and sewage fertilizer are used for cultivations and it could be a main reason for contaminating leafy vegetables with bacteria at the pre-harvesting stage (De Silva, Abayasekara and Dissanayake, 2013). Some studies have discovered that pathogenic *E. coli* contaminated water dropped on the spinach leaves directly contribute to uptake and internalization of pathogen and it also reveals that pathogen is unable to internalize to the spinach plant through contaminated soil (Mitra et al., 2009). It means, post harvesting washing also plays a major role in both contamination and pathogenesis of food-borne bacteria. Rathnasiri and Manage, (2015), demonstrated a study to evaluate water quality in South Colombo region and revealed that almost all the wells in this particular area are contaminated with faecal coliform bacteria. As the vendors usually use well water for cleaning and sprinkling vegetables, there is a high possibility to contaminate vegetables with coliforms.

When purchasing spinach especially from local markets, they were under wet condition and the water sprinkled on to the spinach could be contaminated. Also, spinach leaves were bundled and kept along with other vegetables which enhances susceptibility to contaminate from other vegetables. Although, samples were purchased from local and supermarkets under different storage conditions, significant difference was not observed in bacterial distribution through this study. However, Ananchiapattana et al., (2012), has carried out a Thailand based study and recovered 44% and 15% of *E. coli* respectively from the leafy vegetable samples collected from local markets and supermarkets representing considerable difference in percentages. Therefore, it can be suggested that bacteria presentation would be drastically changed by place to place with their hygienic and environmental conditions. Normally,

majority of the leafy vegetables supplied to the local and supermarkets in South Colombo area through Dambulla and Pettah whole sale market at where have poor sanitary conditions. Therefore, there is a high chance to contaminate spinach even at the post-harvesting stage. (Perera, Kodithuwakku and Weerahewa, 2004).

Escherichia coli, *Enterobacter* spp, *Citrobacter* spp, *Klebsiella* spp and *Erwinia* spp. were detected from the samples purchased from Maharagama, Boralesgamuwa, Nugegoda and Dehiwala. The *Serratia* spp. was found only from the samples purchased from Nugegoda. According to studies, *Serratia* spp. are rarely isolated from the environmental sources such as vegetables. The *Serratia* spp. are sporadically perceived as a reason for medical clinics acquired infections (Khanna, Khanna and Aggarwal, 2013). Bacterial soft rot of spinach could observe from certain leaves of the samples. *Erwinia* spp. is the one of the main bacteria type involved for causing soft rot of vegetables during harvesting or storing at ambient temperature (Rawat, 2015).

From the samples collected from Dehiwala, 31% of *Escherichia coli*, 23% of *Citrobacter* spp., 23% of *Klebsiella* spp. and 23% of *Erwinia* spp. were identified (Figure 10). *E. coli* distribution was higher in Dehiwala compared to other regions. The Dehiwala markets were close to drainage lines with polluted water and there were lot of flies around the vegetable cages. Insects are also a possible cause of bacterial contamination. Some studies have shown that contaminated flies are able to directly transfer bacteria to vegetables or green leaves (Fels-Klerx, 2018). *Escherichia coli* is a type of bacteria which provide signs of faecal contamination in water and leafy vegetables, it means spinach samples were directly or indirectly exposed to faeces. Poor hygiene of vendors also could

contribute for the contamination of spinach (Hoang, Quy and Chi, 2018).

This study suggests that spinach should be properly cleaned with clean water and disinfectants and appropriately cooked before consumption to avoid food-borne diseases. Usually, people use salt solutions, vinegar, and turmeric water as disinfectants to clean green leafy vegetables while cooking, but according to previous studies, these common disinfectants have low efficacy to eliminate faecal coliforms (Subramanya, 2018). However, Amoah et al., (2007) has found that 0.001% Potassium permanganate solution is an effective disinfectant to reduce bacterial load in ready to eat green leafy vegetables.

CONCLUSION

According to the results obtained from biochemical tests and chromogenic media, fresh ready-to-eat spinach were highly contaminated with *Escherichia coli* (15.91%), *Klebsiella spp* (22.73%), *Citrobacter spp* (22.73%), *Erwinia spp* (20.45%) and *Enterobacteria spp* (15.91%). Therefore, it can be concluded that spinach should be properly cleaned before consumption with strong disinfectants such as very diluted 0.001% Potassium permanganate to reduce the risk of bacterial infections. The main objectives of this study were accomplished successfully, but further tests can be carried out to identify the presence of other bacterial species in spinach including non-lactose fermenting bacteria such as *Salmonella spp*.

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DEVELOPMENT AND VALIDATION OF A RAPID TEST METHOD FOR DETECTION OF PORK MEAT WITH PROCESSED MEAT PRODUCTS

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ABSTRACT

Meat is one of the major dietary components to human and it mainly provides nutrients such as proteins, amino acids, unsaturated lipids, microelements, vitamins and minerals. Pork adulteration in beef is mainly found in Japan, Korea and china and so on because beef meat is expensive and pork is cheap. This fictitious case not only harms for the allergic consumers but also religious behaviors (Muslims and Jews). Therefore detection of pork adulteration in processed meat products is important. In this project, DNA based PCR method was used because DNA structure is more stable and highly rationed allowing identification and discrimination of species not only in raw meat but also in processed meat samples. Repeatability was performed ten times for the same Lingus sample for detects the proximity of the agreement between the results of successive measurements and it was 100% accurate. Secondly, Recovery was performed for the concentrations of 0%, 0.1%, 0.5%, 1%, 5% and 10% for pork sausage and beef sausage mixtures and PCR was followed using bovine and porcine species specific oligonucleotide primers. DNA was extracted using DNeasy Mericon Food Kit, Qiagen (Germany) and limit of detection 5% pork concentration. PCR products of extracted DNA were subjected to the simplex and duplex polymerase chain reaction (PCR) using porcine species specific

oligonucleotide primers and bovine species specific oligonucleotide primers respectively. Finally, detect the pork adulteration in processed meat products available in local market targeting the 289bp porcine and 251bp bovine mitochondrial DNA.

Keywords: bovine, porcine, simplex PCR, duplex PCR, adulteration, repeatability, recovery.

INTRODUCTION

Nowadays, food adulteration is major problem in the world and which began in 13th century A.D. at Florence in Italy with wine was adulterated by sugar to get sweet taste (Bhat et al., 2016). Adulteration of food can define as adding extraneous substances to food products and it reduces the essential nutrients from food (Aysa and Belete, 2015). This adulteration process occurs for various types of reasons for example, financial gain, enhancing taste, carelessness and lack in proper hygienic condition of processing, storing, transportation and selling (Sharma et al., 2017). For example, pork adulteration in beef is mainly found in Japan, Korea and China and so on because beef meat is very expensive and pork is very cheap in those countries (Ha et al., 2017) and also Pork is often added to other processed meat products because pork has a color and texture similar to beef and lamb. Different

type of food adulteration percentages can be varied according to the demand of consumers and profits of manufacturers and adulteration of meat has been increased.

In Sri Lanka, farm pork is adulterated by adding wild boar which is which is restricted by the Fauna and Flora Ordinance in Sri Lanka. (Samaraweere et al., 2011). Identifying the pork adulteration of processed meat products is one of the most important food- quality issue because of it will be allergenic and increased the level of risk of colon cancer for some consumers and as well as some group of people does not consume pork because of religious food ethics and preference (Ha et al., 2017). For example, many Hindus do not eat beef, Islam and Jews prohibited the pork and the halal authentication is credited to purity of meat by Islam and Kosher by Jews (Yang et al., 2018). The relative investigation of the real example examines in the laboratory and the label unveiled in the package of chicken burgers sold in the state of Kuwait uncovered a dissention of labeling. (Bourguiba-Hachemi and Fathallah, 2016). And also pork adulterations in halal beef burgers were discovered in some European countries (Yang et al., 2018). Those types of counterfeit cases are testified by European criminal police organization (EUPOL) and international criminal police organization (INTERPOL) and they have confirmed in monitoring food security, resulting in 2500-ton illegal and fictitious food (EUROPOL, 2015).

There are various types of analytical methods that have been utilized to detect pork adulteration in processed meat products. For example, high-performance liquid chromatography, enzyme-linked immunosorbent assays, Fourier transform infrared (FTIR) and electrophoretic techniques are used as protein based methods (Al-Kahtani et al., 2016). But in recent years, most attention has been

turned towards DNA-based analytical methods as it is very reliable, sensitive and rapid. DNA analysis is more applicable than protein analysis because proteins lose their biological activities after animal death and denature the proteins during processed (Calvo, Osta and Zaragoza, 2002). DNA analysis can be detected through polymerase chain reaction (PCR) such as duplex droplet PCR, PCR- RFLP, real time PCR, or species specific PCR (Tanabe et al., 2007). Mitochondrial DNA is a good target for phylogenetic reconstruction at various taxonomic levels. There are 1000 of copies and therefore mitochondrial DNA has high variability compared to nuclear DNA. This allows the differentiation of closely related species. Cytochrome b is a functional gene which located between mitochondria and it used for molecular marker in detection of pork adulteration. This gene contains species specific information and it has been used in an extensive number of studies on phylogenic and dealing with forensic science and food inspection (Hassan and Tauma, 2014).

Main aim of this research is detection and validation of pork adulteration in commercially available processed meat products in local markets. Those processed foods are determined by DNA extraction using DNeasy Mericon food kit, Qiagen. It extracts total nucleic acids from range of food sample types (Sample and Assay Technologies, 2014). An extracted DNA is amplified using conventional PCR method because it is simple, rapid and specific nucleic acid amplification method for the identification of pork species. Duplex PCR is amplifying two different DNA sequences at one PCR reaction (Tang, 2009). Therefore it can distinguish pork which adulterated in other processed meat items. Finally, gel electrophoresis is used to visualize the amplified PCR product for the detection of pork adulteration.

Method validation is used for take clear and high sensitive results of meat samples and confirm the reliability of a method that is resolve by validation results, limit of detection and sensitivity are reported for recognize the least amount of DNA that the primers will be sensitive for (Ozkan, 2018). In this project, repeatability is performed for the Lingus sample which contains both pork and beef meat to validate the method. Recovery for pork DNA will be evaluated at a concentration of 0%, 0.1%, 0.5%, 1%, 5% and 10% for pork beef mixtures using conventional PCR for detection of limit of detection (LOD) of pork.

METHODOLOGY

Collection of samples

Positive meat samples (Pork, beef) and processed meat samples were purchased from the Arpico super center, Hide Park. Those products stored under frozen condition -18 ± 1 OC to prevent from enzymatic degradation of DNA in meat samples.

DNA Extraction

Repeatability

Genomic DNA was extracted from 200mg of Lingus using DNeasy Mericon food kit, Qiagen (German) (Ref No: 69514) and some steps were optimized to get high yield of DNA. Firstly, Lingus sample was homogenized using sterile mortar and pestle. Then 200mg of homogenized meat samples were transferred in to 10 numbers of 2ml micro centrifuge tubes and added 1ml food lysis buffer and 5 μ l Proteinase K solution. That sample was vortexed for 30s. After that samples were incubated in the shaking incubator GFL for 30 minutes at 60oC with constant shaking with 180rpm and after the incubation kept on ice for 5 minutes. After incubation, the sample was centrifuged for 5 minutes at 7500 x g. 500

μ l of chloroform was pipetted to another fresh 2 ml eppendorf tubes. Next 700 μ l of supernatant was pipetted out and added to the tube which containing chloroform. Again the samples were vortexed for 15s and centrifuged at 14,000 x g for 15 minutes. 1ml of PB buffer was added into a fresh 2ml micro centrifuge tubes (10X) and 250 μ l of upper aqueous phase was added to the tubes containing buffer PB and vortexed thoroughly. Then 600 μ l of the mixture was added into QIAquick spin columns and placed in a 2ml collection tube. And sample was centrifuged at 17,900 x g for 1 minute and discarded flow-through. Again the same step was repeated and discarded the flow through. Then 500 μ l AW2 buffer was added to the QIAquick spin column and centrifuged at 17,900 x g for 1 minute and discarded the flow through. Again sample was centrifuged at same conditions to dry the membrane. Finally spin column was transferred to a 1.5ml eppendorf tube and pipetted 100 μ l of EB buffer and incubated for 1 minute at room temperature and the samples were centrifuged at 17,900 x g for 1 minute to elute.

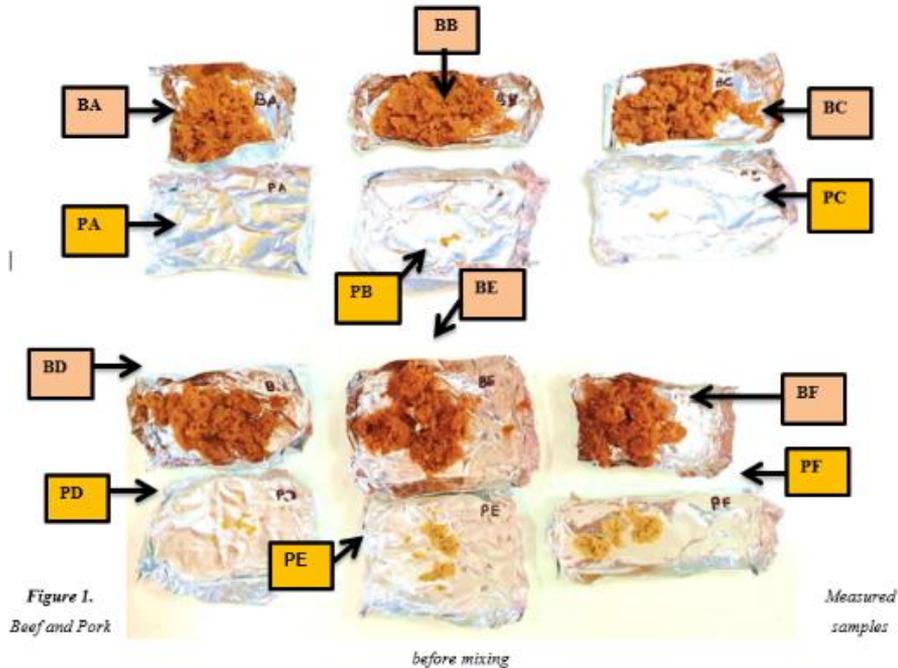
Recovery

Beef and Pork Sausages were Homogenized separately using mortar and pestle and measured precisely using an analytical balance to get the following beef pork concentrations (Table 1).

Table 1. *Pork beef concentrations*

	Pork	Beef
A	0g (0%)	10g (100%)
B	0.01g (0.1%)	9.99g (99.9%)
C	0.05g (0.5%)	9.95g (99.5%)
D	0.1g (1%)	9.9g (99%)
E	0.5g (5%)	9.5g (95%)
F	1g (10%)	9g (90%)

After the measuring of pork sausage and beef sausage samples, mixed to get 0%, 0.1%, 0.5%, 1%, 5%, and 10% pork, beef sausage mixtures and homogenized into a fine paste using separate mortar and pestle (figure 1).



BA + PA – 100% of beef sausage sample + 0% Pork sausage sample, BB + PB – 99.9% beef sausage sample + 0.1% pork sausage sample, BC + PC – 99.5% beef sausage sample + 0.5% pork sausage sample, BD + PD – 99% beef sausage sample + 1% pork sausage sample, BE + PE – 95% beef sausage sample + 5% pork sausage sample, BF + PF – 90% beef sausage sample + 10% pork sausage sample.

Those measured samples were extracted according to the 200mg small fragment protocol of DNeasy mericon food kit with some modification, same for the repeatability (Table 2).

Table 2. DNA extraction protocol for recovery (*DNeasy Mericon Food Handbook, 2014*) (Adapted).

Steps	Original Protocol	Optimized steps
Homogenized using sterile mortar and pestle	-	0.5µl of food lysis buffer
Homogenized sample taken into 2ml micro centrifuge tube	200mg	200mg
Volume of food lysis buffer and proteinase K added	1ml of food lysis buffer and 2.5µl of proteinase K	5µl of proteinase K
vortex	-	30 seconds
Incubation	For 30 min at 60°C with shaking incubator at 1000rpm	For 30 min at 60°C with GFL incubator at 180rpm
Cool the samples to room temperature (25°C)	-	5 minutes
Centrifugation	For 5 min at 25,000xg	For 5min at 7500xg
Volume of chloroform added into fresh 2ml micro centrifuge tube	500 µl of chloroform	500 µl of chloroform
Volume of supernatant transferred into 2ml micro centrifuge tube	700 µl supernatant	700 µl supernatant
vortex	15 seconds	15 seconds
Centrifugation	For 15 minutes at 14000xg	For 15 minutes at 14000xg
Volume of PB buffer added into the fresh micro centrifuge tube	1ml of PB buffer	1ml of PB buffer
Volume of upper aqueous phase transferred into the 2ml micro centrifuge tube	250 µl of aqueous phase	250 µl of aqueous phase
Volume of solution added into QIAquick spin column	600 µl of solution	600 µl of solution
Centrifugation	For 1 minute at 17,900xg	For 1 minute at 17,900xg
Discard flow-through	-	-
Repeat above 3 steps for remaining 600 µl of samples	-	-

Volume of AW ₂ added into QIAquick spin column	500 µl of AW ₂	500 µl of AW ₂
Centrifugation	For 1 minute at 17,900xg	For 1 minute at 17,900xg
Discard flow-through	-	-
Centrifugation	For 1 minute at 17,900xg	For 1 minute at 17,900xg
Volume of buffer EB added to QIAquick spin column	100 µl	100 µl
Incubate	1 minute at room temperature	1 minute at room temperature
Centrifugation	1 minute at 17,900xg	1 minute at 17,900xg

DNA extraction from processed meat samples

Each processed meat samples were homogenized into a fine paste using separate mortar and pestle and DNA was extracted from 200mg small fragment protocol by DNeasy Mericon food kit, Qiagen but some steps were changed to get more DNA yield same as the recovery (Table 2).

DNA Confirmation using spot test

Spot test is performed to confirm the presence of DNA. 0.1mg of agarose powder was measured and dissolved in 10ml of TAE buffer (25X) in a conical flask. After dissolving the agarose completely 1µl of ethidium bromide (0.5µg/ml) was added to the solution. That solution was poured to petri dish and kept to set. 1% of agarose gel piece was cut and placed on the tray. Then 1 µl extracted DNA samples were placed on the gel. DNA confirmation was visualized from Image Lab Software with the gel documentation system.

PCR Assay

The extracted DNA was subjected to PCR amplification using duplex PCR technique for adulteration detection.

Repeatability

The PCR amplification was performed in a final reaction volume of 15µl 4.4µl of

PCR water, 7.5 µl of Ceygen master mixture (2X), 0.4 µl of each primers (10µM), 0.5 µl of Taq (1U/µl) solution and 1 µl of DNA samples of Lingus were added respectively to the 10 PCR tube (Table 3).

Table 3. *The components of the PCR master mixture in repeatability*

PCR Mixture	Reaction volume (1x)
Ceygen master mixture(2X)	7.5µl
Pork F ₂ (10 µM)	0.4 µl
Pork R ₂ (10 µM)	0.4 µl
Bovine F (10 µM)	0.4 µl
Bovine R (10 µM)	0.4 µl
Taq (1U/µl)	0.5 µl
DNA sample	1.0 µl
PCR water	4.4 µl
Total Volume	15 µl

Recovery

Simplex PCR

The extracted DNA pork sausage sample was subjected to simplex PCR. In this step, porcine species specific forward and reverse oligonucleotide primers were used (Table 4).

PCR Mixture	Reaction volume (1x)
Ceygen master mixture (2x)	7.5µl
Pork F ₂ (10 µM)	0.7 µl
Pork R ₂ (10 µM)	0.7 µl
Taq (1U/µl)	0.5 µl
DNA sample	1.0 µl
PCR water	4.6 µl
Total Volume	15 µl

Duplex PCR

The extracted DNA (beef sausage & pork sausage) was subjected to duplex PCR. In this step, porcine and bovine both species specific forward and reverse oligonucleotide primers were used as in table 3.

Detection of pork adulteration in processed meat samples

Table 5. *The components of the duplex PCR of detection in processed meat samples*

PCR Mixture	Reaction volume (1x)
5xFIREPOL® Master Mixture	4.0µl
Pork F ₂ (10 µM)	0.6 µl
Pork R ₂ (10 µM)	0.6 µl
Bovine F ₂ (10 µM)	0.6 µl
Bovine R ₂ (10 µM)	0.6 µl
DNA sample	1.0 µl
PCR water	7.6 µl
Total Volume	15 µl

The amplification conditions for PCR for cyt b gene were given (Table 6).

Table 6. *The amplification conditions for bovine and porcine specific duplex and simplex PCR*

PCR Condition	Temperature	Time
Initial denaturation	94°C	5 min
Denaturation	94°C	30 sec
Annealing	59°C	30 sec
Extension	72°C	60 sec
Final extension	72°C	5 min

35 cycles

Agarose Gel Electrophoresis

Gel electrophoresis used to separate DNA and proteins according to their size and charge.

The PCR products of repeatability, recovery and the detection of pork in processed meat sample were analyzed using 1.5% agarose gel electrophoresis techniques and visualized under UV light using the Bio Rad molecular imager gel documentary system to validate the method and detect the pork adulteration respectively.

To prepare 1.5% agarose gel, 1.5g of agarose powder was measured and 100ml of TAE buffer was added to the conical flask. To the melted agarose solution 2.0µl of ethidium bromide (0.5µg/ml) was added. Next the comb was placed on the gel cassette. Prepared solution was poured to the casting tray and left it solidifies and after few minutes comb was removed from gel without damaging wells. All the samples were mixed with the 1 µl gel loading dye (6X) and loaded into the wells according to the below table. (Table 9)

Table 9, Taken Samples and volumes of gel electrophoresis

Well number	Samples	Volumes
1	100bp ladder	4.0 μ l
2	Positive sample	2.5 μ l
3	PCR Products of the lingus sample	3 μ l
4		3 μ l
5		3 μ l
6		3 μ l
7		3 μ l
8		3 μ l
9		3 μ l
10		3 μ l
11		3 μ l
12	Negative sample	3 μ l

Results

DNA quantification using spot gel test.

Spot gel of DNA extracted from the beef and pork mixture in repeatability (figure 2).

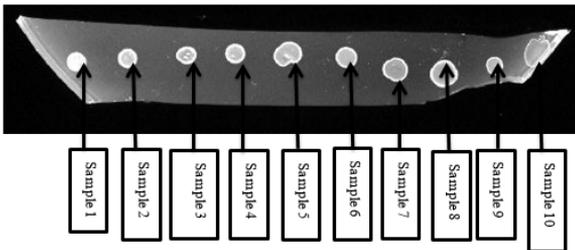


Figure 2. Spot gel of DNA extracted from Lingus for repeatability.

Spot gel of DNA extracted from the beef and pork mixture in recovery

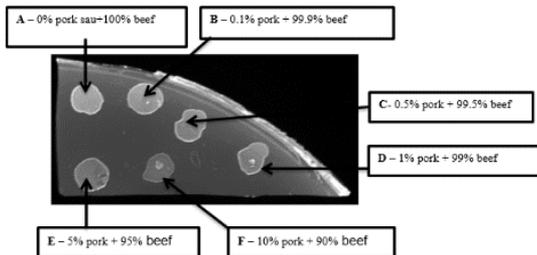


Figure 3: Spot gel of recovery

Spot gels of DNA extracted from processed meat products

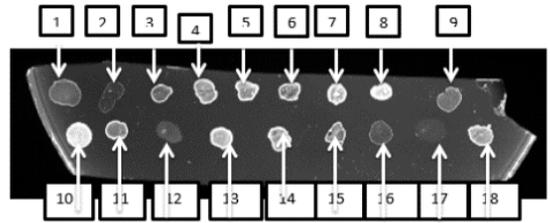


Figure 4. Spot gel image of extracted DNA from processed meat product.

1 - Lingus, 2 – Lingus outer cover 1, 3 – Lingus outer cover 2, 4 – pork sausage 1, 5 – pork sausage 1 outer cover, 6 – beef sausage, 7 – Chicken sausage 1, 8 – chicken ham 1, 9 – chicken sausage 2, 10 – chicken sausage 3, 11 – chicken meat bal 1, 12 – corned mutton, 13 – chicken ham 2, 14 – chicken meat ball 2, 15 – pork sausage 2, 16 – pork sausage 2 outer cover, 17 – chicken spread, 18 – fish sausage.

Agarose gel electrophoresis results of duplex PCR in repeatability

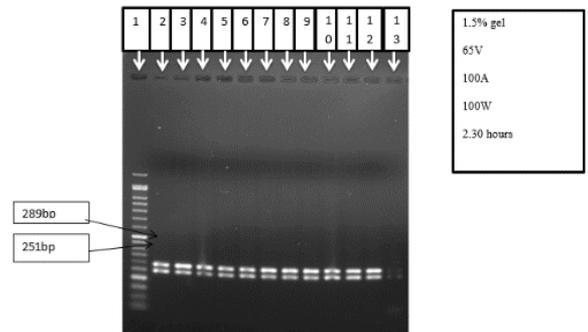


Figure 5. Agarose gel image of PCR samples from beef pork mixtures in repeatability

Lane 1- 100bp ladder, Lane 2 – beef and pork positive, Lane 3,4,5,6,7,8,9,10,11,12 – Lingus samples, Lane 13 – Negative sample (PCR water)

Agarose gel electrophoresis results of simplex PCR in recovery

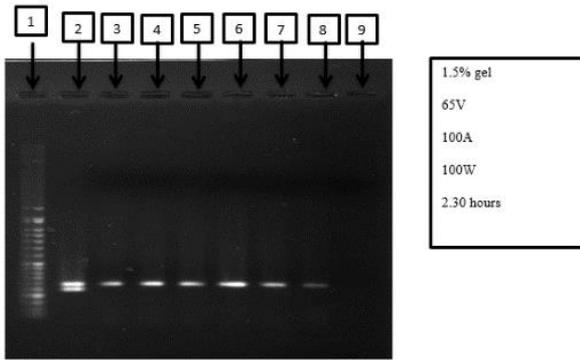


Figure 6. Agarose gel image of extracted DNA from beef pork mixtures in recovery

Lane 1- 100bp ladder, Lane 2- positive sample (pork + beef), Lane 3- 0.1% pork sausage sample, Lane 4- 0.5% pork sausage sample, Lane 5- 1% pork sausage sample, Lane 6- 5% pork sausage sample, Lane 7- 10% pork sausage sample, Lane 8- 100% beef sausage sample, Lane 9- negative sample (PCR water)

Agarose gel electrophoresis results of duplex PCR of recovery

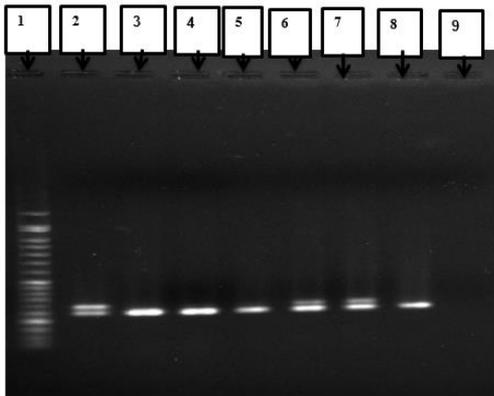


Figure 7. Agarose gel image of extracted DNA from beef pork mixtures in recovery

Lane 1- 100bp ladder, Lane 2- positive sample (pork + beef), Lane 3- 0.1% pork sausage sample, Lane 4- 0.5% pork sausage sample, Lane 5- 1% pork sausage sample, Lane 6- 5% pork sausage sample, Lane 7- 10% pork sausage sample, Lane 8- 100% beef sausage sample, Lane 9- negative sample (PCR water)

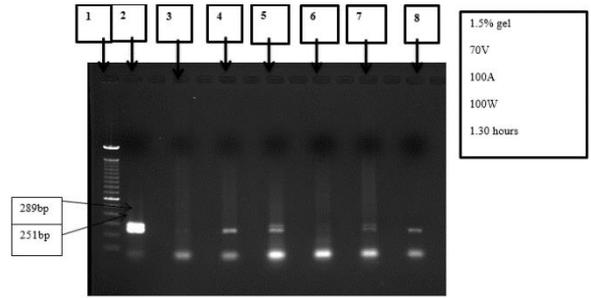


Figure 8. Agarose gel image of DNA extracted from processed meat products

Lane 1- 100bp ladder, Lane 2- positive sample (Pork + beef), Lane 3- Chicken sausage 1, Lane 4- chicken ham 1, Lane 5- Chicken ham 2, Lane 6- chicken sausage 2, Lane 7- Chicken meat ball, Lane 8- Negative sample (PCR water)

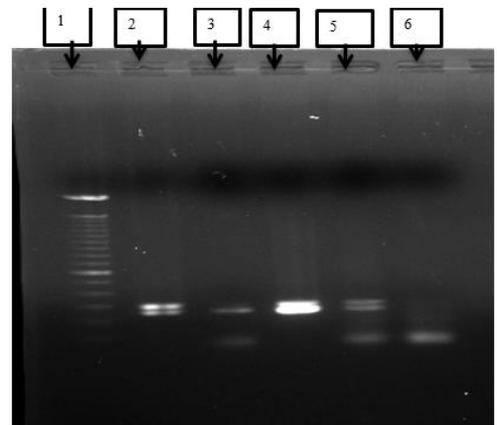


Figure 9. Agarose gel image of DNA extracted from processed meat products

Lane 1- 100bp ladder, Lane 2- Positive sample (Pork +beef), Lane 3- Chicken sausage, Lane 4- Minced mutton, Lane 5- Chicken ham, Lane 6- Negative sample (PCR water)

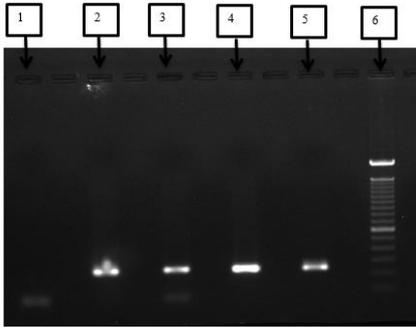


Figure 10. Agarose gel image of DNA extracted from processed meat products

Lane 1- Negative sample (PCR water),
Lane 2- Lingus, Lane 3- fish sausage, Lane
4- beef sausage, Lane 5- positive sample
(pork+beef), Lane 6- 100bp ladder

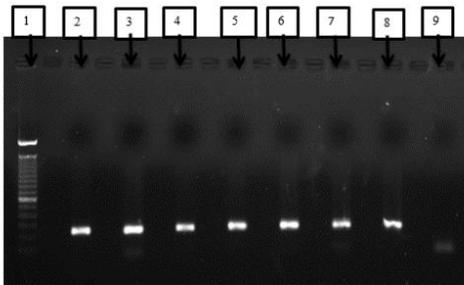


Figure 11. Agarose gel image of DNA extracted from processed meat products

Lane 1-100bp ladder, Lane 2-Positive
sample (pork+beef), Lane 3-lingus, Lane
4-Lingus outer cover1, Lane 5-Lingus
outer cover2, Lane 6-pork sausage, Lane
7-pork sausage outer cover, Lane 8-
Negative sample (PCR water)

DISCUSSION

Food adulteration is a main issue for many years in processed meat products. Pork meat is often mixed with other meat products intentionally, as well as unintentionally. Pork meat is very cheap; therefore it mixed with other meats like beef (Ha et al, 2017). When discussed about unintentional methods that occur in pork adulteration, main one is unclean grinding and cutting machines utilization.

The main aim of the first part of the project (repeatability) is the proximity of the agreement between the results of successive measurements of the same measured carried out under the same condition of measurement (Barry, Taylor and Kuyatt, 2010). The second part of the project is aimed at primer sensitivity consideration of porcine oligonucleotide species specific primers. Recovery is done for recognize the least amount of pork DNA that the primers will be sensitive for (Ozkan, 2018). As a final, detect the pork adulteration in processed meat samples

In repeatability, Lingus were used because it has included both beef and pork meats in the ingredients list. DNA was extracted from the DNeasy Mericon food kit, Qiagen, 200mg small fragment protocol with some modifications. It is used for the processed meat products because it is easy to extract total number of DNA from small scale and processed meat products are highly fragmented because those samples has been subjected to extensive thermal treatments, Irradiation, Drying, high pressure and pH changes. And also this kit is used modified cetyltrimethylammonium bromide (CTAB) extraction (DNeasy Mericon Food Handbook, 2014).

In the extraction, all samples were homogenized using mortar and pestle and during the homogenization, food lysis buffer was added for even homogenization of the sample. After that, food lysis buffer was added to break down the cell membrane and proteinase K was added to digest the proteins. The samples were incubated at 60°C with constant shaking incubator for enhance the cell disruption by food lysis buffer and enhance the activity of proteinase K. After the incubation, samples were cooled on ice to enhance the inhibitor precipitation. Centrifugation takes place to separate the layers and it was done at the room temperature by spinning the sample at

high speed, the components in the mixture are subjected to centrifugal force. In that process, inhibitors are precipitated (pelleted) and extracted DNA remains in the solution called supernatant liquid (Majekodunmi, 2015). Addition of chloroform is supported to separate the phases furthermore, called aqueous phase and organic phase. Aqueous phase contains DNA and small amount of inhibitors and organic phase contains proteins, lipophilic inhibitors and cell debris. As a trouble shooting, chloroform as an organic solvent started to leak from the pipette tip. By calibrating the pipette by pipetting up and down in the solvent repeatedly before transferring was helped to avoid it. Buffer PB (binding buffer) is added to clean up the DNA and bind DNA to the silica membrane in the QIAquick spin column. QIAquick spin column is a silica membrane which binding on the column and optimized reagent amounts. This allows a high yield of short DNA fragment to be extracted from the samples. Buffer AW2 is a wash buffer and it contains 70% ethanol to wash the salts in DNA. Buffer EB (elution buffer) is added to release pure DNA from silica membrane and store DNA for after use (DNeasy Mericon Food Handbook, 2014).

After the extraction of DNA, a spot gel test was performed to visualize the strength of the extracted DNA and it provide comparison between each extracted DNA to get some idea about how much DNA has been extracted (Dar et al., 2016). According to the figure 3 to 5, bright spots can be visualized and which indicates large amount of DNA, proteins and RNA. Dark spots also visualized and those spots contain least amount of DNA, proteins and RNA (Figure 3 -5).

The PCR products of DNA samples were subjected to agarose gel electrophoresis to prevail the results and those products were run on a 1.5% agarose gel because of good and clear separation of the bands. Porcine species specific

oligonucleotide is 289bp and bovine species specific oligonucleotide is 251bp so both species has close base pair length and band separation is very important to take a good results.

Measurements of repeatability refer to the difference in repeat measurements which made on the same subject under same conditions same instrument method, same observer, and the same measurement (Bartlett and Frost, 2008). In repeatability, DNA extraction, PCR, gel electrophoresis was repeated by the same person under the same condition and according to the same procedure for 10 times and results were 100% accurate because both pork and beef bands were line up with correct base pair lane. In primer sensitivity (Recovery), duplex and simplex PCR were used to get clear understanding about samples and duplex PCR product was used as positive sample for gel electrophoresis of simplex PCR for detect the contaminations of primers. However porcine species specific oligonucleotide primer was sensitive to 5% of porcine DNA and 0.1% and 0.5% porcine DNA is not sensitive for adulteration detection.

According to the figure 8, Chicken sausage1, 2 and chicken ham 1 have slight band with beef but not adulterated with pork but chicken ham 2 and chicken meat balls have been adulterated with both pork and beef DNA. In that case PCR water was used as the negative and it also contaminated with the beef primers. According to the figure 9, Chicken sausage, Minced mutton and chicken ham were adulterated with both pork and beef DNA but chicken sausage has very slight band of pork. Negative sample was not contaminated with any DNA or primers and there have been accumulated the primer dimers on the bottom which not utilized. According to the figure 10, Lingus has both pork, beef and pork has slight band of DNA but it was not adulterated because the manufactures have been mentioned on the label that has both

pork and beef meat. Beef sausage was not adulterated with pork and it performed only beef band. However, those adulterated samples were not mentioned in labels. This pork adulteration could be both intentional and unintentional. And slight bands might be performing according to the unintentional adulteration and sharp bands might be performing according to the intentional adulteration. When some gel electrophoresis, Band were taken dumbbell shape due to the high current and voltage. According to the figure 11, there was main issue with pork forward and reverse primers, so pork bands were not observed on the gel. Therefore it can be concluded that pork primers are degraded.

CONCLUSION

DNA of processed meat samples were extracted by DNeasy Mericon Food kit, Qiagen. According to the above results, minimum detection level of pork sausage is 5%. In repeatability, DNA extraction, PCR, gel electrophoresis was repeated for 10 times and results were 100% accurate because both pork and beef bands were line up with correct base pair lane. Pork adulteration in processed meat products were detected in chicken ham, chicken meat balls, chicken sausage and some chicken hams, chicken sausages, chicken meat balls have been adulterated with beef. Beef sausage was not adulterated with pork and it pure beef. Therefore according to validated results, the above mentioned conventional PCR was a cost effective, efficient and reliable method for beef pork adulteration detection in highly processed meat products.

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ANTIBACTERIAL ACTIVITY OF CENTELLA ASIATICA LEAVES ACCORDING TO THEIR MATURATION AND THE SYNERGISTIC ACTIVITY OF CENTELLA ASIATICA ANTIBIOTIC DISCS TOWARDS STAPHYLOCOCCUS AUREUS

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ABSTRACT

Centella asiatica (*C. asiatica*) is a medicinal herb which had been used by many countries around Asia, Africa and Australia. This plant can be used as a green leafy vegetable, medicine or as a cosmetic. This study will focus on the antibacterial activity of *C. asiatica* leaves according to their maturation stage; as pre mature, post mature and mature. *C. asiatica* extract was obtained by ethanol extraction method by mixing 15g of *C. asiatica* leaf powder with 25ml of 95% ethanol. From each extract antibiotic discs were prepared by using No.1 Whatman's filter paper. According to the obtained results, mature *C. asiatica* leaves had the highest antibacterial activity towards *Staphylococcus aureus* (*S. aureus*) with a 12.3mm zone of inhibition in nutrient agar medium. The least antibacterial activity was obtained in the pre mature *C. asiatica* leaves, which had given 7.2mm zone of inhibition and post mature leaves had shown a moderate antibacterial activity of 10.3mm on Nutrient agar. By using the antibiotic discs, which were created by, using mature *C. asiatica* extract; synergistic activity with Ciprofloxacin, Gentamycin and Vancomycin was observed. Both Ciprofloxacin and Gentamycin antibiotic discs activity were reduced from 32mm to 26mm and 34mm to 30mm respectively: when they are combined with the *C. asiatica* extract where Vancomycin had given increased antibacterial activity from 23mm to 24mm when it was synergised

with *C. asiatica* leaf extract. This study will help to understand about the antibacterial activity of *C. asiatica* leaves' extracts towards *S. aureus*. Since the antibiotic resistance is a major problem in the presence this study had also focussed on the antibiotic synergism by synergising the created *C. asiatica* antibiotic discs with well-known antibiotics such as Vancomycin, Gentamycin and Ciprofloxacin.

Key words: Antibiotic Synergism, *Centella asiatica*, Ethanol extraction

INTRODUCTION

Centella asiatica (*C. asiatica*) which is also known as pennywort or 'gotu kola (Sri Lanka)' is a commonly eaten raw food (Puttarak et al., 2017). *C. asiatica* is a perennial creeping weed which grows mostly in moist grounds (Oyedeki and Afolayan, 2004) in Sri Lanka, India, China, Madagascar, Indonesia, Malesia and Africa (James and Dubery, 2009). This herbaceous plant is categorized under Apiaceae family (Figure 1) which consists about 50 species (James and Dubery, 2009). This project is about the antibacterial activity of *C. asiatica* leaves which are shaped as a spade.



Figure 1-Scientific classification of *C. asiatica* (Database of Medicinal and Aromatic Plants in Rajasthan, 2016).

Since the prehistoric time *C. asiatica* is mostly used as an ayurvedic medicinal plant in China, India, Africa and Sri Lanka (Soyingbe, Mongalo and Makhafola, 2018). They had used this plant as an anti-inflammatory, anti-cancer, anti-oxidant (Dash et al., 2011), anti-microbial, anti-depressive agent in their treatments. Also it has been found that this plant can be used as a brain tonic (Omar et al., 2011), to treat chronic mental disorders (Arumugan et al., 2011) eczema, atherosclerosis, leprosy, rheumatoid arthritis and also to treat kidney disorders (Idriz and Nadzir, 2017). Most of the folk healers had used this plant as a wound healing agent (Gohil, Patel and Gajjar, 2010). Even though this plant consists too many medical values this research will be based on anti-bacterial activity of *C. asiatica* leaves. At the end of this research it will reveal that which maturation stage has the best antibacterial activity towards *Staphylococcus aureus*. To prepare the antibiotic discs *C. asiatica* extracts were obtained using ethanol.

Various antibiotics have been developed over the years to improve human quality of life. However unwise use of antibiotics make the bacteria resistant towards the antibiotics. Therefore, it required antibiotics to counteract with bacteria which may cost more (Dash et al., 2011). Beside the drug resistance, undesirable side effects of certain antibiotics encourage the use of natural sources (mostly plants extracts) as

antibacterial agents (Nasution et al., 2018). The growing concern regarding the increase of bacterial resistance to antibiotics and increasing interest towards application of natural medicine have led to the search of new antibacterial agents mainly from plant extract. Medicinal herbs are alternative treatment which is preferable for human and animal health which believe to have least side effects.

According to Nasution et al., 2018 they had discovered that *C. asiatica* leaves consist antibacterial activity towards *Staphylococcus aureus*, *Staphylococcus albus*, *Streptococcus pyogenes*, *Streptococcus pneumonia*, *Aspergillus niger*, *Aspergillus flavus*, *Escherichia coli* and *Microsporium bouldardii*. *Staphylococcus aureus* (*S. aureus*) is prevalent contagious pathogenic bacteria. So that *S. aureus* was chosen for this research (Lalitha, Kiran and Raveesha, 2013). It has been found that *C. asiatica* inhibit the growth of *S. aureus* and reduce the inflammation. Triterpenes are the most prominent biologically active compound which is present in *C. asiatica* (Wijeweera et al., 2006). Triterpenes consists asiatic acid, madecassic acid and asiaticoside (Bylka et al., 2013). Among them, asiatic acid is an aglycone of asiaticoside which can be isolated from *C. asiatica* (Taemchuay et al., 2009), is mostly used for wounds as a healing agent: as an antibacterial and potentially anti-fungal: as an anti-oxidizing agent: as a dermis reconstructing agent which stimulates the collagens synthesis or as an anti-aging agent which reinforce the bio-mechanic properties of mature skins (Taemchuay et al., 2009).

According to Abaza et al., 2017 who were researched on Olive tree plants had discovered that phytochemical content and their characteristics are varying according to their development stage. So that this research was designed to detect changes in the antibacterial activity of *C. asiatica* leaves according to their maturation.

In Sri Lanka most of the time people tend to buy pre mature *C. asiatica* leaves as it has more milky taste when compare with mature and post mature leaves, believing that it is much better for health. This study was designed to identify, which maturation stage has the maximum antibacterial activity towards *S. aureus* which is a gram positive bacteria.

S. aureus was selected as the bacterial strain in this project. According to Soyingbe, Mongalo and Makhafola, 2018 they had discovered that *S. aureus* gives a considerable zone of inhibition when compared with *Escherichia coli* when using ethanol as the extraction medium.

Main goal of this project: Identify the antibacterial activity of the ethanol extract of *C. asiatica* leave towards *S. aureus* and the synergistic effect of *C. asiatica* extract with Ciprofloxacin, Gentamycin and Vancomycin.

METHODOLOGY

Centella asiatica powder making.

Centella asiatica leaves were bought from a local market at Ingiriya, Sri Lanka. Leaves were separated from stem and they were collected according to their maturation by palpating the texture and by observing the colour and the size of the leaves. Pre mature leaves are light green, in colour and small in size. Mature *Centella asiatica* leaves are smooth in texture and green in colour where post mature leaves are rough in texture and greenish yellowish in colour.



Figure 2. *C. asiatica* leaves according to the maturation (a- pre mature, b- mature and c- post mature).

All the leaves were rinsed with water and then soak in the salt water for 15 minutes. After washing all the separated leaves were dried under the direct sunlight and grinded well. Then the *C. asiatica* extract was obtained by the solvent extraction method.

Before starting the lab work all the glass ware and agar were autoclaved and the working area was cleaned by using 70% ethanol.

First Extraction

15g of mature, pre mature and post mature *Centella asiatica* powder was measured and added to three 50ml falcon tubes and 25 ml from the 95% ethanol was added to it as follows (Table 1). The samples were placed on the roller mixture let them mix overnight.

Table 1. Samples and the added 95% ethanol volume.

95% ethanol volume Sample	25ml	25ml	25ml
Premature (15g)	✓	✓	✓
Mature (15g)	✓	✓	✓
Postmature (15g)	✓	✓	✓

Then the samples were filtered by using a cotton cloth and then the extract was again filtered with a 'Munktel' filter papers and extracts were separated. By using Whatman's no.1 filter papers empty antibiotic discs (diameter: 7mm) were prepared. Each disc was saturated with *C. asiatica* extract by pipetting each volume with five minutes breaks (Table 2). Meanwhile the nutrient agar plates were prepared and *S. aureus* was streaked on the plate by using 'Kerby Beuer' disk diffusion method. The bacterial

concentration (x 108 CFU) was calculated according to the 0.5 McFarland's solution.

Table 2. Volume for each antibiotic disc.

Volume (µl)	5	5	5	5	4	3	3	2	ove	3	3	3	2	2	ove	3	3
Sample									n						n		
2g:15ml (pre mature)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2g:20ml (mature)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2g:25ml (post mature)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

All the discs were kept on the oven at 400C for 30 min. Then the discs were placed on the petri plates as shown in Figure 3.

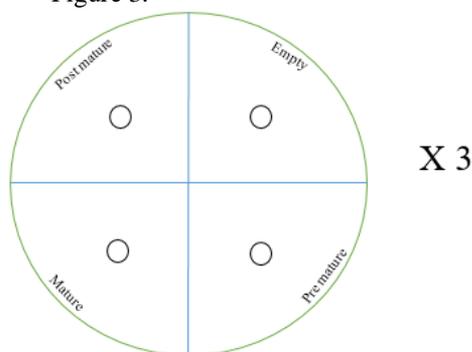


Figure 3. The antibiotic discs organization in First extraction.

The negative and the positive controls were made on nutrient agar as shown in Figure 4. The petri plates were incubated at 370C for 24h and the zone of inhibition was measured.

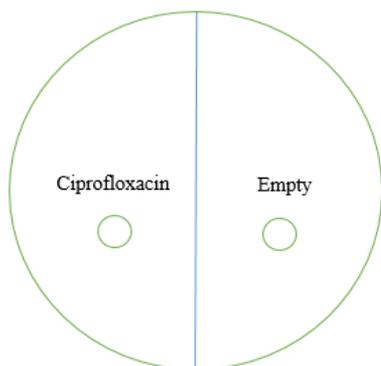


Figure 4. Organization of the control antibiotic discs (Ciprofloxacin- Positive control and Empty disc saturated with ethanol- Negative control).

Second extraction.

15g of mature (2 falcon tubes with same concentrations), pre mature and post mature C. asiatica powder was measured and added to four 50ml falcon tubes and 25 ml (Table 3) from the 95% ethanol was added to it. The samples were placed on the roller mixture let them mix overnight.

Table 3. Samples and the added 95% ethanol volume.

Sample	95% ethanol volume		
	25ml	25ml	25ml
Pre mature (15g)	✓	✓	✓
Mature (15g)	✓	✓	✓
Mature (15g)	✓	✓	✓
Post mature (15g)	✓	✓	✓

Then the samples were filtered by using a cotton cloth; then the extract was again filtered with a 'Munktel' filter papers and extracts were separated. By using Whatman's no.1 filter papers empty antibiotic discs (diameter: 7mm) were prepared. Each disc was saturated with C. asiatica extract by pipetting each volume with five minutes intervals (Table 4). By adding mature Centella extract: Ciprofloxacin, Gentamycin and Vancomycin antibiotic discs were re-prepared by pipetting each volume with five minutes intervals according to Table 4. Meanwhile the Mueller Hinton agar plates were prepared and S. aureus was streaked on the plate by using 'Kerby Beuer' disk diffusion method. The bacterial concentration (x 108 CFU) was calculated according to the 0.5 McFarland's solution.

Volume (µl)	5	5	5	4	4	4	4	4	oven	4	3	3	3	3	oven	3	2	oven
Sample																		
Pre mature	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Mature	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Post mature	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 4. Volume for each antibiotic disc

The antibiotic discs which are made according to the Table 4 were placed on the petri dishes as shown in Figure 5.

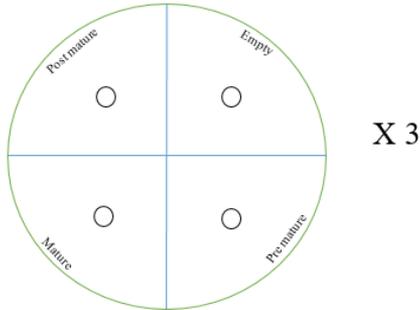


Figure 5. The antibiotic discs organization in forth extraction.

The negative and the positive controls were made on Mueller Hinton agar as shown in Figure 4. The petri plates were incubated at 370C for 24h and the zone of inhibition was measured.

Antibiotic synergism Test.

By using *C. asiatica* extract which are obtained by the second extraction, following steps were carried out.

Table 5. Volume for each re-preparing antibiotic disk.

Volume (µl)	5	5	5	5	5	4	4	4	4	oven	5	5	5	5	5	5	5
Sample																	
Ciprofloxacin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Vancomycin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Gentamycin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Volume (µl)	oven	5	5	5	5	5	oven
Sample							
Ciprofloxacin	✓	✓	✓	✓	✓	✓	✓
Vancomycin	✓	✓	✓	✓	✓	✓	✓
Gentamycin	✓	✓	✓	✓	✓	✓	✓

All the discs were kept on the oven at 400C for 30 min. The antibiotic discs which are made according to the Table 5

were placed on the petri dishes as shown in Figure 6

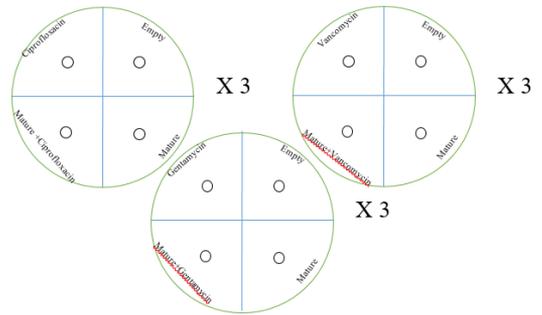


Figure 6. The antibiotic discs organization in the antibiotic synergism test.

When preparing the antibiotic discs as shown in Figure 6 empty discs which is saturated from ethanol was used as the negative control and mature *C. asiatica* discs was added as the positive control. All the petri dishes were incubated overnight and the zone of inhibition was measured.

RESULTS

First Extraction Results.

Table 6. Results of the first extraction.

Sample	Zone of inhibition			Mean of zone of inhibition
	A	B	c	(a+b+c)/3
Pre mature	7mm	7.2mm	7.4mm	7.2mm
Mature	13mm	12mm	12mm	12.3mm
Post mature	10mm	10mm	11mm	10.3mm

Second Extraction Results.

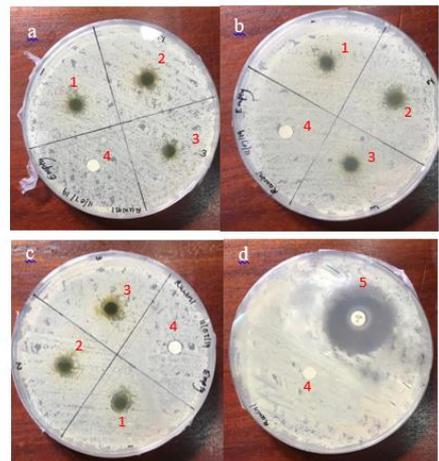


Figure 7. Results of the second extraction Table.4 by using Mueller Hinton agar and the positive control and the negative control. (1: pre mature, 2: mature and 3: post mature, 4-negative control and 5-positive control)

Table 7. Results of the second extraction.

Sample	Zone of inhibition			Mean of zone of inhibition $\frac{(a+b+c)}{3}$
	A	B	c	
Pre mature	7mm	7mm	7mm	7mm
Mature	9mm	10mm	9mm	9.3mm
Post mature	8mm	8mm	7mm	8.3mm

Antibiotic synergising test Results.

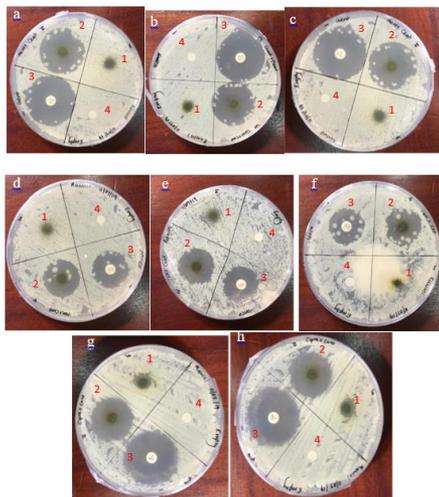


Figure 8. Results of the fourth extraction antibiotic synergism. (a, b and c are the results for mature Centella and Gentamycin combination, d, e and f are the results for Vancomycin and mature Centella combination; and g, h and i are the results for mature Centella and Ciprofloxacin combination. 1-Mature, 2-Synergised antibiotic, 3-antibiotic alone (positive control) and 4-negative control)

Table 8. Results of the Vancomycin combination.

Sample	Zone of inhibition			Mean of zone of inhibition $\frac{(a+b+c)}{3}$
	a	b	C	
Vancomycin	23mm	23mm	23mm	23mm
Vancomycin + Mature <i>C. asiatica</i>	23mm	25mm	24mm	24mm
Mature	10mm	9mm	9mm	9.3mm

Table 9. Results of the Gentamycin combination.

Sample	Zone of inhibition			Mean of zone of inhibition $\frac{(a+b+c)}{3}$
	a	b	C	
Gentamycin	34mm	34mm	34mm	34mm
Gentamycin + Mature <i>C. asiatica</i>	31mm	30mm	29mm	30mm
Mature	9mm	9mm	9mm	9mm

Table 10. Results of the ciprofloxacin combination.

Sample	Zone of inhibition			Mean of zone of inhibition $\frac{(a+b+c)}{3}$
	a	b	c	
Ciprofloxacin	24mm	32mm	32mm	32mm
Ciprofloxacin + Mature <i>C. asiatica</i>	25mm	27mm	-	26mm
Mature	9mm	10mm	9mm	10.3mm

DISCUSSION

C. asiatica leaves were separated into three age groups by observing and by palpating the texture. This method is more reliable rather than cultivating *C. asiatica* and pluck the leaves according to the date since they were planted. The problem of the cultivation method is the root system of *C. asiatica*. In this plant the roots are spreading every day and start growing new leaves. So that it is hard to measure the age of each leaf and also it consumes more time. When drying the leaves direct sunlight was used. Other than the direct sunlight, wind or the oven (400C) can be used for drying. Even though the drying method is different it won't be able to affect the phytochemical activity (Nelson and Bugbee, 2015); as the temperature which obtained from the sunlight is also around 400C (Volokin and ReLlez, 2014).

To grind the dried *C. asiatica* leaves the mixer grinder was used. When the leaves are not dehydrated or dried properly it won't be easy to grind and the grinder will generate heat; which will burn the leaves. Then the grinded leaves were sieved from the sieve which is usually used in the kitchens. As the sieve had larger pores, the obtained *C. asiatica* powder was not very fine, so that it might have affect the extraction procedure by increasing the

surface area (Chemistry libretexts, 2019) and by reducing the extract concentration. When using a fine powder for the extraction it will increase the surface area of the solute and give more concentrated C. asiatica extract.

According to Dash et al., 2011 in C. asiatica; ethanol extract gives the highest zone of inhibition (17mm) towards S. aureus in nutrient agar, other than chloroform, methanol and n-hexane. So that 95% ethanol was used to obtain the C. asiatica extract. As the third and fourth extraction mixtures were highly concentrated, a clean, sterile and white colour cotton cloth was used for the filtration. First extraction was done by using 15g from post mature, mature and pre mature C. asiatica powder along with 25ml of 95% ethanol. As it is hard to filter the extract from the filter paper a cotton cloth was used. According to Table 6 it shows that the median zone of inhibition of pre mature C. asiatica leaves was 7.2mm, which was the least value. Post mature C. asiatica leaves have given a moderate value 10.3mm where the mature leaves had given the highest median zone of inhibition of 12.3mm (Table 6). According to these results it can be concluded that mature C. asiatica leaves gives the highest zone of inhibition which describes that it has the greatest antibacterial activity when comparing with post mature and premature leaves. Pre mature leaves had the lowest zone of inhibition which further confirms that it has the lowest antibacterial activity when compared with the post mature C. asiatica leaves.

These changes of the values must have arose due to the maturation of C. asiatica leaves and mature leaves which are at their younger age must be having the highest phytochemical activity where the pre mature leaves which are at their early stage of maturation might not have grown enough phytochemicals (Khoo et al., 2018). So that the pre mature leaves has

lowest antibacterial activity. The moderate antibacterial activity was obtained from the post mature C. asiatica leaves. This might happen due to the aging of the leaves which degrade the phytochemicals (Thi and Hwang, 2014).

Nasution et al., 2018 had used rotary evaporator to create the concentrated extract and in this project a rotary evaporator had not been used. So that the concentrations of extracts might be different in these two studies. As there is no use of rotary evaporator step to concentrate the extract, C. asiatica concentration of this study extract should be reduced when compared with Nasution et al., 2018. So that the produced antibiotic discs concentration is also reduced. This might be the reason for the reduction of the zone of inhibition (Table 6) from 17mm to 12.3mm. In all the experiments an empty antibiotic disc which is saturated with ethanol was used as the negative control. Since none of the negative controls had a zone of inhibition it can be concluded that these inhibitions were not due to the solvent (ethanol) but due to the C. asiatica extract. Then the second extraction results which are shown in Figure 7, was cultured on Mueller Hinton agar for further confirmation. It also give similar results as the first extraction which was performed on the Nutrient agar, but the radius of the zone of inhibition (Table 7) was reduced.

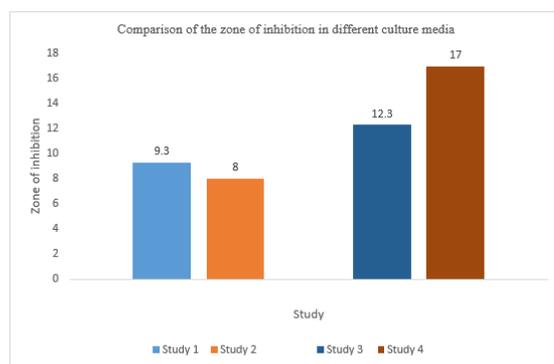


Figure 9. The difference between the zones of inhibition (Study 1-Second extraction, Study 2-Nasution et al., 2018, Study 3- First extraction and Study 4- Dash et al., 2011)

Figure 9 is a comparison between the studies and this project results. According to Figure 9 it shows that study 2 which was done by Nasution et al., 2018 by using Mueller Hinton agar had given 8mm zone of inhibition where the second extraction give 9.3mm zone of inhibition when using Mueller Hinton agar. Also the study 4 which was done by Dash et al., 2011 by using Nutrient agar had given 17mm zone of inhibition where the first extraction which is similar to study 2 had given only 12.3mm zone of inhibition. According to these results it clearly shows that when using different agar mediums it gives different results. The gold standard culture media for the Kirby Bauer disk diffusion is Mueller Hinton agar (Nassar, Hazzah and Bakr, 2019). Even though Mueller Hinton is the gold standard, the antibiotic discs which are made from the *C. asiatica* extract had given maximum zone of inhibition in Nutrient agar. So according to these results it can be concluded that for *C. asiatica* studies using nutrient agar will give visible results when compared to the Mueller Hinton agar. Nassar, Hazzah and Bakr, 2019 and Donkor et al., 2008 had concluded that replacing Mueller Hinton agar with Nutrient agar will give rise to multiple errors on *S. aureus* etc. in antimicrobial susceptibility tests. Nassar, Hazzah and Bakr, 2019 said that the Mueller Hinton agar is a loose agar which will enhance the diffusion of the antibiotics in the culture medium and the starch which is a component of Mueller Hinton agar also absorb the bacterial toxins; must be the cause for larger zone of inhibition when compared to Nutrient agar (Nizet, 2017).

According to Baym, Stone and Kishony, 2016 synergising antibiotics is a recent development in the pharmaceutical industry. Nowadays most of the scientists are interested in antibiotic synergism as it has given good effect most of the time; on the bacteria and their antibiotic resistant phenotypes (Kuok et al., 2017). Also

Dhiman et al., 2016 had performed an in vitro study of herbal extracts including *C. asiatica*; combinations towards the bacteria's associated with fruit juices. This further confirms that combining herbal antibiotics are effective than the antibiotic alone.

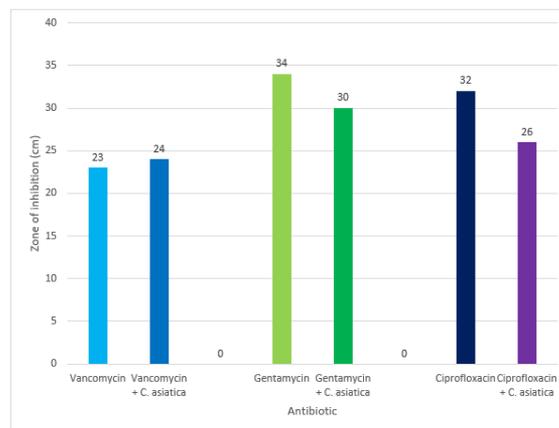


Figure 10. Comparison between different antibiotics and their combination with *C. asiatica* leave extract.

When combining mature *C. asiatica* leaves extract with existing antibiotics (Figure 10) such as Vancomycin, Gentamycin and Ciprofloxacin it gives different results. The median zone of inhibition was reduced in combined antibiotic discs such as Gentamycin and Ciprofloxacin. But in Vancomycin it had increase the median zone of inhibition (24mm) from 1mm than the antibiotic alone (23mm).

These reductions of the zone of inhibitions might have arose due to oven incubation at 40°C. As the antibiotic discs are storing 40°C or less than that (Chen et al., 2013) the high heat must have damaged its properties (Cheesman et al., 2017). Also the synergising the antibiotics might have cross reacted with each other. According to Dhama et al., 2014 this reduction might have occurred due to the bacterial resistance towards the antibiotic.

CONCLUSION

According to the obtained results mature *C. asiatica* antibiotic discs had given the maximum zone of inhibition of 12.3mm. The post mature extract got the second maximum zone of inhibition (10.3mm) and according to this study the least antibacterial activity or the lowest zone of inhibition (7.2mm) was obtained from the pre mature *C. asiatica* extract. When combining *C. asiatica* with the other antibiotics such as gentamycin, ciprofloxacin and Vancomycin it shows that Gentamycin and the Ciprofloxacin have a negative impact on their normal antibacterial activity. But when the *C. asiatica* extract is mixed with Vancomycin it shows that this combination had increased the antibacterial activity of Vancomycin.

According to these results, using mature leaves of *C. asiatica* will give the maximum antibacterial activity rather than using the other maturation stages.

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MUSIC THEORY AND ITS TRAITS IN ENHANCING INFORMATION SECURITY

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ABSTRACT

The Data Communication plays a vital role in the Information and Communication Technology era. The new Technologies have changed the conventional way of information exchange with the advancement of information and communication technology. Music, fine art, or an art of ordering tones and sounds in succession and in combination that's concerned with the medium of sound and can be created using musical instruments with musical notes to produce splendor of harmony and expression of emotions. In this era, the demand for securing information is particularly needed and preferred. Music theory and its attributes have been used in securing information exchange in the form of cryptography from the early days. Presently, music is immeasurably utilized in securing information with the utilization of steganography. The craft of scrambling and covering messages utilizing music is named as Musical Steganography. Further melodic notes and images have been utilized as codes and keys. The covering up is actualized by planning a calculation for the encryption of a piece designed message into music utilizing its traits and the decoding in the other way around. In this paper, we propose a calculation which changes over the bit into melodic notes by utilizing some numerical properties. Further, the study two-level safety efforts utilizing the Musical Cryptography and with Musical Steganography strategies. In this way, the

security of the message improves through the above proposed scheme.

Keywords: Steganography, Cryptography, data security, information hiding, Musical steganography

INTRODUCTION

During the most recent couple of decades, there is a gigantic advancement in Information and Communication Technology. The Data communication has been assuming a significant job in our everyday lives, with the accessibility of numerous innovations. The ICT contributes in many aspects of human life such as communications, education and online commercial activities. In this manner, security in the data in communication through the Internet has become a threat.

With the advancement in ICT, most of the information is kept electronically; consequently, the efficient security mechanism is required to assure confidentiality, integrity and authentication. Different mechanisms have been utilized for secure communication from the ages of Julius Caesar. The process of secure information exchange demands techniques that convert the message into an unintelligible form. For communication over the public network, information can be ensured by predominantly two procedures that are Cryptography and Steganography (Chandan Kumar, 2014) (M. Yamuna).

Cryptography converts the data by any other encryption algorithm using the key in the scrambled form; only those having access the key can decrypt the encrypted data. In steganography, the secret information is hidden inside some other file without degrading the quality of the file. Various steganography techniques use a cover file that also called a stego object to hide the message in it. Due to the enormous advancement of computing power, some techniques address the issues of Confidentiality, Integrity, and Authentication. In this paper, we present an algorithm with the combination of cryptography and steganography techniques associated with the music theory to enhance the security of the data transmission in a public network (M. Yamuna).

The melodic notes in Western music are Do–Re–Mi–Fa–Sol–La–Ti–Do. A similar melodic notes in Indian music are alluded to as Sa-Re-Ga-Ma-Pa-Da-Ni-Sa. In western music, we imply them utilizing English letter alphabets– to be specific C, D, E, F, G, A, B, and C as shown in Figure 1. Any music can be represented using these symbols. A key is a set of seven notes collectively called a scale. The scale is built by a specific relationship between the notes depending on major or minor scale. In the scale, there are seven tones which are noted as C, D, E, F, G, A and B.

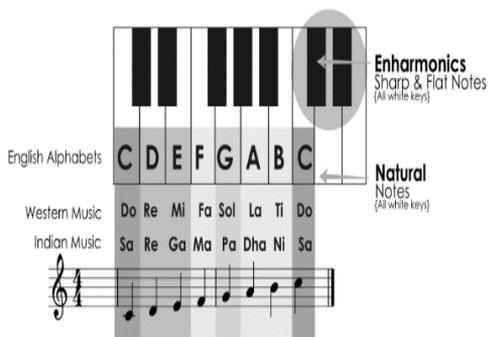


Figure 1. The Musical Notes of Western Music and Indian Music

The chromatic scale is a melodic scale with twelve pitches, each a semitone above or below its neighboring pitches comprising of sharp and flat notes. Sharp intends to go up a half advance, while flat intends to go down a half advance. Accordingly, in 12-pitch equivalent disposition (the most widely recognized temperament in Western music), the chromatic scale covers every one of the 12 of the accessible pitches as shown in Figure 2.

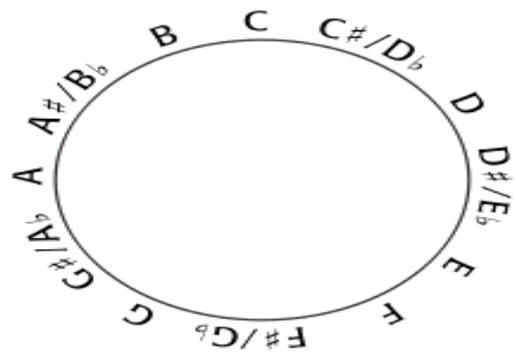


Figure 2. The Chromatic Scale

The basic construction of any scale is an association of whole steps and half steps. The steps are calculated using Melodic Intervals as when two notes appear one after the other, they create a melodic interval. A melody is basically a succession of melodic intervals arranged in a certain musical shape that makes sense to us.

LITERATURE REVIEW

Many researchers have involved with the researches incorporating some of the musical attributes with the Information Security. (Sandip Dutta, A Symmetric Key Algorithm for Cryptography using Music, 2013) Used Distinct frequencies for each and every English alphabet (A-Z) and digits (0-9) to encrypt a message which contains the upper alpha and numeric characters. Further (Sandip Dutta,

Hiding Messages using Musical Notes: A Fuzzy Logic Approach, 2015) uses some techniques which involves in the musical steganography. Most of the researches have done for a text message. Creation of different distinct forms of an attribute is used in encryption and Decryption.

METHODOLOGY AND EXPERIMENTAL DESIGN

Any permutation and combination of melodic notes may deliver some kind of music. Music structure comprises of a lot of rules and language grammar (M. Yamuna). Here we propose a technique to ensure security of any message utilizing the conventional western melodic English letters as a stego object. In the proposed strategy we apply encryption of bits utilizing a permuted music notation where the bits produce a cipher text that is covered up as far as music notes. Here, we select a key of length n ($n < 12$) permuted arrangement of 12 chromatic musical notes as a key for encryption and decryption

Algorithm for Encryption

Step 1: Select your Message (M) to be sent.

Step 2: Convert your Message (M) into the binary Format (B₁).

Step 3: Select the Key (K) to be used in the Ciphering Process.

Step 4: Convert Your Bit Format (B₁) to a Musical File (M_f) with Musical Notes. Each Bit is Computed to a single musical note by analysing the bit (1 or 0) and the musical note is selected according to the Full/ Whole tone or Half/Semi tone.

Step 5: The Musical File (M_f) will be encoded into binary format (B₂) and it will be transmitted through Public Network by performing normal standard Encryption.

The steps involved in encryption are illustrated in the Figure 3 below

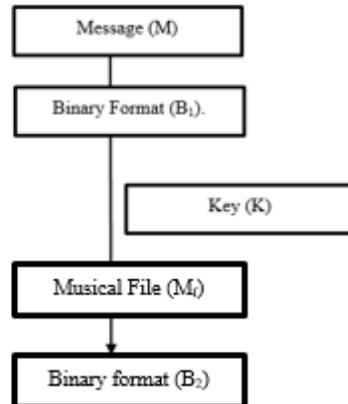


Figure 3. Encryption Process

Algorithm For Decryption

Step 1: Get the Binary Formatted (B₂) Message which undergoes normal standard decryption.

Step 2: The Musical File (M_f) will be obtained from the bit decoding process.

Step 3: Process the Key (K) to be used in the Deciphering Process.

Step 4: Convert Your Musical File with Musical Notes (M_f) to a Bit Format (B₁). The Musical File (M_f) will Populate its own musical notes as used in Encryption Process.

Step 5: The binary format (B₁) will be decoded into the Message (M)

The steps involved in Decryption are illustrated in the figure 4 below.

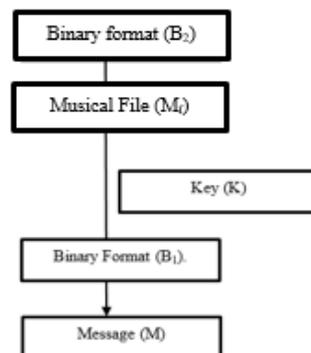


Figure 4. Decryption Process

RESULTS AND DISCUSSIONS

The Manipulation of Encryption Process is shown below with sample illustration.

- The Message to be sent: HI
- Each Letters ASCII code is considered in encoding to Binary format.0100100001001001
- The Key used in Ciphering: ABC#DFGA#
- The Musical Notes (music file) will be Computed: If the bit is 1 is will computed as Full/Whole tone, else it will compute as Semi/Half tone.
ABDFGABC#DFA#ABDFGA
- The Music File will be encoded to a bit formatted message (Sampling and Quantizing) to be transmitted through the Public Network with the standard encryption Systems.

The Decryption is Processed in the Vice Versa. The algorithm utilizes the combining security mechanisms by utilizing the encryption and steganography (The message is hid in the format of music) utilizing the traits of music. By this, the guarantee the security of communication over an open channel is enhanced, which makes it hard to recognize the data passing through the network. Depending upon the bit design they are encoded utilizing the key, the aftereffects of the encryption procedure were found very satisfactory as far as aesthetic intrigue. The encoded message as a melodic piece we saw as progressively practical, the intruder cannot figure the melodic piece as a encoded message. The key utilized in encryption and decryption is certainly not a simple one to one substitution so speculating the key is

difficult by and by. Through the Implementation of the proposed algorithm, a secure and hidden layer is manipulated in the transmission Process.

CONCLUSIONS

Cryptography and steganography are the two most extreme significant procedures in Information security today. This study investigated combining music and its traits to make musical cryptography and musical steganography mechanisms. To accomplish this, we used the classical music theory and a cipher based function to the bit pattern.

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ENHANCE BODY CONTOURED WOVEN OCCASIONAL WEAR, INSPIRING FROM PERFORMANCE WEAR PRODUCTION

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ABSTRACT

Studies have confirmed, most of the women face many difficulties when choosing stylish occasional wear, because of they could not wear them with an appropriate bra. Visibility of bra straps and discomfort when wearing stylish occasional wear become main problem when selecting perfect stunning occasional wear. Performance wear techniques ensure good upward support, limited breast motion and comfortability. There are precise pattern cutting and garment construction techniques are used in performance wear manufacturing. Bras are in-built in most of the performance wear products. This research focuses on identify woven body contouring fashion market in Sri Lanka, identify customer need of alleviating wearing a separate bra with occasional wear, examines performance wear pattern cutting and construction techniques and check the possibility of applying them to woven body contour occasional wear manufacturing. The aim of this research is to introduce woven body contouring wear bodice alleviating the need of wearing a separate bra inspired from performance wear techniques. This research discusses the analysis of data that gathered using questionnaire survey, performance wear and occasional wear product survey and experiments based on various experiments. The proposed woven body contouring experiments developed by exploring performance wear techniques and applied them to woven fabric flat pattern cutting and conducted a fit evaluation to identify upward support,

comfortability and aesthetic values. All results indicated woven body contoured wear with in-built breast support can be achieved from performance wear pattern cutting and construction methods and elasticated adjustable back methods without fastenings.

Keywords - Sports performance wear, woven fabrication, Body contoured wear, Inbuilt support

INTRODUCTION

Creating a perfect, sensuous and stunning silhouette become more prominent among working women in Sri Lanka. Most of the women looking for a perfect blend of fashion, comfort, and function (Lawrence, 2011). Although many difficulties appear when choosing stylish occasional wear styles, because of difficulty in choosing appropriate bra. Visibility of bra straps and discomfort in wearing stylish occasional wear become main problem when selecting perfect stunning occasional wear. When considering the fabric preference in Sri Lankan customer there is huge market to woven fabrics.

Functionality, fashion, and style are key contributors in performance apparel (Watkins & Dunne, 2015). Performance wear techniques ensure good upward support, limited breast motion and comfortability. There are precise pattern cutting and garment construction techniques are used in performance wear manufacturing. Since performance wear

are in-built with breast support, it minimized the wearing of separate bra.

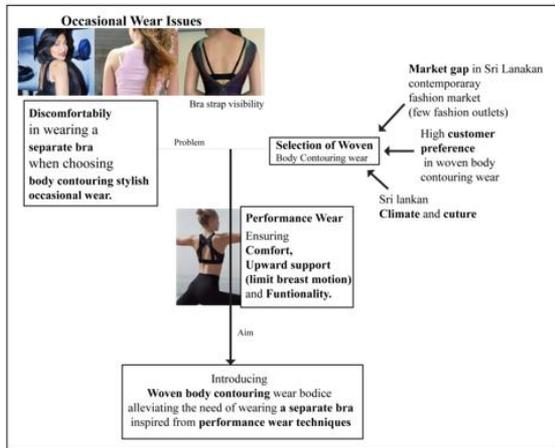


Figure 1 Flow chart

This study examined those performance wear pattern cutting and construction techniques and check the possibility of applying them to woven body contour occasional wear manufacturing. Enhancing body contouring effect for woven garments, alleviate the need of wearing a separate bra. As the result of multiple experiments with feasibility tests, this study presented the best methods to enhance body contouring of woven based garments. Finally this study confirmed the in-built breast support with elasticated adjustable back (back or wings – use most appropriate word) methods without fastenings will show better results.

Problem Identification

Discomfortability in wearing a separate bra when choosing body contouring stylish occasional wear

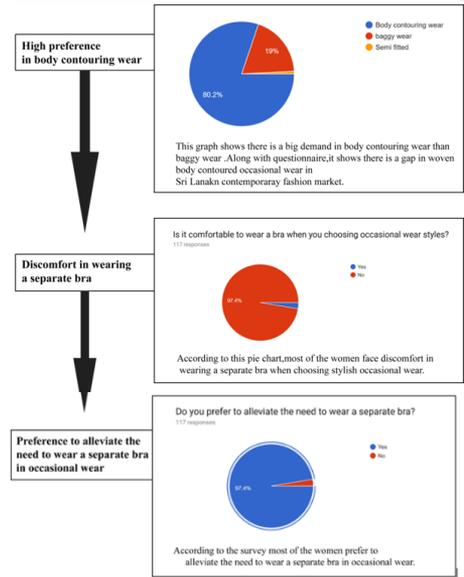


Figure 2 Problem identification

Aim of the study

-Introducing Woven body contouring wear bodice alleviating the need of wearing a separate bra inspired from performance wear techniques

Objectives

1. Identify woven body contouring fashion market in Sri Lanka and identify need of alleviating wearing a separate bra with occasional wear.
2. Examine those performance wear pattern cutting and construction techniques and check the possibility of applying them to woven body contour occasional wear manufacturing.
3. Introduce Woven body contouring wear bodice alleviating the need of wearing a separate bra inspired from performance wear techniques

Significance of the study

-Visibility of bra straps and discomfort when wearing stylish occasional wear become main problem when selecting perfect stunning occasional wear.

-Introducing Woven body contouring wear bodice alleviating the need of wearing a separate bra inspired from performance wear techniques

LITERATURE REVIEW

Performance Wear

Performance apparel is defined as garments that perform or function for some purpose such as to help athletes and active people keep cool, comfortable and dry using moisture management and other techniques (Davis, 2016).

Sports Bra

Sports bras, available in encapsulation and compression forms, are designed to control, support, and contain breast tissue during strenuous exercise while many are purported to facilitate moisture as well (Krenzer, Starr, & Branson, 2005).

An improved sports brassiere possesses multiple enhancements comprising adjustable wider straps for increased comfort, high quality stretch material, and two adjustment points on either side thus ensuring a perfect fit, is herein disclosed. The brassiere is also provided with underwire Supports and a large quantity of lace material across the upper portion of each cup for enhanced aesthetic quality (Johnston, 2011)

Figure 3 Technical drawing of back adjustment of the sports bra(Johnston, 2011).

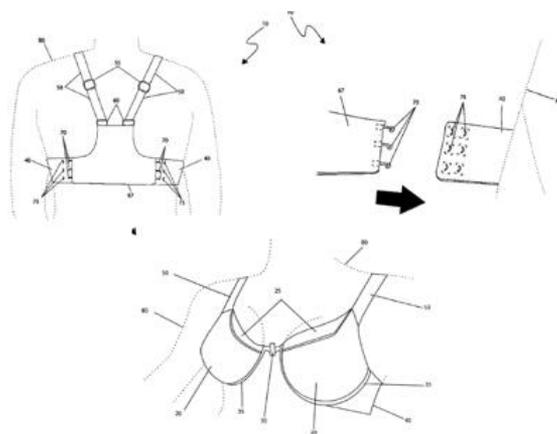
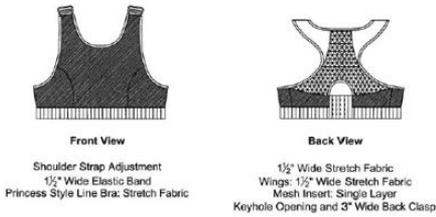


Figure 4 Technical drawing of front adjustment of sports bra (Johnston, 2011).

A method for installing and utilizing the adjustable sports bra may be achieved by performing the following steps: unlatching the front closure; applying the adjustable sports bra to one's torso by looping the straps over one's arms in a normal manner, adjusting in turn each strap using the adjustable fasteners to obtain a correct shoulder height; adjusting the side panel length as required using the hooks and loops; latching the front closure; flexing one's torso in such away as to test for a comfortable secure fit of the adjustable sports bra(Johnston, 2011).

Development of a supportive sports bra prototype

Exterior Bra



Inner Bra

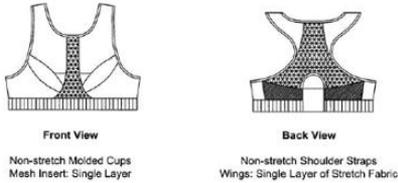


Figure 5 Front and back technical drawing of prototype bra (Krenzer et al., 2005)

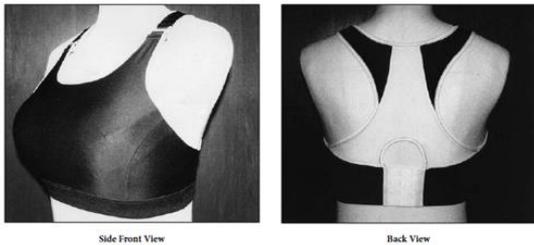


Figure 6 Prototype sports bra (Krenzer et al., 2005.)

The prototype sports bra was designed to address the following needs: support breast tissue, minimize breast motion, provide a flattering look, facilitate thermal comfort, provide coverage, and offer ease in donning and doffing. To support breast tissue and minimize breast motion, the prototype combined an encapsulating inner bra with a compression-style outer bra: the inner bra separates and contains each breast and the outer bra compresses the breasts to the chest cavity by means of a high modulus knit fabric. Motion was also minimized through the presence of wide, non-adjustable shoulder straps. A high neckline and wide side bands offered greater coverage than in typical sports bras. An adjustable back closure and a wide under bust band made it easy to don

and doff the bra, as well as providing support, comfort, and good fit (Krenzer et al., 2005).

Adhesive interlining

Interlining is a layer of fabric inserted between the face and the lining of a garment to give clothing a suitable appearance and stability. Interlining which uses a thermoplastic resin for attaching the face fabric is known as an adhesive or fusible interlining and it is usually used nowadays because of its convenience. Adhesive interlining generally gives a higher level of quality in a garment (Kim, Inui, & Takatera, 2011).

Bonded Seams

Table 1. Possibility of constructing different seam types.

Seam category	Seam type	Possibility of bonding	Possibility of needle stitching
Super-imposed seam	Plain seam-SSa	Possible	Possible
	French seam-SSe	Possible (more thicker)	Possible
Lap seam	Lap seam-LSc	Possible	Possible

Table 2. Seam strength behavior of plain seam (test reports).

Seam type	Composition	Fabric IM	Bonded (adhesive) strength KGF 2.5	Sewing strength KGF 2.5
Plain seam	100% Cotton	363255 6F ANTHRA	25.68	9.69
	100% Poly	441223 DGHTR	46.72	1.96
Plain seam	12% Spandex 88% Poly	309377 BLUE/421976 BLACK	32.85	2.54
	12% Spandex 88% Poly	470426 BLACK	52.19	1.94

Table 3. Seam strength behavior of French seam (test reports).

Seam type	Composition	Fabric IM	Bonded (adhesive) strength KEF 2.5	Sewing strength KEF 2.5
French seam	100% Cotton	363255 6F ANTHRA	41.77	5.07
	100% Poly	441223 DGHTR	52.05	3.08
French seam	12% Spandex 88% Poly	309377 BLUE/421976 BLACK	52.05	34.53
	12% Spandex 88% Poly	470426 BLACK	52.05	3.42

Figure 7 Bonded seams strength (Seram & Nandasiri, 2015)

In terms of the strength of the seams, the result shows that the bonded seam is the most reliable technique for constructing seams (Seram & Nandasiri, 2015).

Based on experiments on performance wear pattern cutting and construction techniques which check the possibility of applying them to woven body contour occasional wear manufacturing, below findings are gathered

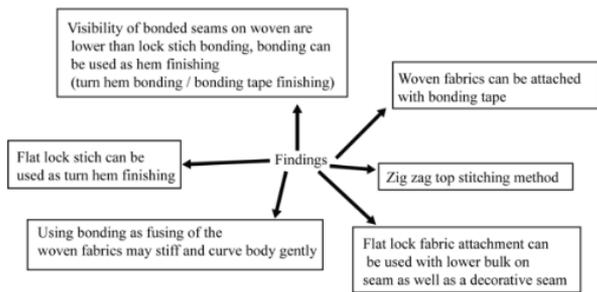


Figure 8 findings

Body contouring wear

Body contouring wear holds or molds a body to a certain shape. During the past decade or so, greater emphasis has been observed in the desire to have clothing aid the wearer in appearing to have a desired typically sexy torso (Russo & St, n.d.).

Achieving body contouring techniques

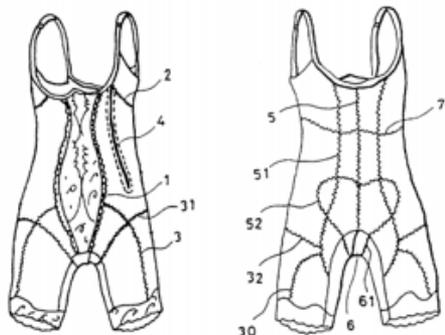


Figure 9 Drawing of Front and back style lines (Huang, 2000)

The front vertical torso seams 1 are closer together to each other at the breast position and are further apart at the abdominal position. The seams 1 are formed into two curved lines. two bodice side seams 2 are extended from the lower position of the shoulder to the back section and are then formed together to form a front horizontal bodice seam 7 the two lateral sides of the center vertical back seam 5 is provided with a left vertical back

seam 51 and the two left vertical back seams(Huang, , 2000).

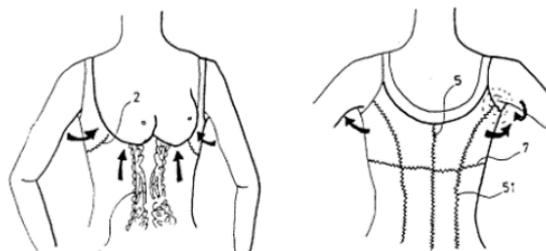


Figure 10 Drawing of muscle compression (Huang, 2000)

in view of the above structure, when a lady wears the undergarment of the present invention, the bodice side seam 2 and the front vertical torso seam 1 push the body fat at the waist upward to the direction of the breast Accordingly, the breast of the wearer is stiffer(Huang, , 2000).

Garment with Integral Brassiere

A woman's garment includes a tubular garment body and an inner support unit .The preferred inner support unit comprises a liner secured to the garment body along an upper edge portion of the garment body a pair of underwire members. the wearer's torso to provide a comfortable fit and support without detach able fasteners (not shown) which complicate the garment and show through to the exterior creating unsightly bulges(Katze, O'Donnell, & Meehan,2001).

Returning exclusively the preferred underwire members each comprise a U-shaped, rigid metallic or polymeric underwire encapsulated in soft fabric material to provide Support for, and contouring of, the breasts (not shown) of the wearer(Katze et al., 2011).

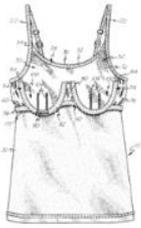


Figure 12 Outer front (Ize et al., 2011).



Figure 13 Outer back (Katsa et al., 2011).

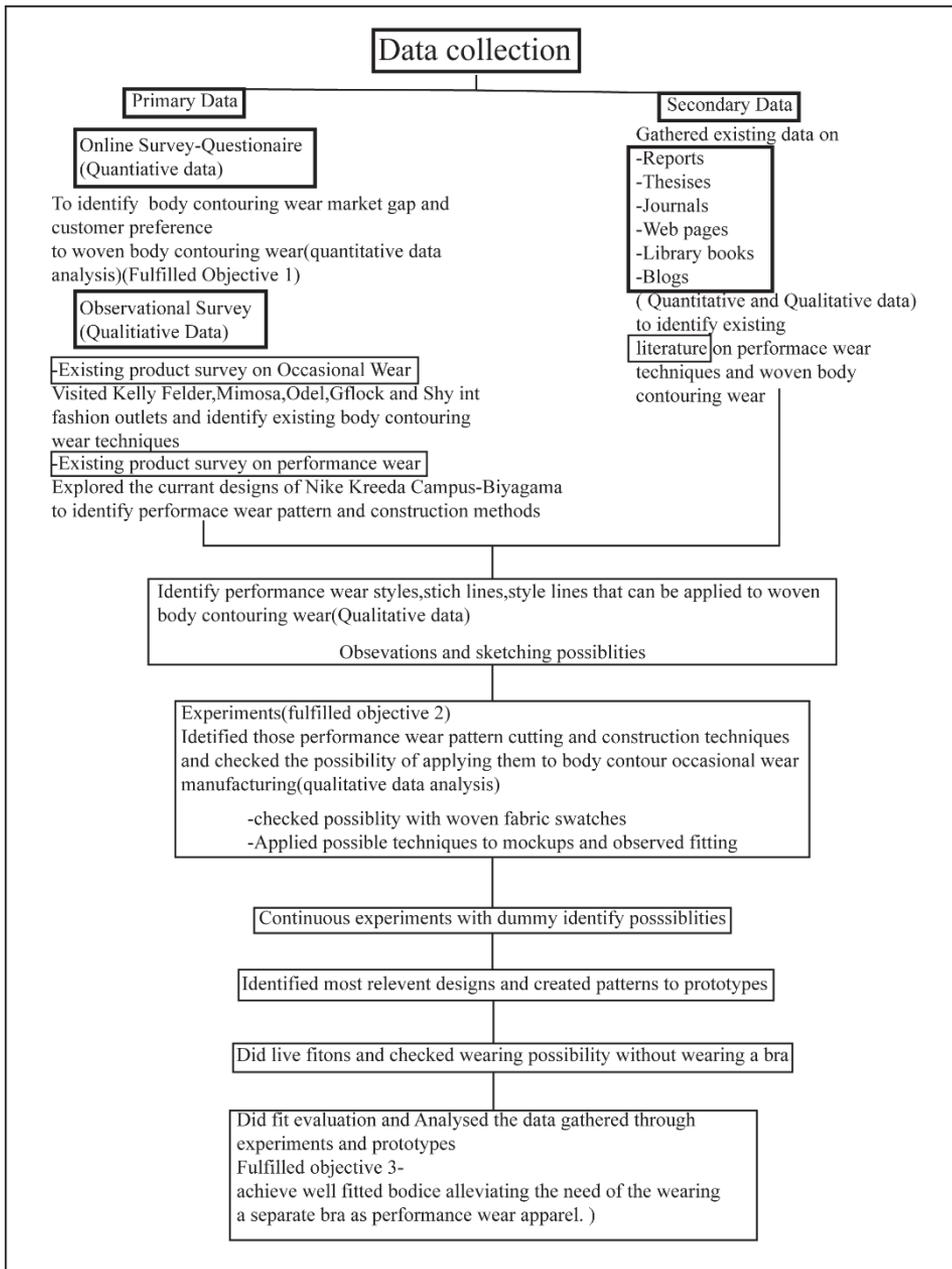


Figure 14 Inner back (Katsa et al., 2011).

Figure 11 Inner front

RESEARCH METHODOLOGY

This chapter consists of the methods that the researcher used to achieve the objectives of the study. Researcher explains how the research designed based on the objectives, data and data collection methods used in this study.



Secondary Research

Secondary research methods were used to find the background data and identify the research problem. Literature related to the study such as research papers, thesis, Industrial web sites, books and blogs were used to find the initial data for the study.

Primary Research

Primary research is carried out in three ways

1. Questionnaire survey
2. Product Survey (performance wear and occasional wear)
3. Experiments

Questionnaire survey

Questionnaire survey has been carried out as the primary data collection method and it was distributed via internet. Random Sample of 110 people in 20-30 age gap, used as sample for the questionnaire.

This is conducted to identify woven body contouring fashion market in Sri Lanka and identify need of alleviating wearing a separate bra with occasional wear.

Product Survey

- Occasional wear product survey
- Performance wear product survey

Occasional wear product survey

Occasional wear product survey is conducted to identify occasional wear designs, pattern cutting and construction methods (when achieving body contours) ,finishing methods ,fabrics used ,customer preference ,colour combinations.

Fashion outlets- ODEL,Cotton Collection,Kelly Felder,Gflock,Mimosa, and Shy int

Performance wear product survey

- Performance wear product survey is conducted to identify, stich types, pattern cutting techniques, fabric selection,

construction methods and fastening methods. Current designs of Nike Kreedaa Campus-Biyagama are explored.

Experiments

1. Experimenting swatches- to identify performance wear construction methods on woven fabric

2. Mockups- to identify performance wear pattern cutting methods on woven fabric

3. Prototypes- to introduce woven body contouring wear bodice techniques alleviating the need of wearing a separate bra

Data Collection

This chapter discusses the analysis of data that gathered using

-Research Method 1 - Questionnaire survey

-Research Method 2 - Performance wear and Occasional wear product survey

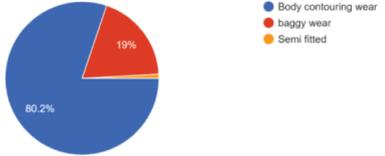
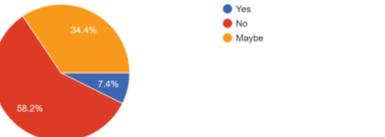
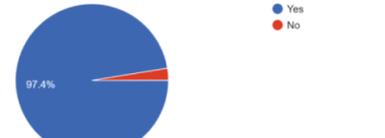
-Research Method 3 - Prototype experiments.

The gathered data has been analyzed and discussed under main objectives of the research by using relevant analyzing methods.

Research Method 1 - Questionnaire survey –

To identify woven body contouring fashion market in Sri Lanka and identify need of alleviating wearing a separate bra with occasional wear (Objective 1)

Table 1 Questionnaire results

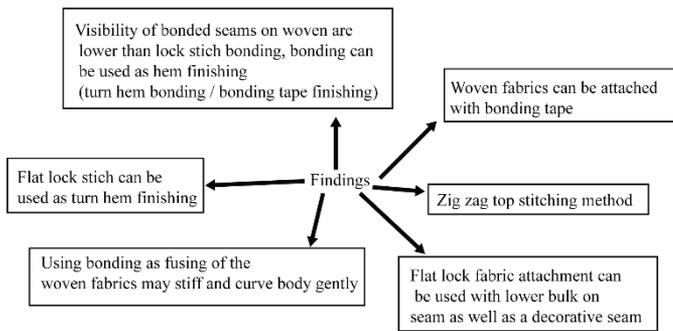
	Result	Description
<p>High preference in body contouring wear</p>	<p>Select your preference in occasional wear 116 responses</p>  <p>Legend: Body contouring wear (Blue), baggy wear (Red), Semi fitted (Yellow)</p>	<p>This graph shows there is a big demand in body contouring wear than baggy wear .Along with questionnaire, it shows there is a gap in woven body contoured occasional wear in Sri Lankan contemporary fashion market.</p>
<p>Fewer capabilities in Sri Lankan fashion market</p>	<p>Could you find perfect woven body contouring wear outlet in Sri Lanka easily? 122 responses</p>  <p>Legend: Yes (Blue), No (Red), Maybe (Yellow)</p>	<p>-According to the questionnaire, there is a gap in woven body contouring outlets in Sri Lanka. -There are fewer capabilities in Sri Lankan fashion market when finding the body-contoured occasional wear.</p>
<p>Discomfort in wearing a separate bra</p>	<p>Is it comfortable to wear a bra when you choosing occasional wear styles? 117 responses</p>  <p>Legend: Yes (Blue), No (Red)</p>	<p>According to this pie chart, most of the women face discomfort in wearing a separate bra when choosing stylish occasional wear.</p>
<p>Preference to alleviate the need to wear a separate bra in occasional wear</p>	<p>Do you prefer to alleviate the need to wear a separate bra? 117 responses</p>  <p>Legend: Yes (Blue), No (Red)</p>	<p>According to the survey most of the women prefer to alleviate the need to wear a separate bra in occasional wear.</p>

Research Method 2 - Performance wear and Occasional wear product survey

This study examines those performance wear pattern cutting and construction techniques and check the possibility of applying them to woven body contour occasional wear manufacturing.(Objective 2)

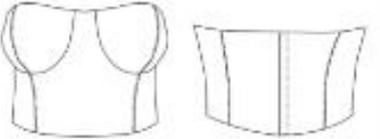
Experimenting performance wear construction techniques

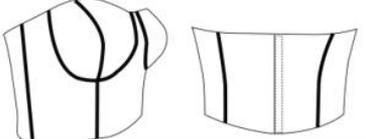
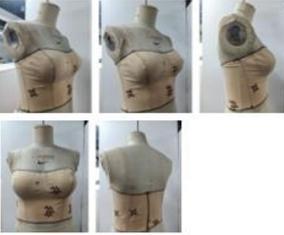
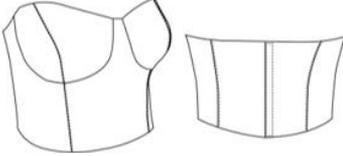
According to the product survey results, experiments are conducted to realize feasibility.



Experimenting performance wear pattern cutting techniques

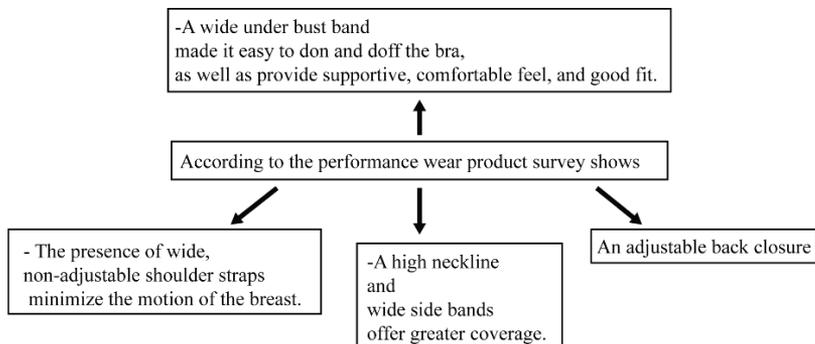
Table 2 Performance wear pattern cutting techniques experiment

Experiment	Technical drawing	Description	Outcome
		-Initial stage-finalizing fitting with woven fabrics -experimenting possibility of achieving perfect fit from woven fabric	-Woven body contouring can be achieved from previous pattern cutting methods of performance wear
		-Finalizing fitting and style lines with woven satin fabric -experimenting possibility of achieving perfect fit from satin woven fabric	-Woven body contouring can be achieved from previous pattern cutting methods of performance wear

		<p>-Experimenting body fitting by applying flat seam for style lines.</p>	<p>-Flat seam attachment on seams may add more strength and decrease the seam bulk as well as performing as a decorative stitch</p>
		<p>-Experimenting French seam with cotton fabric</p>	<p>-Attaching cotton fabric with French seam adds more strength and create body curves in more body hugging way</p>
		<p>-Parallel style lines fitting with flat seam</p>	<p>-Attaching bodice with parallel flat lock stitch lines cut down body muscles and create body curve</p>
		<p>-Inserting stretch panel to side seam</p>	<p>-Adding side seam panel with stretch fabric adjust body curve</p>

Research Method 3 - Prototype experiments.

Introducing Woven body contouring wear bodice alleviating the need of wearing a separate bra inspired from performance wear techniques (objective 3)



The prototype woven body contouring bodice styles were designed to address the following needs inspired from performance wear: minimize breast motion, support breast tissue, facilitate comfort and offer ease in donning and doffing (no fastening)

DATA ANALYSIS

In this phase of the study, The prototype woven body contouring bodice styles were designed to address the following needs inspired from performance wear: minimize breast motion, support breast tissue, facilitate comfort and offer ease in donning and doffing (no fastening).

Experiment 1

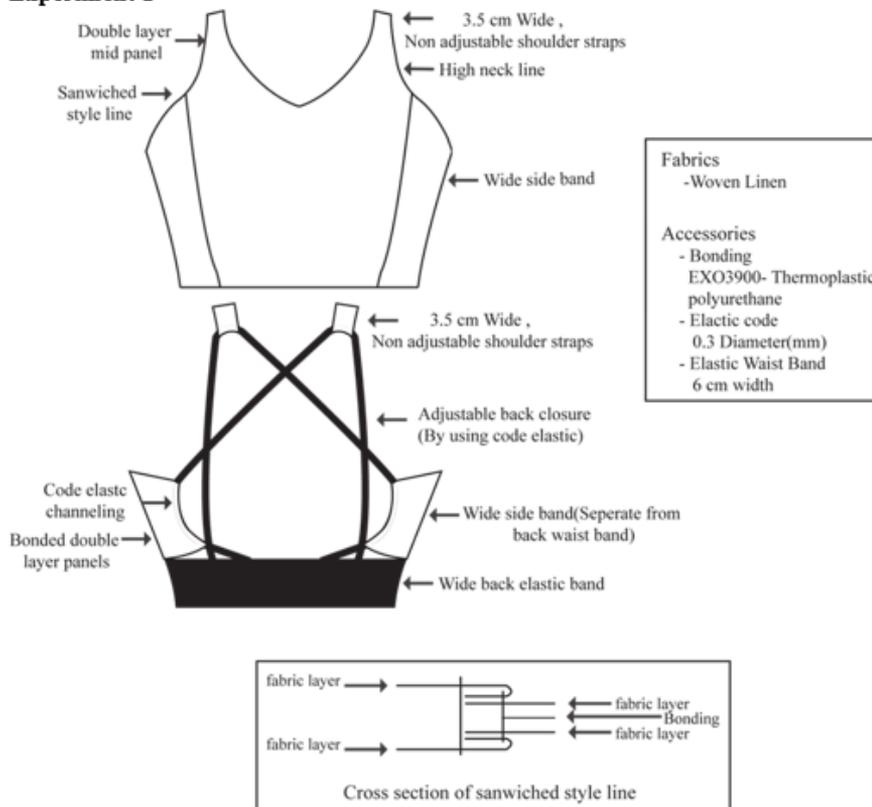


Figure 15 Experiment 1

Experiment 2

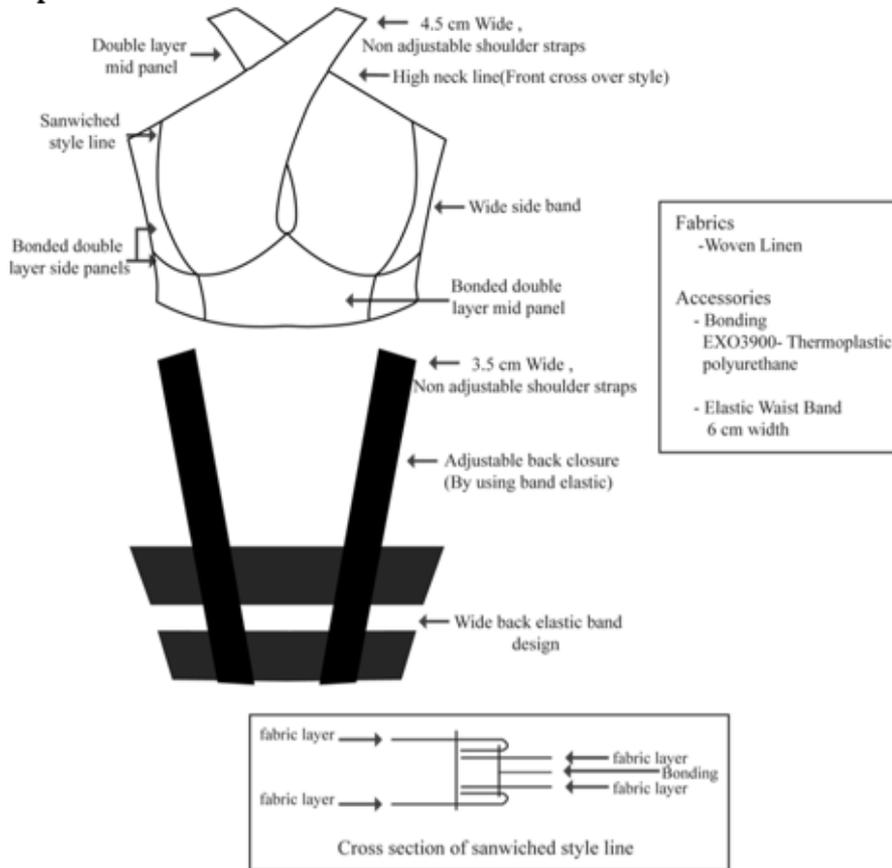


Figure 16 Experiment 2

Experiment 3

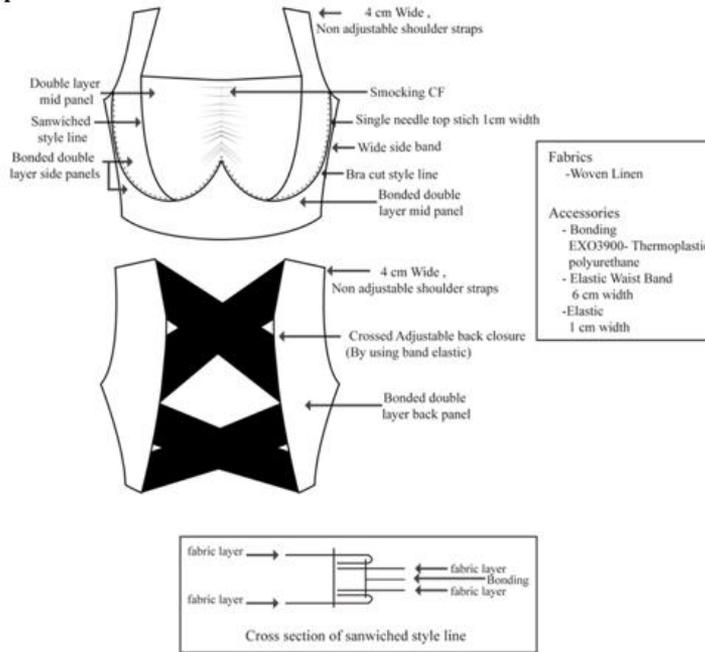


Figure 17 Experiment 3

Experiment4

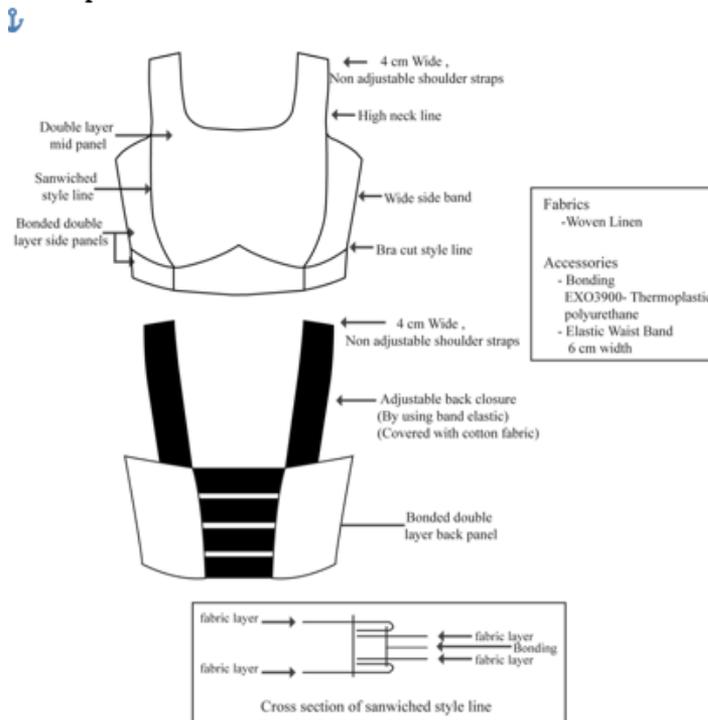
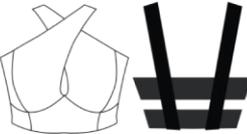
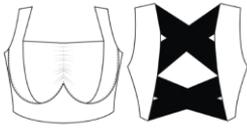
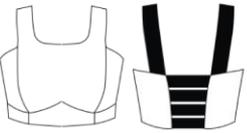


Figure 18 experiment 4

Table 1 Performance wear techniques experimenting with woven fabric

Experiment	Fabrics	Accessories	Experimented key features
1 	- Woven Linen	- Bonding EXO3900- Thermoplastic Polyurethane - Elastic code 0.3 Diameter(mm) - Elastic Waist Band 6 cm width	-Double layer mid panel -Sanwiched style line -3.5 cm Wide , Non adjustable shoulder straps -High neck line -Wide side band -Code elastic Channeling -Bonded double layer panels -Adjustable back closure(By using code elastic) -Wide side band(Seperate from back waist band) -Wide back elastic band
2 	- Woven Linen	- Bonding EXO3900- Thermoplastic polyurethane - Elastic Waist Band 6 cm width	-Double layer mid panel -Sanwiched style line -Bonded doublelayer side panels -4.5 cm Wide , Non adjustable shoulder straps -Wide side band -Bonded doublelayer mid panel -Adjustable back closure(By using band elastic) -Wide back elastic band design
3 	- Woven Linen	- Bonding EXO3900- Thermoplastic polyurethane - Elastic Waist Band 6 cm width -Elastic 1 cm width	-4 cm Wide , Non adjustable shoulder straps -Smocking CF -Wide side band -Bra cut style line -Bonded double layer mid panel -Bonded double layer side panels -Sanwiched style line -Bonded double layer side panels - Crossed Adjustable back closure(By using band elastic) -Bonded doublelayer back panel
4 	- Woven Linen	- Bonding EXO3900- Thermoplastic polyurethane - Elastic Waist Band 6 cm width	-4 cm Wide , Non adjustable shoulder straps -High neck line -Wide side band -Bra cut style line -Double layer mid panel -Sanwiched style line -Bonded double layer side panels - Adjustable back closure(By using band elastic) (Covered with cotton fabric) -Bonded double layer back panel

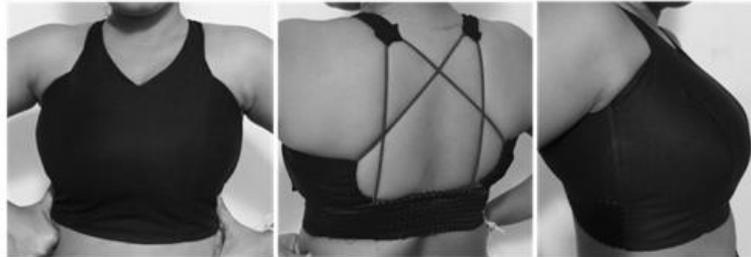
Experiments based on performance wear pattern cutting and construction methods prove the presence of wide, non-adjustable shoulder straps minimize the motion of the breast, a high neckline and

wide side bands offer greater coverage, Front bonded panels, an elasticated adjustable back closure and a wide under bust band made it easy to don and doff the bra, as well as provide supportive, comfortable feel, and good fit.

Introduced woven body contoured wear bodice, alleviating the need of wearing a separate bra inspired from performance wear techniques, is appointed woven body contoured wear with in-built breast

support with elasticated adjustable back methods without fastenings.

Fit Evaluation



Prototype 1
Front view

Prototype 1
Back view

Prototype 1
Side view



Prototype 3
Front view

Prototype 3
Side view

Prototype 3
Back view



Prototype 2
Front view

Prototype 2
Side view

Prototype 2
Back view



Prototype 4
Front view

Prototype 4
Side view

Prototype 4
Back view

The wearers' perceived fit responses to seven questions on each sample were

analyzed to compare the wearers' responses for each sample.

Table 3 Fit evaluation question table

Question 1	Physiological Fit (Physical comfort)
Question 2	Psychological Fit (Wearer's Satisfaction)
Question 3	Upward support (Limit Breast Motion)
Question 4	Comfortability
Question 5	Provide Coverage
Question 6	Offer Ease in Donning and Doffing
Question 7	Aesthetic Value (front and back styling)

Subjects were asked to express their agreement or disagreement on a five point

response scale from 1 (strongly disagree) to 5 (strongly agree).

1-5 Scale

Table 4 1-5

1	Very Dissatisfied
2	Dissatisfied
3	OK
4	Satisfied
5	Very Satisfied

Analyzing wearer perception

The wearers' perceived fit responses to seven questions on each sample were analyzed to compare the wearers' responses for each sample.

Table 5 Wearer perception of fit evaluation

Prototype	Wearer Perception of Fit Evaluation						
	Physiological Fit (Physical comfort)	Psychological Fit (Wearer's Satisfaction)	Upward support (Limit Breast Motion)	Comfortability	Provide Coverage	Offer Ease in Donning and Doffing	Aesthetic Value (front and back styling)
Prototype 01	3	4	5	4	3	4	5
Prototype 02	5	5	4	5	4	5	5
Prototype 03	4	4	5	4	5	4	4
Prototype 04	5	3	5	4	4	4	4

Based on wearer comments overall result is shown in this bar chart. All requirements that need to complete when developing woven body contouring wear alleviating the need of the wearing a separate bra are fulfilled.

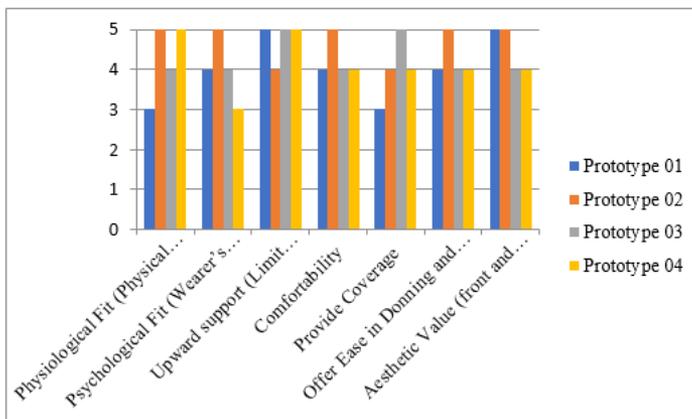


Figure 19 Comparing wearer satisfaction

Analyzing upward support

Motion was also minimized through the combining sports bra techniques such as presence of wide nonadjustable shoulder straps, high neck line and wide side bands. This line chart shows these all designs can be wear without a bra in occasional wear with good support.

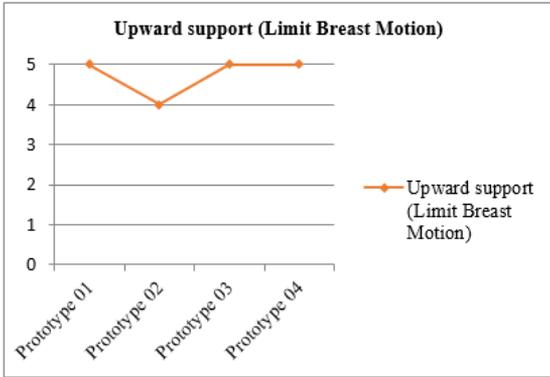


Figure 20 Line chart of upward support according to wearer perception

Analyzing comfortability

Main purpose of alleviating the need of wearing separate bra is increase comfortability .It is evident from below chart.

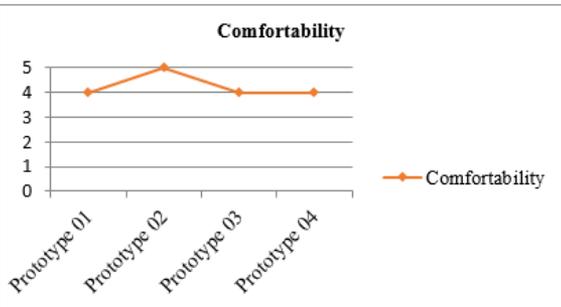


Figure 21 Line chart of comfortability according to wearer perception

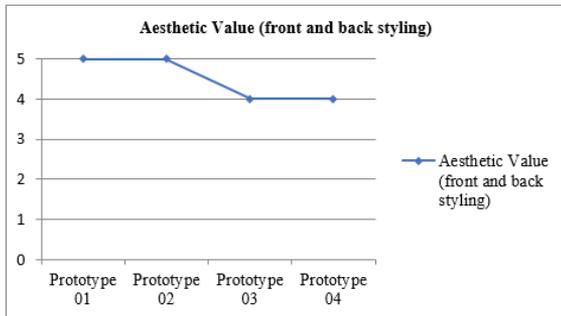
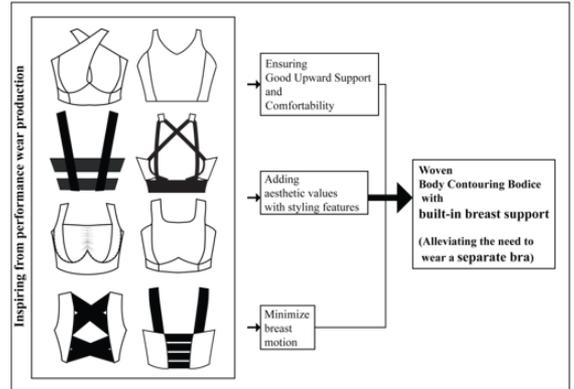


Figure 22 Line chart of aesthetic value according to wearer perception



According to the above charts it ensure the breast motion minimization, comfortably and higher aesthetic value. Based on those key features it was clear the aim of the study. All data prove it is possible to develop a woven body contouring wear bodice alleviating the need of a separate bra.

CONCLUSION

Visibility of bra straps and discomfort when wearing stylish occasional wear become main problem when selecting perfect stunning occasional wear.

Performance wear techniques ensure good upward support, limit breast motion and comfort ability. There is no need to wear a separate bra when wearing performance wear. This research was based on identify these performance wear techniques and check possibility of applying them into woven body contouring wear.

This research was targeted to achieve through three objectives. The first objective was to identify woven body contouring fashion market in Sri Lanka and identify customer need of alleviating wearing a separate bra with occasional wear. The questionnaire results indicate that there is a clear gap in woven body contouring wear in Sri Lanka and most of

the women prefer to alleviate the need of wearing a bra in occasional wear.

The second objective was to examine performance wear pattern cutting and construction techniques and check the possibility of applying them to woven body contour occasional wear manufacturing. The product survey results and performance wear construction experiments on woven fabrics shows woven fabrics can be attached with bonding tape ,visibility of bonded seams on woven are lower than lock stich bonding, bonding can be used as hem finishing(turn hem bonding / bonding tape finishing),Flat lock fabric attachment can be used with lower bulk on seam as well as a decorative seam, flat lock stich can be used as turn hem finishing, zig zag top stitching method and Using bonding as fusing of the woven fabrics may stiff and curve body gently.

Performance wear pattern cutting experiments on woven fabrics shows woven body contouring can be achieved from precious pattern cutting methods of performance wear, Flat seam attachment on seams may add more strength and decrease the seam bulk as well as performing as a decorative stich, Attaching cotton fabric with French seam adds more strength and create body curves in more body hugging way, attaching bodice with parallel flat lock stich lines cut down body muscles and create body curve and Adding side seam panel with stretch fabric adjust body curve.

The third objective was to introduce woven body contouring wear bodice alleviating the need of wearing a separate bra inspired from performance wear techniques. The systematic developments with performance wear pattern cutting and construction experiments ensure it is possible to alleviate the need of wearing bra. Based on fit evaluation, all experiments prove breast motion minimization, comfortably and higher aesthetic value..Further experiments of

variety of performance wear styles can be carried out in future. Introduced woven body contoured wear bodice, alleviating the need of wearing a separate bra inspired from performance wear techniques, is appointed woven body contoured wear with in-built breast support with elasticated adjustable back methods without fastenings.

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DEVELOPING A “READY-TO-WEAR” SAREE BLOUSE USING APPROPRIATE FABRICATION AND PATTERN CUTTING METHODS

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ABSTRACT

“Sareeya” is the commonly used office attire and & occasional wear in Sri Lanka. However, inaccurately fitted saree blouse is a significant problem. Therefore, it is essential to improve the fit of the saree blouse. The existing problems of saree blouse were identified using an online questionnaire. This study explored various methods of developing the saree blouse and presented reasonably accurate product using pattern cutting techniques and the correct raw material selection. The secondary research was carried out to examine, relevant shapewear techniques in the current market and new inventions. In addition, shop visits were used to investigate the drawbacks of ready-to-wear saree blouse which are currently available in the market. Therefore both quantitative data & qualitative data were used for final analysis. In addition experimental research method carried out for fulfill final outcome. All the findings were used to design the experiments to develop the proposed saree blouse based on right selection of raw materials, pattern cutting methods and proper construction methods. Triple cut saree blouse style was selected as the core style. Final samples constructed according to experiments and made subjective wearer trail as a validation. Ease, the number of wrinkles & seam line deviation were the criteria that have scored.

It was revealed that interesting pattern cutting techniques that can apply to enhance the fit of the saree blouse. This

study can develop further to find out more advanced methods to improve the fit, however the final product outcomes need to be validated with the cost of manufacturing.

Keywords – Experiments, fit of the saree blouse, pattern cutting techniques, raw materials, subjective wearer trial

INTRODUCTION

Clothing is a symbolic expression of non-verbal communication in modern society. According to Sharma, Agrawal, & Pathak (2014) costume is an important adjunct of personality. In Sri Lanka “Sareeya & Ohoriya” are the conventional attires that exhibit the social stratification. With modern influences, contemporary saree drapings expose sensual women body curves & the femininity. Both, six to nine yards of fabric piece and saree blouse give comparatively equal contribution to enhance natural contours of the female. The correct fit-on of saree blouse is a kind of body-fitted upper garment that covers the upper body & gives a slim and sleek shape to the feminine body contour. But it have been difficult to find correct fitted ready-to-wear saree blouse within Sri Lankan market.

Due to wide variety of body shapes and sizes, it is difficult to achieve correct fit as a ready-to-wear garments. Therefore fit problems continue to be an issue for apparel manufacturers without clear solutions.

A comfortable fit consequently makes confidence inside the wearer. The visual appearance of any garment is directly affected by the characteristics of the fabric in which it is made (Aldrich, 2012). A single design looks differently due to the variety of its raw materials.

Only few published literature exists with regards to the product named saree blouse. Since saree blouse is a body fitted garment, it compresses the body. Technically the purpose of wearing shapewear garment similar to the objective of wearing saree blouse. Shapewear has been used as foundation garment, it does not feel comfortable. Every single technique in shape wear stayed to be appear slim and sleek by compressing the body, sculpting it into a particular shape. Shape wear with firm and medium compression are best worn for only few hours because it provides powerful control to specific areas squeezing the wearer's body and restricting blood circulation. If shape wear is too restrictive, wearer may have trouble in breathing properly. (Kumanayake & Vithanage, 2017).

Therefore this study investigates the techniques of shapewear garments and apply those into saree blouse without any discomfort.

The primary outcome of this research was to introduce well fitted saree blouse using novel pattern cutting techniques as well as the appropriate raw materials. Firstly, this study depicts existing drawbacks which are related to saree blouses & identify the relevant areas to improve the product. Then Questionnaire was emailed to the relevant audience to examine significant issues with reference to saree blouse. Consequently, this study investigates the pattern cutting techniques of shapewear garments which can be used to enhance the body shape construction. And then select appropriate fabrication to develop proposed ready-to-wear saree blouse. After collate all the findings and

experiments to check the fit of the product for the purpose. Finally, this study develop fit of saree blouse without any discomfort or any health issue to wearer. Therefore, the contribution made here has broad applicability. Moreover, this product will improve the morale of the wearer of traditional "Oheriya & Sareeya" among Sri Lankan women in the future.

LITERATURE REVIEW

By the way modern Sri Lankan women more intended to wear ready-made saree blouses because of their busy life style. It saves their money, time and help to build self-confidence. The traditional saree blouse has short sleeves and a low neckline in front and back that is designed to support and mold the soft tissues of the upper female form (Varghese & Thilagavathi, 2012). However fit of the saree blouse founded as major concern (Ukalkar, 2008). This study intends to identify the issues of fit of saree blouse & develop this product to achieve the accurate fit. The fit of a garment is like a relationship between the body & the garment. The poor fit in a garment is due to the wrong measurement between any back and front length and width. The garment should lie smoothly on the body without any stain or gaps caused by excess fabric (Minott, 1991) as cited by (Varghese & Thilagavathi, 2012).

Shapewear and its construction methods were studied at the beginning of this research as of the product similarity. Shapewear generally refers to undergarments designed to control the wearer's body shape into a desired form. Typical materials used in shapewear include elastane, polyamide, latex, etc. These materials are used because of its elasticity to provide a compression. In other words, because these materials are elastic, shapewear garments can be made to be tight fitting and restrictively hold the wearer's body into the desired shape.

Common garments used as shapewear include bodysuits, brassieres, corsets, control underwear, etc.(Conde & Conde, 2014).

Shape memory materials such as shape memory polymer, shape memory alloy have qualities to deform when cold but return into pre-deformed shape when heated. Fabrics & accessories which have these qualities can use restore from deformed state back to the previous shape when induced by a specific temperature or pressure. According to Conde & Conde (2014) this techniques aid in the lifting and supporting breasts as well as other targeted areas of body. Anvaripour & Monica (2012) proposed a garment which has diamond shape area on abdomen .See fig 01, it explained this diamond shape work as a guard for providing support and

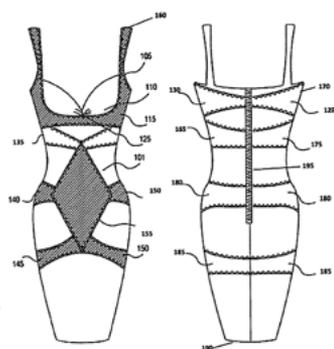


Figure 1- illustration of a garment reprinted from GARMENT FOR PROVIDING BODY SHAPNG (Anvaripour, K.2012)

Noel (n.d.) contemplated a shapewear garment which comprise sleek nylon-spandex threads that can worn under a multitudes of clothing & styles. It has described as a second skin which has high compression to slim the body for those who desire an even tighter appearance. In figure 02, comprise straps that are knitted with a gentle yet supportive weave. Those straps are thin due to prevent bulk & wide to prevent cutting into shoulders. The shoulder straps are positioned with an

flattering the stomach. It has three layers of mesh on heavy duty performance fabrics, which is use as base fabric. Top layer of mesh layers cut approximately 40% smaller than other layers of stomach guard because when it sewn to the garment it will pulls & flatten the stomach. There are three bands around the body contour and upper band support to lift the breast, middle band wrap around the hips and connect to the stomach guard to provide support to “love handles” which are besides of the waist. Third band connected stomach guard to shape and slim buttocks. Power mesh which is around back helps to reduce back fat and smooth bulges caused by bras. Performances of power mesh helps to reduce lumps and irregular shaping of the body. Zigzag stitch used to give extra strength, durability and flexibility.

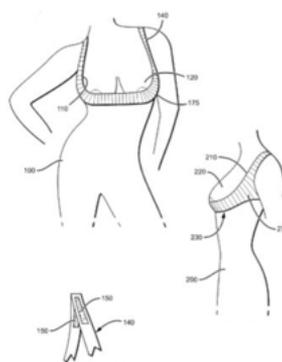


Fig BODY GARMENT AND SHAPEWEAR DESIGN AND METHOD OF USE (Noel, n.d.)

inward design which can prevent being seen when worn a sleeveless garment. Trimmed upper areas of shoulder straps to perform as shelf bra that can be easily tucked under the lower seam of a separated bra. A band which is goes under shoulder straps gently woven as a support. This multi-purpose, complex design allows the shelf bar to fit comfortably into a bra, or to support the breast when not worn a bra.

It is natural to visible skin flabbiness and wrinkles around upper arms and

forearms due to muscle aging & excess weight. Thompson (n.d.) contemplated some ideas to overcome from that issues.

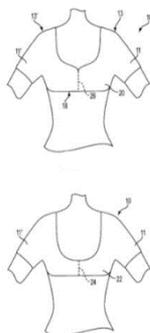


Figure 3-illustrate front and back views of a Women's sleeved under/outer garment, according to an embodiment of the present invention reprinted from (Thompson, n.d.)

This invention can wear as an either outer wear of inner wear. Sleeves of this contemplated garment can be attached or removable.in figure 03, area 20 which is made with elastic material comprise the breast instead of wearing separate bra, and also there is a foam cup to give lifting and desired shape. Sleeve area also made from similar material. But sleeve can be short or long as requirement. Sleeves fitted around arm to get sleek look. Shoulder areas made with same elastic and tight material due to comprise that area by creating sleek, fitted look. But as the requirement can be change the material. In addition shoulder section provide additional support to conventional bra to prevent slipping off the shoulders of the wearer. Lower midriff edge positioned according to desired shape. If it is placed just below the bust line it will give a snug fit over conventional bra. Lower midriff may be positioned lower to minimize undue bulkiness of torso. Thompson (n.d.) derived some other contemplated ideas from this core idea.

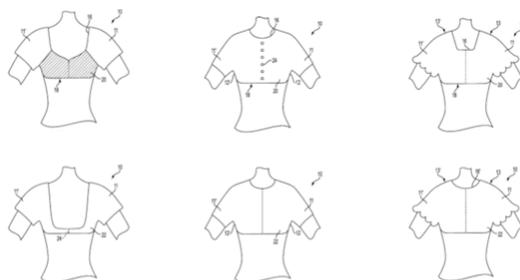


Figure 4- illustrate front and back views of another embodiment of the present invention including decorative sleeves (Thompson, n.d.)

Figure 5-illustrate front and back views of yet another embodiment of the present invention including tight fit under-arm regions. (Thompson, n.d.)

Figure 6- illustrate front and back view of yet another embodiment of the present invention including a multiple material covering (Thompson, n.d.)

Today, as result of development of technology shape wear is combined with different compression levels to achieve desired shaping results. Different techniques such as seamless technology, advanced pattern cutting techniques and advanced materials are used. Not only using body compression methods but also combine with body enlarging methods such as applying silicone form, pads help to fulfill different requirements and reach perfect body shape.

According to Conde & Conde (2014) , one drawback with traditional shapewear is that the garments are intentionally made to be tight fitting, by providing over all compression to accomplish the shaping goal. However, this makes the garments difficult to wear. It can be a struggle to even get into the garment itself. The underwire are typically rigid and tend to dig into the body of the wearer, and as a result, may be very uncomfortable for a wearer. & also (Morosini, 2016) described that wearing garments which are compress our body for long time may cause to health issues.

In addition Stretch is a most important property of textile that can contribute to wearer comfort. The stretch yarn and fabrics are widely used in last few years all over the world because of their shape retention properties.

Drapability of fabric decided the placement of the seams of the garment. The drape coefficient was greater on samples with seams than samples without a seam (Varghese & Thilagavathi, 2012).

Moore (1992) as cited by (Varghese & Thilagavathi, 2012) described fabric grain alignment is one of the most important factors to consider when analyzing a garment's fit and drape. Varghese & Thilagavathi (2012) revealed that warp grain received a higher rating from wearer trail and gave better fit with fewer wrinkles, the saree blouse material with higher thickness, weight, and cover factor draped well through the body corners and gave better fit to the wearer. Lightweight blouse materials show more wrinkles and seam line deviations in blouse and affect the fit of the blouse.

McKinney et al. (2012) developed a model to study the relationship of the human body to the garment. According to that model fit evaluation with objective measurements involves space between the body and the garment. The subjective measure is studied by analyzing the observer's perception of the garment fit and wearer's perception of how the garment fits (Varghese & Thilagavathi, 2012).

Research Approach

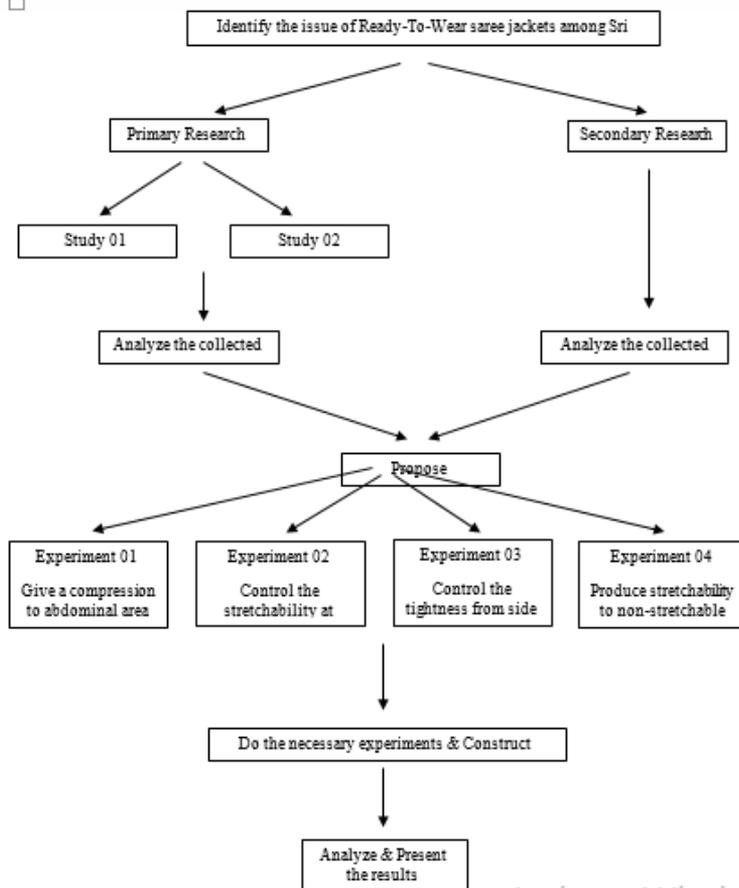


Figure 7-Research Process

Study 01 – Questionnaire survey

Initial survey was carried out to identify research gap. It revealed existing issues relevant to the saree blouse. The questionnaire was distributed via social media among working & non-working women who are in the 20-60 age range, living in the western province. Data received from 100 participants.

Table 1- age range of sample

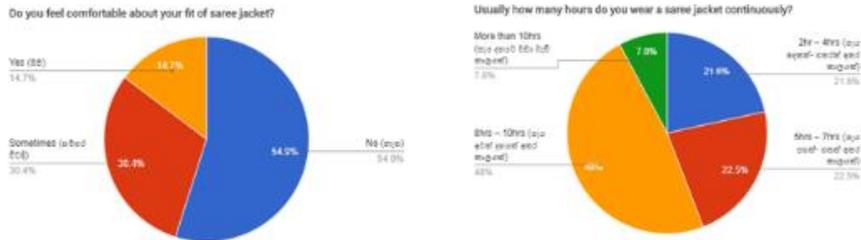
Age range	Sample size
20-30	59
31-40	25
41-50	15
51-60	3

Table 2 -occupations of sample

Occupation of participants	Sample size
Undergraduate	27
Educational	46
Creative industries	6
Business & financial	8
Healthcare	3
Engineering & manufacturing	10

The highest number of responses received from teachers who are in the age limit of 20-30. Therefore, that sample was referred when designing the experiments.

According to the survey results, majority of women were not satisfied with fit comfort of saree blouse & 48% women wear saree for more than 8 hours.



Too tight, rolled-up the waist line, shoulder fallen down, not having accurate bust shape, bust point not in accurate point, underarm wrinkles, too tight, poor posture, skin irritations, back pain, neck pain, shoulder are the issues found from investigation. The majority of women (22%) suffered from the tightness of the saree blouse due to the fact of its being a tight-fitting costume.

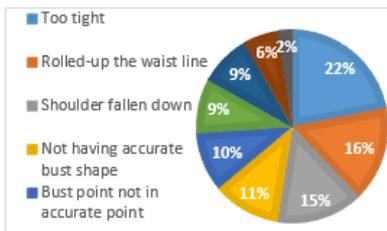


Figure 10- Problems due to incorrect fit of the saree blouse

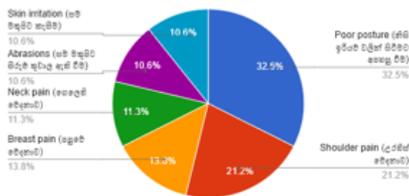


Figure 11- Prolonged issues due to fit of the saree blouse

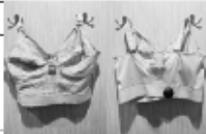
Due to the difficulties mentioned above, customers faced prolonged health issues such as displayed on (fig.7). 32.5% of women faced the issue of poor posture. Therefore, this study intends to develop a saree blouse to overcome those issues.

Study 02 – Product survey

Product survey were carried out to explore existing shapewear products and its construction including fabrication. High street shops in Sri Lanka was selected for the Product survey and branded export quality products also reviewed at the manufacturing organizations. Products were reviewed for its construction and raw materials.

Analysis of existing shapewear garment techniques

Table 3-Analysis of data gathered from shop visit

PRODUCT CODE		01 – shapewear for upper body (cover the breast & it look like a bra which have extended up to waist line)			
MATERIALS		<ul style="list-style-type: none"> Elastics (different widths) Stretchable fabrics Non-stretchable fabrics Lace Stabilizers 	<ul style="list-style-type: none"> Rings and slides Plastic bones Hook & eye Strap elastic 		
FASTENING METHOD		Hook and eye			
STITCHES	STITCH TYPE	zigzag (this stitch type used at stretched areas of garment)	Flat lock (this stitch type use at stretched areas but it has more secure than which has used zigzag)	Double needle (type of lock stitch)	
	USAGE	<ul style="list-style-type: none"> Neckline Underarms Attached strap elastic, hook and eye 	<ul style="list-style-type: none"> Attached bottom band to waist line (give extra length to garment) 	<ul style="list-style-type: none"> Used for attach all pieces (because at side seams do not need to stretch just need to fixed the shape from that places) 	
TECHNIQUES		<ul style="list-style-type: none"> Used 2" wide elastic as a bottom band – it gives more support to lift and shape the abdominal areas. Used plastic bones at side seams – it gives extra lifting and shaping. Front panel divided into 14 pieces symmetrically, according to body shaping control zones (each side has seven panels). Used different type of lining fabrics according to the areas which need to shape up. Used wide strap elastics to give extra strength to lifting the breast. The elastic which are used to neckline and underarm also wider than normal bra usage. Used hook and eye with two stripes of adjustable. Combine two layers in the areas which need high shaping like belly area (as here use the lace fabric to control stretchability of base fabric). Attached tape using cover seam method to cover all the seams. 			
PRODUCT CODE		02 – shapewear for upper body but doesn't cover the breast (coverage start under the bust line)			
MATERIALS		<ul style="list-style-type: none"> Power mesh Lace Elastics Plastic bones Hook and eye 			
FASTENING METHOD		Hook and eye			
STITCHES	STITCH TYPE	Zigzag	Overlock	Flatlock	Double needle
	USAGE	<ul style="list-style-type: none"> Attach bottom band, elastic hook and eye, front lining layers, back lining layers to base fabric Neckline & underarm 	<ul style="list-style-type: none"> Shoulder attachment Attached front and back panels together 	<ul style="list-style-type: none"> Attached front panels together 	<ul style="list-style-type: none"> Fortitude attachment
TECHNIQUES		<ul style="list-style-type: none"> Used 1.5cm width elastic at the waistline. Used bones at the back, it helps to shape the back extra fat & help to lift them. Attached fortitude to side seams give extra tension. For requirement of high body shaping parts used double layers of fabric. Hook and eye-six rows, six adjustable (this technique helps to increase the durability of garment). According to body shape control areas attach liner fabric in same as base fabric at the back and use zigzag stitch to attach them. Neckline & armhole covered using piping. Bottom band fold and turn over. Then attach elastic using zigzag. Front panels assemble using both flatlock and zigzag. Front and back panels attached using overlock at side seams. Then cover it using fortitudes. 			

PRODUCT CODE		03 – Shapewear for upper body (Attached a hook and eye at gussets.)		
MATERIALS		<ul style="list-style-type: none"> Knit fabric Lace Power mesh Elastic Covering zipper Hook and eye Zipper – at center front Hook and eye – at center front and gussets 		
FASTENING METHOD		<ul style="list-style-type: none"> Zipper – at center front Hook and eye – at center front and gussets 		
STITCHES	STITCH TYPE	Flatlock	Lockstitch	Double needle
	USAGE	<ul style="list-style-type: none"> Attached front, lower panels 	<ul style="list-style-type: none"> Attached back panels, front panels at side seams, back panels at center, hook & eye and zipper, lining at the back 	<ul style="list-style-type: none"> Attached upper parts of front panel
TECHNIQUES		<ul style="list-style-type: none"> This garment has enhanced different shaping areas than previous garments. Used different type of fabric as base fabrics. It looks like a knitted fabric & also used lace and power mesh as lining. Used covering zipper as a fastening method of front base layer. For underneath layer used hook and eye as fastening method (different fastening methods used at same places). Neckline, underarm and leg whole edges covered using piping. There is an elastic at the center back. It has attached using zigzag. It seems base of back panel separately attached at the center back and attached elastic on the seam of it. Used flatlock stitch at the lower parts of front panels, upper parts attached using double needle stitch. Overlock & attached gussets to upper body parts of garment. Hook and eye attached to gussets. Lining done using mesh fabric and it has attached using zigzag. 		



Activate
Go to Settings

PRODUCT CODE		04 – Shapewear for both upper & lower body (all in one garment)		
MATERIALS		<ul style="list-style-type: none"> Power mesh Knit fabric (looks like a t-shirt fabric/used for piping) Lace 		
FASTENING METHOD		Hook & eye		
STITCHES	STITCH TYPE	Zigzag	Flatlock	Lockstitch
	USAGE	<ul style="list-style-type: none"> Attached bottom band, hook and eye, lining, elastics, piping 	<ul style="list-style-type: none"> Attached front lining 	<ul style="list-style-type: none"> Side seams
TECHNIQUES		<ul style="list-style-type: none"> In front of the garment there were two layers. The top layer covers only upper body and use hook & eye as fastening method. It seems it'll give good support to shape up the body. There are bones align to rib cage. It helps to shape the belly area. This top layer fully lining with the same fabric. At the waist line there was an elastic which has attached as a bottom band. Second layer was start at the under bust line & it extended as a short to shape the lower body. It has used lockstitch at the side seam & attached elastic to cover that seam. At the center back there is an elastic. There was a zigzag stitch along the shape of buttock area to enhance that shape & attached elastic using zigzag to panty lines of back. Neckline, armhole finished using piping. 		



PRODUCT CODE		05 – Shapewear which covers only belly area		
MATERIALS		<ul style="list-style-type: none"> Knitted elastics which have plastic fibers Plastic bones Woven elastics Velcro tapes Knitted fabric 		
FASTENING METHOD		Velcro tape		
STITCHES	STITCH TYPE	Lockstitch	Zigzag	
	USAGE	<ul style="list-style-type: none"> Attached woven elastic, velcro tapes, additional stripes Stitched the divided front pieces together 	<ul style="list-style-type: none"> Covered the edges using piping 	
TECHNIQUES		<ul style="list-style-type: none"> It has used knitted elastic which has mixes plastic fibers. This elastic doesn't narrow when it stretched. Therefore, the durability of this garment comparatively higher. There are woven elastic straps and additional strap attached at center back. Woven elastics attached in some distance in vertically. It gives more support to lift excess of fat. The additional straps can stretch as consumer's favor and fastening using Velcro tapes. There are removable semi-rigid plastic bones at the back of garment, it gives or strength to lift the back muscles. Edges covered using knit fabric as a piping. 		



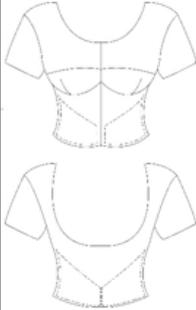
Advantages & disadvantages of existing ready-made saree blouse & tailor-made saree blouse

Table 4-analysis of existing ready-made saree blouses and tailor-made saree blouses

	Advantages	Disadvantages
<p>Ready-to-wear saree blouse</p> 	<ul style="list-style-type: none"> • It has comparatively low price. • Can use it right away after buying. • Available on online stores. • Save time spent on construction as in case of tailor-made saree blouse. 	<ul style="list-style-type: none"> • Sizes are standardized and with a limited fit. • The garment cannot be customized. • Fabrics are not always of the best quality. • Fit is not satisfied level. It showcase belly fat, back fat clearly.
<p>Tailor-made saree blouse</p> 	<ul style="list-style-type: none"> • It has perfect fit. • It can be completely customized. • Can be use quality materials. • Can be highlight personal style. 	<ul style="list-style-type: none"> • Must go to a tailor. • Waiting time is often very long. • Numerous refinement meeting are needed. • The price is rather high.

Proposed Experiments

Table 5-Explanations of experiments

	Product design sketch	Expected outcome	Inspiration
Experiment No. 01		<ul style="list-style-type: none"> • Reduce appearance of belly area & back fat using different accessories such as power mesh 	<ul style="list-style-type: none"> • “Garment for providing body shaping”- research paper by (Anvaripour & Monica, n.d). • Shapewear product review
Experiment No. 02		<ul style="list-style-type: none"> • Control extra stretchability of fabric in certain areas blouse while shaping the body • Give extra stretch at waist line to prevent rolled up issued. 	<ul style="list-style-type: none"> • Shapewear product review
Experiment no 03		<ul style="list-style-type: none"> • Shape up the body using both stretch fabric & non-stretch fabric & it control the tightness issue of saree blouse 	<ul style="list-style-type: none"> • “Handle and Comfort Characteristics of Cotton Core Spun Lycra and Polyester/Lycra fabrics for application as Blouse”- research paper by (Varghese & Thilagavathi, 2012) • Shapewear product review
Experiment no 04		<ul style="list-style-type: none"> • Give <u>stretchability</u> to saree blouse using non-stretchable fabric 	<ul style="list-style-type: none"> • “Designing of functional sari blouse for arithmetic women”- research paper by (Ukalkar, 2008)

Development of the saree blouse
Material aspects

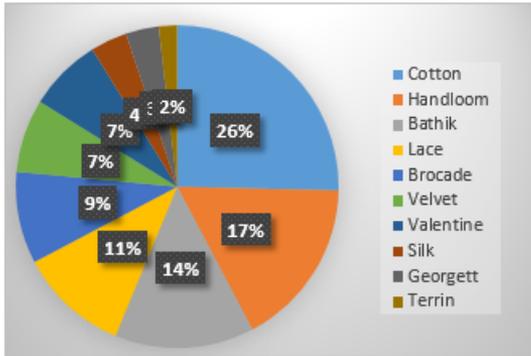


Figure 12-Fabrics used for saree blouse

(Varghese & Thilagavathi, 2014) described, Stretch is often the most impotent property of a textile that contributes to weather comfort. But it is difficult to get stretchability from 100% cotton fabric. It gave the influence to go for the stretch cotton.

From advance pattern cutting techniques supposed to achieve slim & sleek appearance & to go to apply shapewear techniques to saree blouse. Stretchability is the main requirement for shapewear.

As a final result, 100% pure cotton, stretch cotton (cotton 97%, spandex 3%), knitted polyester fabric (polyester 80% spandex 20%) have chosen as experimental fabrics.

Pattern design & Garment construction

The response of the questionnaire showcases what is the most preferable saree blouse style (fig.9) Therefore, chosen the triple cut style as the core style & use the basic pattern of this style to cut panels. Hook & eye used as a closer method.

Through the questionnaire able to find out what is the most preferable fabrication use for a saree blouse.

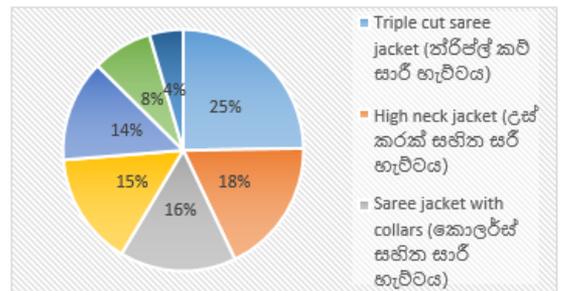


Figure 13-Most wearable saree blouse styles of saree blouse by consumer

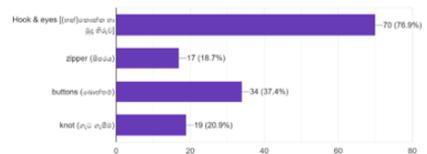


Figure 14-Most preferable closure methods

UK size 12 was chosen as the desired size criteria. Standardized UK size 12 dummy measurements are shown in the following table.

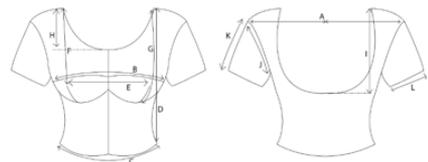


Figure 15-Body dimensions

Table 6-Measurement table

	Description	Measurements (inches)
A	Shoulder length	15
B	Circumference of bust	34 ¼
C	Circumference of waist	26 1/8
D	Blouse length	15 ¼
E	Distance between bust point	7 ¼
F	Shoulder to bust point	9 ¼
G	Shoulder to under bust	12 ¼
H	Front neck depth	6 ½
I	Back neck depth	9
J	Armhole circumference	17 3/8
K	Sleeve length	5
L	Sleeve open	11 ¼

Pre-Product Planning (mock ups)

Before the experiments it has done some mock ups to select best methods which are going to apply from each experiment.

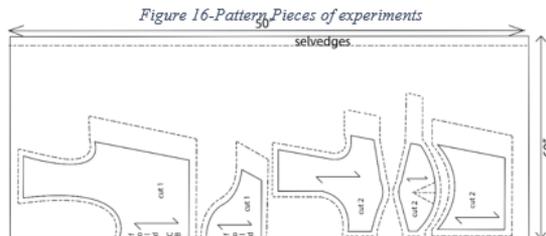
Table 7-Pre-product experiments

Knitted polyester fabric used as base fabric. Power mesh used as lining fabric.		
		
Both base and lining fabric in same size.	Lining smaller than ¼ inches than base fabric.	Lining smaller than ½ inches than base fabric.
<ul style="list-style-type: none"> No wrinkles Control the stretchability from power mesh Smooth fit 	<ul style="list-style-type: none"> Slight wrinkle on base fabric Perfect fit Give extra tightness due to the smaller lining 	<ul style="list-style-type: none"> Wrinkles clearly visible Comparatively too tight
Stretch cotton fabric used as base fabric. Power mesh used as lining fabric.		
		
Both base and lining fabric in same size.	Lining smaller than ¼ inches than base fabric.	Lining smaller than ½ inches than base fabric.
<ul style="list-style-type: none"> comparatively fit it smooth than polyester base 	<ul style="list-style-type: none"> Tight but not too much Slight wrinkle 	<ul style="list-style-type: none"> Too tight than others Wrinkles clearly visible than other samples
Elastic which have 1 ½" wide (made using plastic fibers)		
		
Attached elastic using lockstitch.	Attached elastic using zigzag.	
<ul style="list-style-type: none"> Break the stitches easily 	<ul style="list-style-type: none"> Give excess ease to stretch without any breaks 	
Control extra stretchability at certain areas using fusing		

		
One layer of fusing paste on stretch cotton.	Paste Two layers of fusing.	Attached two layers of stretch cotton fabrics which have separately paste one layer of fusing in each stretch cotton layer.
<ul style="list-style-type: none"> Control the stretchability but pasted fusing has torn easily. 	<ul style="list-style-type: none"> Too tight and the area which has not fusing didn't perform well as stretch fabric. 	<ul style="list-style-type: none"> Two layers gave extra strength and it was not torn.
Try smoking methods to get stretchability from non-stretchable fabric		
		
Smoked using elastic thread.	Smoked using honey comb smoking method.	
<ul style="list-style-type: none"> It was difficult to finish the edges. 	<ul style="list-style-type: none"> Comparatively have more fabric excess to be stretch 	

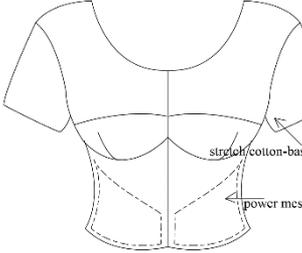
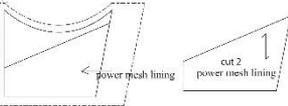
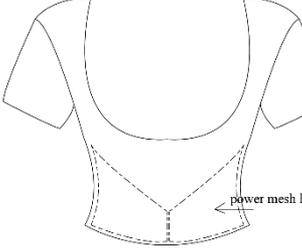
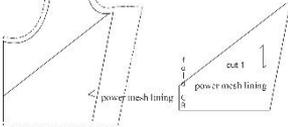
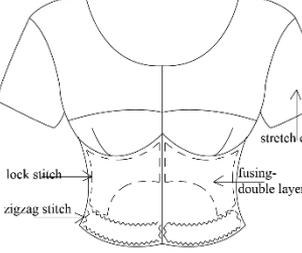
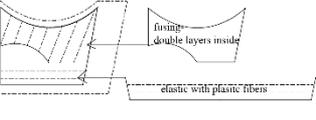
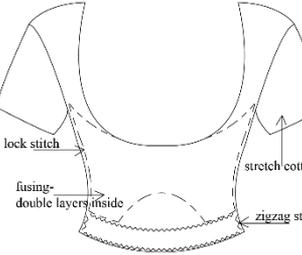
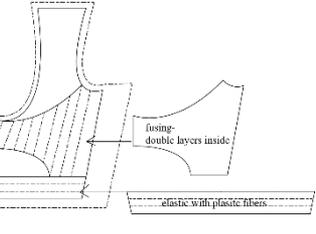
Lay plan of the core pattern pieces.

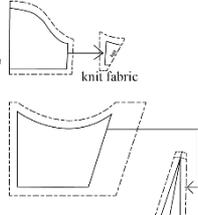
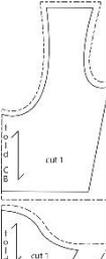
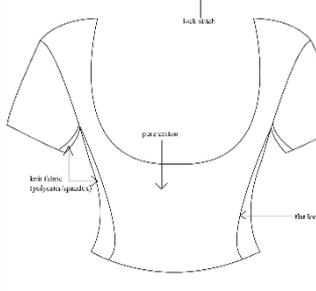
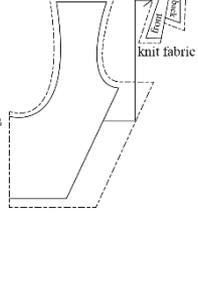
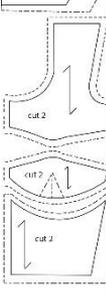
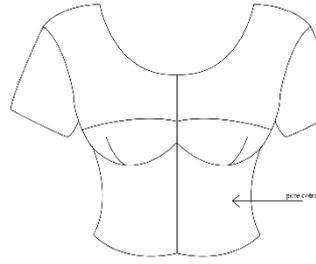
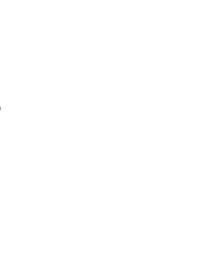
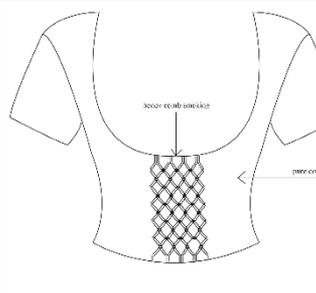
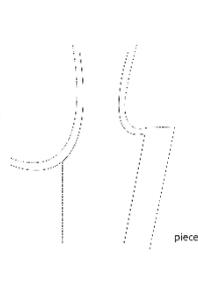
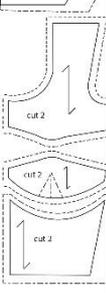
This is the lay plan of triple cut saree blouse pattern pieces which was use for the experiments



The table below describes the alternations which have done for core pattern pieces in each experiment & visual analysis of predicted experiments.

Table 8- Lay plan for each experiment

	Illustrated embodiment	Pattern pieces
<p>01</p> <p>Front</p>		
<p>Back</p>		
<p>02</p> <p>Front</p>		
<p>Back</p>		

<p>03</p> <p>Front</p>			
<p>Back</p>			
<p>04</p> <p>Front</p>			
<p>Back</p>			

DATA ANALYSIS & RESULTS

Table 10-Technical analysis of experiments

	Fabrics	Accessories	Stitch type	Techniques
Experiment no 01	<ul style="list-style-type: none"> Stretch cotton (97 % cotton / 3 % spandex) Power mesh 	<ul style="list-style-type: none"> Stabilizer Hook & eye 	<ul style="list-style-type: none"> Single needle – attached front panels Double needle – attached power mesh 	<ul style="list-style-type: none"> Double layers of power mesh used to shape up the abdominal area. Top layer of power mesh smaller than bottom layer. Edges of mesh layer covered using stabilizer Mesh layer attached using double needle to give extra tension
Experiment no 02	<ul style="list-style-type: none"> Stretch cotton (97 % cotton / 3 % spandex) 	<ul style="list-style-type: none"> Fusible web Stabilizer 	<ul style="list-style-type: none"> Single needle – attached front panels. Attached fusing to panels. Zigzag – attached elastic band 	<ul style="list-style-type: none"> Stretch cotton used as a main fabric. Used double layers of fusible web to compress to abdominal area and back fat. Elastic which have 1 ½” width attached to waist line (that elastic made with plastic fibers which can control excess extensions). Used single needle stitch type along edges of fusing layers to give extra strength.
Experiment 03	<ul style="list-style-type: none"> Pure cotton (100% cotton) Knit fabric (80% polyester / 20% spandex) 	<ul style="list-style-type: none"> Hook & eye – 1 row, 2 adjust (1 ½ inches) 	<ul style="list-style-type: none"> Single needle – attached front panels, shoulders Flatlock attached knit fabric and cotton fabric layers at the side seam 	<ul style="list-style-type: none"> Attached knitted polyester fabric at the both sides. But removed side seams. Attached adjustable hook and eye as the fastening method
Experiment 04	<ul style="list-style-type: none"> Pure cotton (100% cotton) 	<ul style="list-style-type: none"> Hook and eye 	<ul style="list-style-type: none"> Single needle – attached each and every panels Hand stitch – done honey comb smoking 	<ul style="list-style-type: none"> Used honey comb smoking at the back of the blouse. Used elastic thread for smoking because it needs to be flexible to stretch.

Fit evaluation

For the fit evaluation, have completed a Subjective Wearer Trail by the participation of three undergraduate students of Fashion Design & Product Development degree in University of Moratuwa. Before the fit, it has given a brief introduction of this research to them. Then asked them to mark their satisfaction on each criterion. Ease, number of wrinkles & seam line deviation were the criteria that have scaled-down into five stages.

After basic movements, wearer rated on the scale of ease criteria from very flexible to very stiff. After the fit on, the subject was counted the number of wrinkles and rate the number of wrinkles scale. Seam line deviation measured if the seam line precisely at the bodyline. Deviation measured at shoulders, sleeves and side seams.

For the final evaluation above, different scales summarized into one scale rating.

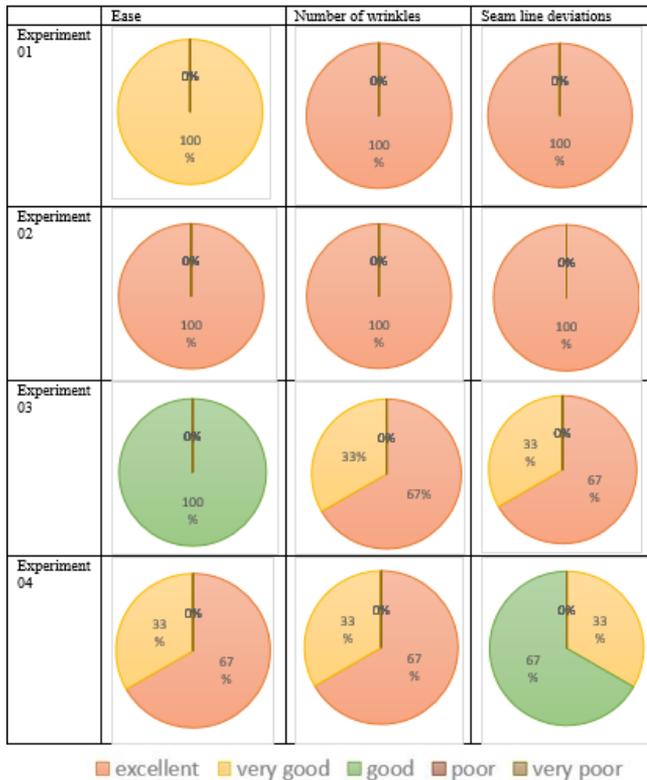
Table 11- Rating scale for ease, number of wrinkles and seamline deviation

	Ease	Number of wrinkles	Seam line deviation (mm)
Excellent	Very flexible	0 – 10	5 – 10
Very good	Flexible	11 – 20	11 – 15
Good	Medium	21 – 30	16 – 20
Poor	Stiff	31 – 40	21 – 25
Very poor	Very stiff	41 – 50	26 – 30

Table 12-Visual evidences of wearer trial

	Experiment 01		Experiment 02		Experiment 03		Experiment 04	
	Front	Back	Front	Back	Front	Back	Front	Back
Wearer 01								
Wearer 02								
Wearer 03								

Table 13-Wearers' score of fit rating



Cost Analysis

Experiment	Materials	Unit cost (LKR)	Consumption	Cost (LKR)
Experiment No.01	• Stretch cotton – (both base and lining fabric)	300 (1 yard)	2 yards	600
	• Power mesh	200 (1 yard)	½ yard	100
	• Hook & eye	3 (1 pair)	4 pairs	12
	• Thread	100 (1 cone)	1/10 cone	10
	Final cost			722
Experiment No.02	• Stretch cotton – (both base and lining fabric)	300 (1 yard)	2 yards	600
	• Fusible web	100 (1 yard)	¼ yard	25
	• Hook & eye	3 (1 pair)	4 pairs	12
	• Thread	100 (1 cone)	1/12 cone	8.33
	Final cost			645.33
Experiment No.03	• Cotton (base fabric)	275 (1 yard)	1 yard	275
	• Poplin (lining fabric)	130 (1 yard)	1	130
	• Polyester spandex mixed fabric	300 (1 yard)	¼ yard	75
	• Hook & eye stripe	100 (1 yard)	¼ yard	25
	• Thread	100 (1 cone)	1/10 cone	10
	Final cost			515
Experiment No.04	• Cotton (base fabric)	275 (1 yard)	1 yard	275
	• Poplin (lining fabric)	130 (1 yard)	1 yard	130
	• Hook & eye	3 (1 pair)	4	12
	• Thread	100 (1 cone)	1/10 cone	10
	Final cost			427

Table 14-Cost Analysis

DISCUSSION

Apparently, wearer complaints about the fit of the saree blouse due to incorrect fit & the appearance. This study carried out some experiments, after analyzing all the data which collected from primary & secondary resources. Power mesh gives strength to the garment due to its stretchability. Experiment No.01 used the power mesh as two layers, and the bottom layer is smaller than the top layer (which is 1/4 inches) because it gives extra support. This support used to reduce the appearance of back fat & belly fat. Using double needle stitch along the edges of power mesh layers create a tension to reduce the excess extensions.

Experiment No.01 & 02 have used stretch cotton as the main fabrication because its stretchability has given the solution for tightness & looseness. Moreover, it does not destroy the aesthetic aspects of the saree blouse due to fabric composition, which has 97% of cotton. The second experiment has been used fusible web layers to avoid extra stretchability on abdominal area & back area. Wide elastic band with plastic fibers gave a solution to the not only rolled-up waistline but also gave extra strength to the waistline.

If there is any consumer who does not interested in stretch cotton, then the experiment No.03 & 04 suggests appropriate solutions. In experiment No.03, it has attached knitted polyester fabric layers at both sides in blouse and sleeves. The tightness of the sleeves can avoid using this solution. This blouse suitable for consumers who have the same cup size but different band sizes on their bra. Instead of using stitch type for attached knit fabric panel at side seams, which can be used as the bonding technique. It gives more finishing effect on the garment. Experiment No.04 reveals a simple solution for the consumers who are concerned about the tight-fitting of the

saree blouse. Honeycomb smoking is popular method to get stretchability from non-stretch fabric.

Experiments that have done in this study can directly apply to the saree blouse because the validation was done with subjective wearer trial. Basically, tailor-made saree blouse & ready-made saree blouse (in the current market) cost around USD 8.04 .However, the proposed product from this study, cost below USD 5.36 without the cost of tailoring, but if add tailoring cost it might increase.

CONCLUSION

It has been clearly revealed that most of the consumers are dissatisfied with the fit of the saree blouse. This study experimented different pattern cutting techniques, with different raw materials to enhance the fit of the ready-to-wear saree blouse. Incorrect fit of saree blouse occurs construction issues, incorrect measurements, unfitted fabrics or belly fat, back fat, armpit fat, different shapes of shoulders. After analyzing the collected data from a structured questionnaire survey, product survey and published literature found out issues that affected to fit of saree blouse & pattern cutting techniques, which can give solutions for those issues.

Experiments were done using different fabrics, accessories, construction methods. Finally, done a subjective wearer trail for validations. According to their responses, those techniques gave sufficient support to enhance the fit of the ready-to-wear saree blouse.

Further studies are recommended to improve the value addition. However, designers and developers can try out various products based on these experiments and propose products according to the product costs.

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PLUS SIZE CLOTHING CHALLENGES AND NEW OPPORTUNITIES FOR ATHLEISURE WOMEN'S WEAR

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ABSTRACT

Being a plus size middle aged woman is a special confidence level, because they concentrate about their health while accepting the fact that they are oversized. To continue an active lifestyle, they have been created a market demand for athleisure wear not only because of the health conscious lifestyle but also it is an acceptable dress code in the working environment to live a fashionable lifestyle. Initially, plus size women's wear have been explored and the data collection was focused in Sri Lankan market. The FEA model was followed to investigate the product attributes and presents the requirement analysis of such clothing. The fear of getting non-communicable diseases (NCD), being busy at work place and lack of time to do exercises, fashion consciousness and high BMI rates motivates plus size ladies to get engaged in activities like jogging, cycling and yoga. Further this study expected to explore the potential opportunities in plus size athleisure market and present the requirement analysis for product design & development. Qualitative research methods were utilized mainly a survey conducted by meeting the relevant participants and extended further open-ended questions by face-to-face interviews with them. Mainly, wearer's responses were collected in their buying behaviour, problem identification and customer satisfaction, consumer preferences in athleisure category.

This study has found out that most of the Sri Lankan plus size middle aged ladies are working women who are busy with their routine and unable to utilize effective time for physical exercises. As preferences, they will be worn black or any dark color, cotton knitted fabric, functional & fashionable athleisure wear not only as a workout wear but as a whole day wear.

Keywords: - Athleisure, FEA model, Plus size clothing, Product attributes

INTRODUCTION

Background of the study

As fashion world is getting more and more competitive, people start to explore it more and more. Not like back in the days, nowadays almost all of the plus size women do not worry about their body sizes because they love their body and give the value to their body. Size 12 body concept is fading away since plus size women came out of the cage and showed their beauty without disappointments. The size of the 'ideal female body' is also getting bigger because of the influence of plus size women to the fashion world. "Studies show that it is possible to be overweight and even obese and fit" (Mitton, 2019).

"What determines your health is how physically active you are, not how thin you are" (Nast, n.d.). This statement shows the

importance of a healthy lifestyle for any body size.

Since most of the plus size middle aged women are working women, they cannot engage in a sport because for a sport they have to get ready, need specific clothes and accessories, most importantly they need dedicated time for that. This research also is to find out what are the activities ladies would do to maintain a healthy life while having a busy lifestyle (Study 01 – Appendix III).

Women’s Plus Size Athleisure Market in the world

The definition of ‘Athleisure wear’ – “According to Merriam-Webster, Athleisure definition is casual clothing designed to be worn both for exercising and for general use” (Hanif, 2018).

In other ‘fashion conscious’ countries, consumers and designers are focusing about athleisure wear categories and offering many choices to consumers to make sure their high standard lifestyle. Apart from athleisure there are many categories such as ath-work, work to jogging, work to run, work to gym kind of categories that inspire consumers to be active in a possible way. Even though there is a huge demand in athleisure wear market, most of the international brands not offering plus size athleisure wear due to, more time consuming, more difficult and more expensive to create the extended sizes. Lacking athleisure wear garments for PS is a common issue to the whole world. When it comes to Sri Lanka, it is very hard to find garments even though Sri Lankan rate of obesity is increasing day by day. “In this first national level study on obesity in Sri Lankan adults, we have shown an alarmingly high prevalence of overweight and obesity especially, in Sri Lanka. Comparison with previous studies indicates an increasing trend of obesity overtime. Being female, physical inactivity, higher income, high level of education, urban living and being in the middle age are associated with obesity

among Sri Lankan adults” (Katulanda, Jayawardena, Sheriff, Constantine, & Matthews, 2010).

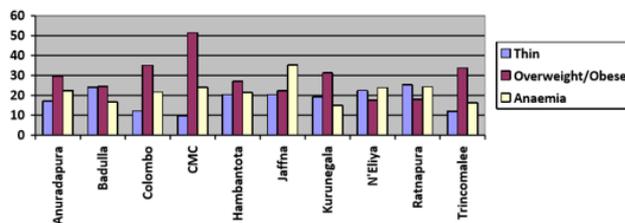


Figure - overweight, obese and Anaemia distribution in Sri Lanka

(2009-Nutrition-and-Food-Security-in-women-SL-.pdf, n.d.-a)

“According to the area of residence the prevalence of overweight, obesity and central obesity were higher in urban population compared with rural population both in men and women. In particular, over half of urban women were centrally obese” (Katulanda et al., 2010a).

Table 4 Prevalence (95% CI) of overweight and obesity by the area of residence according to existing cut-offs for Asians

		Overweight	Obese	Centrally obese
Urban	Male	30.6 (28.2-32.9)	16.4 (14.5-18.3)	28.9 (26.6-31.2)
	Female	34.8 (32.3-37.3)	20.7 (18.6-22.8)	53.2 (50.6-55.7)
	Overall	32.7 (30.9-34.7)	18.5 (17.1-19.9)	40.8 (39.0-42.6)
Rural	Male	20.4 (19.4-21.5)	4.7 (4.1-5.2)	13.2 (12.3-14.0)
	Female	26.2 (25.0-27.4)	8.7 (8.0-9.5)	31.8 (30.5-33.0)
	Overall	23.3 (22.5-24.1)	6.7 (6.2-7.1)	22.3 (21.5-23.1)

Figure - Overweight and Obesity rate in Asians

“The middle aged women had the highest levels of overweight and obesity and the prevalence became lower in older age groups. Compared with generalized obesity, central obesity remained disproportionately high in the older age groups” (Katulanda, Jayawardena, Sheriff, Constantine, & Matthews, 2010b).

	Age (years)	Overweight	Obese	Centrally obese
Male	20-29	17.5 (15.8-19.2)	4.4 (3.5-5.4)	7.5 (6.3-8.6)
	30-39	26.7 (24.6-28.8)	11.3 (9.7-12.8)	22.7 (20.7-24.7)
	40-49	22.6 (20.5-24.8)	10.7 (9.2-12.3)	19.0 (17.0-21.0)
	50-59	29.3 (26.6-32.1)	4.1 (2.9-5.3)	18.9 (16.6-21.2)
	60-69	21.2 (17.9-24.4)	1.0 (0.2-1.8)	16.5 (13.6-19.5)
	>70	13.6 (10.4-16.9)	8.0 (5.4-10.6)	17.3 (13.7-20.9)
Female	20-29	23.7 (21.7-25.6)	5.3 (4.3-6.3)	23.1 (25.1-27.0)
	30-39	29.1 (26.9-31.3)	15.9 (14.1-17.7)	40.6 (43.1-45.5)
	40-49	33.6 (31.0-36.0)	16.4 (14.4-18.3)	44.4 (47.0-49.7)
	50-59	33.0 (30.0-36.0)	12.8 (10.7-15.0)	41.1 (44.3-47.4)
	60-69	23.2 (20.0-26.4)	9.4 (7.1-11.6)	35.1 (38.9-42.6)
	>70	22.8 (19.2-26.3)	4.6 (2.9-6.4)	7.9 (10.5-13.1)

Table 5 Age specific prevalence (95% CI) of obesity among males and females according to Asians cut-off levels

Figure - Male and Female Obesity and Overweight distribution according to age ranges

Table 3 Prevalence (95% CI) of overweight and obesity by gender according to cut-offs for Asians and Caucasians

	Overweight (%)	Obese (%)	Centrally obese (%)
Men*	22.6 (21.6-25.5)	7.2 (6.6-7.8)	16.5 (15.6-17.3)
Women*	28.0 (26.9-28.1)	11.3 (10.5-12.0)	36.3 (35.1-37.4)
Overall*	25.2 (24.5-26.0)	9.2 (8.7-9.7)	26.2 (25.5-26.9)
Men†	14.3 (13.5-15.1)	2.6 (2.2-2.9)	3.1 (2.7-3.5)
Women†	19.4 (18.5-20.4)	4.8 (4.3-5.3)	18.9 (17.9-19.8)
Overall†	16.8 (16.2-17.4)	3.7 (3.4-4.0)	10.8 (10.3-11.3)

Figure - Overweight and Obesity rates

Above chart shows the Sri Lankan adult women overweight, obese and centrally obese rates are 28.0%, 11.3% and 36.3% respectively.

The Plus size, Middle aged, Athleisure wear overview

“Middle aged female rate in Sri Lankan population is 39.34% out of the whole population from age 25 to 54” (2009-Nutrition-and-Food-Security-in-women-SL, n.d.). “Over 45% of women in Sri Lanka are overweight or obese” (“SL women obesity rate exceeds 45%.” n.d.).

With the booming health conscious lifestyle of plus size middle aged women influenced by mainly the non-communicable diseases has increased the demand for athleisure wear both locally and internationally. Sri Lankan brand – ODEL has recognized the need so far and have launched a separate clothing category for athleisure but still they have not extended it up to plus size range.

“With the growing global trend towards fitness, health and wellbeing, where fitness is really a lifestyle now and no longer an option people have recognized the need to stay healthy and fit through regular exercise, with many making a conscious effort to build some form of exercise into their weekly routines.” (Daily FT, 2018).

Definition for ‘Athleisure’

“In this first national level study on obesity in Sri Lankan adults, we have shown an alarmingly high prevalence of overweight and obesity especially, in Sri Lanka. Comparison with previous studies indicates an increasing trend of obesity overtime. Being a female, physical inactivity, higher income, and high level of education, urban living and being in the middle age are associated with obesity among Sri Lankan adults” (Katulanda et al., 2010a). “The fastest growing segment of the fashion industry has been “athleisure”, which Merriam-Webster defines as casual clothing designed to be worn both for exercising and general use (Cheng)” (Madrigal, n.d.).

Women’s health conscious lifestyle in Sri Lanka

“With the increasing global awareness on the importance of being and staying fit, while leading fashion labels have also increased their focus on creating trendy and fashionable athleisure as well as ath-luxury brands with a view to bringing performance and style details together seamlessly without compromising on one or the other, ODEL, being at the forefront of fashion and lifestyle, will launch Fitness Week which we intend making an annual event,” (Mitton (2019,June).

History of “Athleisure” wear?

The birth of athleisure wear is in 1970’s where fitness became a lifestyle trend. Because of this trend lots of people wore casual clothing for exercises those days.

Sports brands took this as an opportunity and began to improve casual clothes suitable for athletic activities. Subsequently, with the materials like Lycra, spandex, nylon and other synthetic fabrics the innovations led the trend to a huge lifestyle trend. The reason why people love athleisure wear is simply because of the comfortability so those happened to be a choice for casual clothing. Sports brands kept developing these athleisure categories more and more by adding values such as breathability, lightweight, UV protection and waterproof and etc.

Cross sectional survey

This is a cross-sectional survey which is conducted where the researcher aims to collect data from a sample of target population at a given time. Researchers can evaluate various variables at a particular time frame.

Study 01 – Identify

Pilot survey 01 and Pilot survey 02

Study 01 is for highlight ‘there was no existing evidence’ to present the research problem, therefore study 01 was carried out to explore the market gap. This below main details has define the scope of the research area and main survey has conducted based on this collected data.

Table – identifying the exact market segment.

Task	Results / Gathered data						
To identify what is the most common plus size age range.	<p>Most common plus size women age range</p> <table border="1"> <tr> <td>15-29</td> <td>18.7%</td> </tr> <tr> <td>30-45</td> <td>68%</td> </tr> <tr> <td>46+ above</td> <td>13.3%</td> </tr> </table>	15-29	18.7%	30-45	68%	46+ above	13.3%
15-29	18.7%						
30-45	68%						
46+ above	13.3%						

	<ul style="list-style-type: none"> 68% of ladies are belongs to age 30 – 45 range which can define as middle-aged women segment. 								
To check the BMI rates to identify health conditions.	<p>BMI Rate</p> <table border="1"> <tr> <td>Lower 18.5</td> <td>3.3%</td> </tr> <tr> <td>18.5-25</td> <td>7.3%</td> </tr> <tr> <td>25-30</td> <td>26%</td> </tr> <tr> <td>30+ above</td> <td>63.3%</td> </tr> </table> <ul style="list-style-type: none"> 63.3% of ladies are in obese level and 26% ladies are in overweight level which is above the BMI healthy range. 	Lower 18.5	3.3%	18.5-25	7.3%	25-30	26%	30+ above	63.3%
Lower 18.5	3.3%								
18.5-25	7.3%								
25-30	26%								
30+ above	63.3%								

This is to identify what most of the plus size ladies are doing / occupation etc.	<p>What plus size women do</p> <table border="1"> <tr> <td>Study/Uni</td> <td>15.3%</td> </tr> <tr> <td>Work</td> <td>80%</td> </tr> <tr> <td>Housewife</td> <td>4.7%</td> </tr> </table> <ul style="list-style-type: none"> 80% out of the total ladies are working women. 	Study/Uni	15.3%	Work	80%	Housewife	4.7%
Study/Uni	15.3%						
Work	80%						
Housewife	4.7%						

Which type of activity type they like to do.	<p>Jogging type activities Vs Specific sport</p> <table border="1"> <tr> <td>Sports</td> <td>5.3%</td> </tr> <tr> <td>Jogging</td> <td>94.7%</td> </tr> </table> <ul style="list-style-type: none"> 94.7% ladies like to do jogging, cycling and yoga type activities over sports. 	Sports	5.3%	Jogging	94.7%
Sports	5.3%				
Jogging	94.7%				

To find out what is the most common plus size.	<p>Body sizes according to UK sizes</p> <table border="1"> <tr> <td>UK 14</td> <td>9</td> </tr> <tr> <td>UK 16</td> <td>26</td> </tr> <tr> <td>UK 18</td> <td>86</td> </tr> <tr> <td>UK 20</td> <td>15</td> </tr> <tr> <td>UK 22</td> <td>12</td> </tr> <tr> <td>UK 24 or up</td> <td>5</td> </tr> </table> <ul style="list-style-type: none"> 57.3% of ladies are UK size 18 which can consider as the most common plus size. 	UK 14	9	UK 16	26	UK 18	86	UK 20	15	UK 22	12	UK 24 or up	5
UK 14	9												
UK 16	26												
UK 18	86												
UK 20	15												
UK 22	12												
UK 24 or up	5												

To find out which clothing category is the most hardest to find plus size clothing category.	<p>Hardest to find plus size clothing category</p> <table border="1"> <tr> <td>Party</td> <td>24.8%</td> </tr> <tr> <td>Athleisure</td> <td>58.8%</td> </tr> <tr> <td>Casual</td> <td>16.3%</td> </tr> </table> <ul style="list-style-type: none"> Athleisure is the most hardest to find plus size clothing category with 58.8%. 	Party	24.8%	Athleisure	58.8%	Casual	16.3%
Party	24.8%						
Athleisure	58.8%						
Casual	16.3%						

The basic idea of study 01:

- Age 30 to 45 is the most common age range which is middle aged women.
- 89.3% of ladies are belongs to overweight and obese level which is above the healthy BMI range.
- 80% of the plus size ladies are working women.
- 94.7% ladies like jogging type activities to maintain health.
- UK size 18 is the most common plus size.
- Athleisure is the most hardest to find plus size clothing category.

Plus Size Middle Aged Athleisure Wear Market Gap

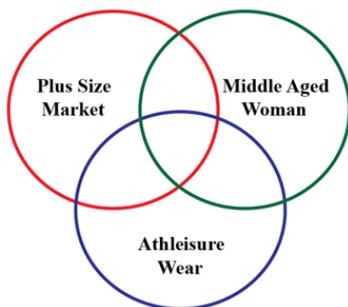


Figure 1-5 market gap identification

Problem statement

Most of the plus size women are facing a common issue which is not having suitable garments for workout needs that can be worn as a whole day wear. Athleisure is a garment category which all plus size women are demanding though designers and manufactures are far behind in fulfilling their needs.

Objectives

Aim

Explore plus size athleisure women's wear market opportunities and the

challenges in designing and present the requirement analysis for such product design and development.

Objectives

1. Identify the buying behaviour of the plus size athleisure wearers.
2. Discover plus size women's athleisure wear attributes according to the consumer preferences and their satisfaction.
3. Analyse those parameters against FEA model.
4. Present the requirements for design and development of plus size athleisure wearers of middle aged women.

Objectives

	Areas Covered
Objective 01	Identify the buying behaviour of the plus size Athleisure wearers. (Income level, motivation to buy athleisure, main concerns when purchase, maximum price range willing to pay for an athleisure top & a bottom, how much spend on athleisure clothing from their total spending for garments for one month, from where they currently shop athleisure)
Objective 02	Discover plus size women's athleisure wear attributes of the consumer preference and their satisfaction. (Consumer's minimum expectations on an Athleisure category, fabric / color / style preferences etc)
Objective 03	Analyse those parameters against FEA consumer needs model. (Functional needs, Expressive needs and Aesthetic needs)
Objective 04	Present the requirements for design & development of plus size athleisure wearers of middle aged women. (Product attributes identification)

Figure 1-6 Objectives Description

Significance

The importance of this investigative study is finding out a new market gap fashion market that can lead to many new opportunities to fashion design students, fashion business people, fashion bloggers, innovators, fashion designers, mass manufacturers, fashion forecasters and many other people to get a new approach to the fashion world.

Limitations of the study

Target market - Only focused about 78 plus size females, responds only from

locals, age limit – 30 – 45 middle aged and clothing category – only athleisure which can be extended more.

LITERATURE REVIEW

Introduction

What is “Athleisure” wear?

“Athleisure is a simple summation of athletic and leisure. It can be worn for exercise and for general use” (Way, 2018). Athleisure wear is very comfortable garment category which consumer can wear all day long. It is a new trend which is a mix of sportswear and outdoor clothing and it is an emerging market segment. Most of the European and American ladies tend to wear athleisure garments to work, then jogging and for the bar. “As a fashion trend, it is a trend in which active wear; clothes designed for athletic activities are worn for other purposes such as work clothes, casuals, to school or social occasions” (Way, 2018).

What is “Plus Size” in the world? UK, USA and Sri Lanka?

“Nearly 40% of the world’s adult population is overweight and by 2045, we’re on track for almost 25% to be obese” (This is what the ‘perfect body’ looks like according to men and women, 2018).

Table 2-1 what is plus size according to UK, USA and Sri Lanka

Market	What is 'plus size'?
UK Market	“One third of UK ladies are size 18 and above according to current research and the average / ideal body size in UK is Size 16 with 36DD bra size” (Xcel. B, 2016).
USA Market	“The average American woman actually wears a size 16 to 18, not size 14, as once was assumed” (Brolley (n.d).
Sri Lankan market	“In SL, 51.89% of the population is ladies” (Trading Economics, n.d). Since there is no specific female figure size chart in Sri Lanka, both BMI rates and UK size guide has used in this research.

Issues in current plus size athleisure market in the world and Sri Lanka

Finding correct fitted PS athleisure wear in the market is a common issue. Since most of the brands do not cater to

plus size consumers, they are frustrated. Some companies like Old Navy and New Look have tried to cater to PS athleisure market by adding extra cost to the selling price but still not fulfilling consumer needs.

“However, many brands explain that it is more time-consuming, more difficult, and more expensive to create these extended sizes, which deters them from producing PS athleisure wear altogether” (Wang, n.d.). “The production costs of creating a new measurements grade, combined with the extra fabric required to create larger clothing, shows a potential financial strain for companies to introduce plus sizes” (Madriral, n.d.).

Athleisure brands / outlets in the world and in SL Market and their available size ranges

Table 2-2 available size ranges in international market

Brands / Outlets	Available plus size range
Day Won	SX – 5X ,0W- 30W for bottoms
Dia & Co.	UK 14 – UK 32
Woman Within	12W – 44W
Torrid	USA 10 – USA 30
Old Navy	1X – 4X
Nike	1X – 3X

Table 2-3 available plus size range in local market

Brands / Outlets	Available PS range
Double XL	Do not offer athleisure garments.
ODEL	L, XL, XXL, XXXL
Decathlon	L, XL, XXL
Nike	L, XL
Adidas	L, XL

Factors influence in Sri Lankan plus size women's demand for athleisure wear?

Following illustration depicts the factors that influence to the athleisure wear demand created by the middle aged women market segment based on the review of literature.

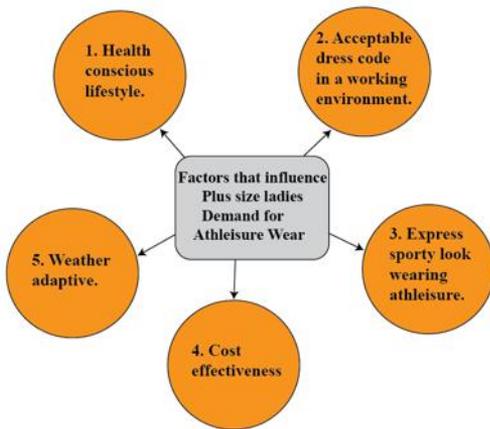


Figure 2-1 Factors affect PS women's demand for athleisure wear

What is FEA Apparel Framework Model?

This model is for assessing user needs and wants incorporates functional, expressive and aesthetic (FEA) considerations. The purpose of this framework is this can be applied to all types of apparel design because it does not distinguish between functional apparel design and fashion design.



Figure 2-2 FEA consumer needs model.

- Functional: - relates to its 'utility'. Ex: - Protection, fit, thermal comfort etc.
- Expressive: - relates to the 'communicative symbolic aspects of dresses. It conveys particular messages and it is attractive. Ex: - Punk attire, wearable arts.
- Aesthetic: - consideration deal with the 'human desire for beauty'. Ex: - Attractive designs.
- All above three factors are dealing with consumer's needs. Consumers can have different needs due to different purposes and by this model all consumer needs can categorize into 3 main key sections which will simplify the analysis process to design a garment.

RESEARCH METHODOLOGY

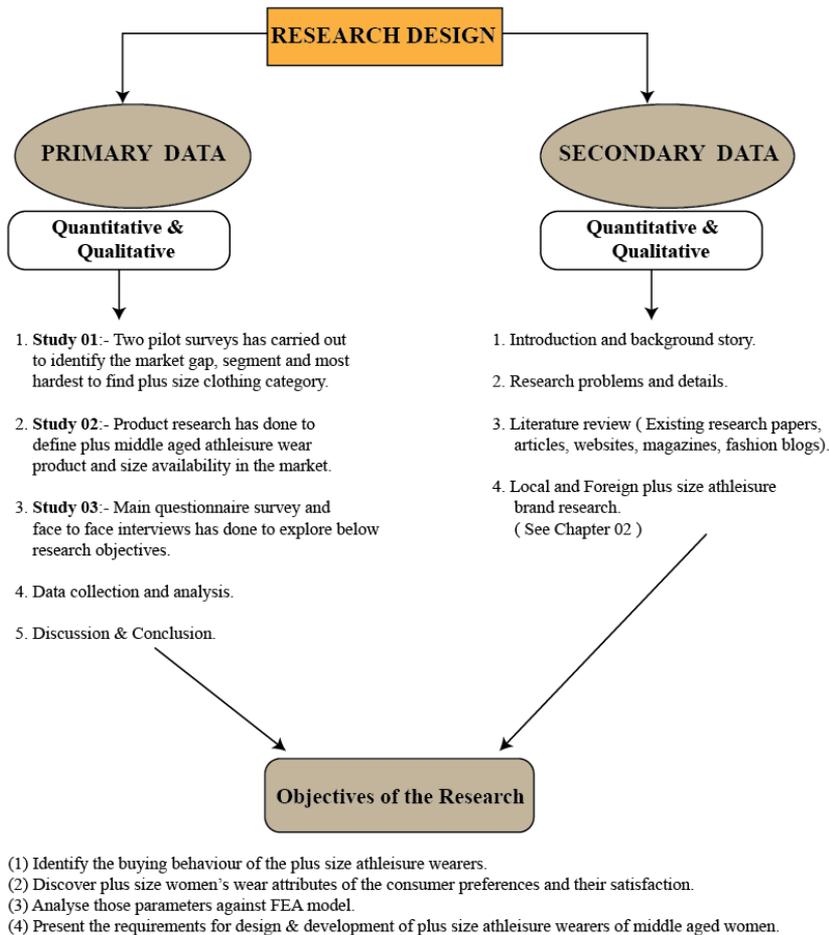
Introduction

This chapter discuss the process of the study. The reasons and objectives of the study has been covered my different data collection methods and information throughout the process.

Research Design

The research design (see figure 3-1) was illustrated the overall design methodology.

For this research it was essential to do both quantitative and qualitative research.



Primary Research

Two pilot surveys and the main survey

The primary research has started with two pilot surveys that used to construct the main survey and a product research.

Study 01 – Pilot survey 01 & Pilot survey 02

Two pilot surveys have carried out to highlight ‘there was no existing evidence’ to present the research. Pilot survey 01 and 02 have done to identify the Market Gap. 150 feedbacks got through random online survey filled by Colombo inner and outer women. It was carried out to get an idea

about the basic scope of the market segment and product category. (Check chap: 01).

Study 02 – Product research shop visit

Product research has been carried out throughout the 08 months, targeting plus size brands / outlets to identify plus size middle aged women athleisure garment availability and size ranges. (Check table 2-3).

Study 03 – Main survey

The ‘cross-sectional survey’ is concerned with sampling, questionnaire

design, questionnaire administration and data analysis (Sukamolson, n.d.).

Sample Characteristics: - Quantitative survey has been carried out to collect data by targeting Sri Lankan middle aged working, urban living women from age 30 to 45. "For this market gap identification research it is important to collect numerical data which can be analysed mathematically like count or percentage etc" (Greetham, 2009).

Sample Selection: - 'Random sample'. The research has been carried out at the jogging tracks, streets and gyms to interview people randomly to make sure the data is more generalizable and manageable, 80 feedbacks.

Design the questionnaire: - To construct the main questionnaire, it was essential to run two pilot surveys. Main questionnaire had made according to FEA Model. These surveys contain of categorical, numerical, multiple choices, multiple responses, like scale and ranking questions.

Questionnaire administration: - With feedbacks, Semi – structured, Face-to-face interviews have been carried out for random ladies. Questions were scheduled questions.

Data analysis: - Has done after summarizing data using graphs, pie charts, bar charts and tables.

Pilot survey objectives.

Task	Question no	Objectives covered
Main survey	01 – 08	Consumer's lifestyle and personal views.
	09 - 14	Objective 01:- Identify the buying behavior of the PS athleisure wearers.
	15 - 30	Objective 02:- Discover PS women's wear attributes of the consumer preference and their satisfaction.
Face-to-face Interviews		Why they are trying to active? Why did they come for jogging or gym rather than going for a sport? What are the NCD they are suffering from?
Task	Question no	Objectives covered
Main survey	01 – 08	Consumer's lifestyle and personal views.
	09 - 14	Objective 01:- Identify the buying behavior of the PS athleisure wearers.
	15 - 30	Objective 02:- Discover PS women's wear attributes of the consumer preference and their satisfaction.
Face-to-face Interviews		Why they are trying to active? Why did they come for jogging or gym rather than going for a sport? What are the NCD they are suffering from?

Task	Question No	Objectives Covered
Pilot survey 01 Sri Lankan plus size fashion market.	01 – 07	Initial data collection (to identify which age category is demanding athleisure wear and BMI rate of that age category to get an idea about their health level) based on Objective 01 and 02.
Pilot survey 02 Sri Lankan plus size fashion outlook.	01 – 10	Support data collection for Objective 01 and 02.

Data Analysis

The review of the existing market of plus size women of Athleisure wear

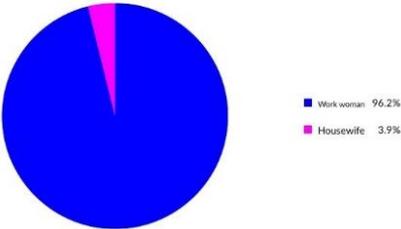
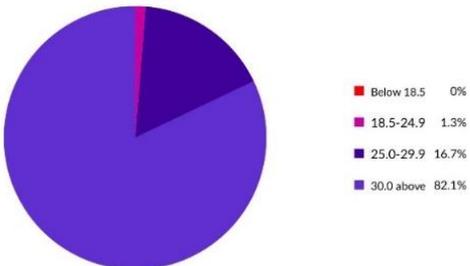
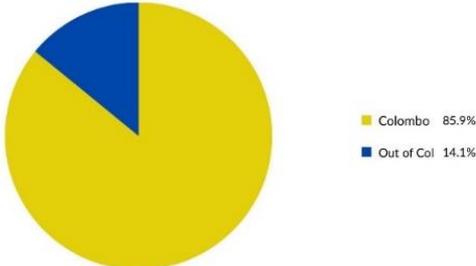
The current market research has carried out through Sri Lankan shops to check the product availability in PS ranges. (See Chapter 02)

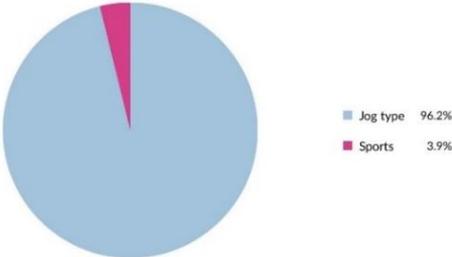
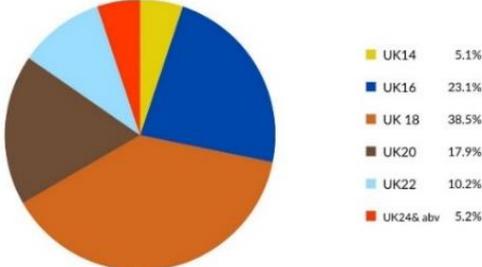
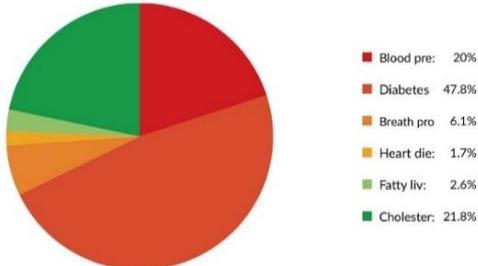
This chapter is the results of the main questionnaire survey. Manual questionnaire has been targeted 80 plus size women. Since 2 ladies are out of the age range, below analysis has done with 78 respondents according to the FEA conceptual framework.

ANALYSIS

Consumer Exploration

Topic	Analysis																		
Common middle age range	<p style="text-align: center;">Age range of participants</p> <p style="text-align: center;">Age Range Of Plus Size Ladies</p> <table border="1"> <thead> <tr> <th>Age range</th> <th>No of woman</th> <th>% Value</th> </tr> </thead> <tbody> <tr> <td>30 – 35</td> <td>25</td> <td>31.25%</td> </tr> <tr> <td>36 – 41</td> <td>44</td> <td>55%</td> </tr> <tr> <td>42 – 45</td> <td>9</td> <td>11.25%</td> </tr> <tr> <td>46 and above</td> <td>2</td> <td>2.5%</td> </tr> <tr> <td>Total</td> <td>80</td> <td>100%</td> </tr> </tbody> </table> <p>55% ladies are in age range 36 – 41 which is the most common middle aged plus size women range.</p>	Age range	No of woman	% Value	30 – 35	25	31.25%	36 – 41	44	55%	42 – 45	9	11.25%	46 and above	2	2.5%	Total	80	100%
Age range	No of woman	% Value																	
30 – 35	25	31.25%																	
36 – 41	44	55%																	
42 – 45	9	11.25%																	
46 and above	2	2.5%																	
Total	80	100%																	

<p>Composition by occupation</p>	<p>Job status</p>  <p>96.2% ladies are working women. Only 3.9% are housewives.</p>										
<p>BMI rate</p>	<p>BMI Classification</p> <table border="1" data-bbox="504 567 784 790"> <thead> <tr> <th>BMI</th> <th>Category</th> </tr> </thead> <tbody> <tr> <td>Lower than 18.5</td> <td>Underweight</td> </tr> <tr> <td>18.5 up to 25</td> <td>Optimal</td> </tr> <tr> <td>25 up to 30</td> <td>Overweight</td> </tr> <tr> <td>30 upwards</td> <td>Obese</td> </tr> </tbody> </table> $\text{BMI} = \frac{(\text{weight in kilograms})}{\text{height in meters}^2}$ <p>BMI rates of the plus size ladies</p>  <p>82.1% are in 'Obese' range which is the BMI rate over 30. 16.7% are in overweight stage.</p>	BMI	Category	Lower than 18.5	Underweight	18.5 up to 25	Optimal	25 up to 30	Overweight	30 upwards	Obese
BMI	Category										
Lower than 18.5	Underweight										
18.5 up to 25	Optimal										
25 up to 30	Overweight										
30 upwards	Obese										
<p>Living area</p>	<p>Living location</p>  <p>85.9% are living in Colombo while 14.1% are living out of Colombo.</p>										

<p>Willing to do an activity for HCL</p>	<p>All 100% (78) ladies are willing to do an activity to maintain a healthy lifestyle.</p>
<p>Activity Selection</p>	<p style="text-align: center;">Activity selection</p>  <p>96.2% ladies like to do jogging, walking, running, cycling, yoga, salsa, zumba, swimming type activities while 3.9% ladies like sports like volleyball, tennis, and badminton, and table tennis, hockey.</p>
<p>Body sizes according to UK sizes</p>	<p style="text-align: center;">Body size according to UK size range</p>  <p>UK size 18 is the most common plus size in Sri Lankan market with 38.5% (30) ladies.</p>
<p>Composition of the sample by non-communicable diseases (NCD)</p>	<p style="text-align: center;">Non communicable diseases</p>  <p>Most of the middle aged women thinking that at the beginning of their 30's they are starting the risk of getting non-communicable diseases (NCD).</p> <p>50% of the ladies are having diabetes.</p> <p>20% of them are having blood pressure.</p> <p>21.8% are having cholesterol. These are the major reasons that drives plus size women to the jogging track.</p>

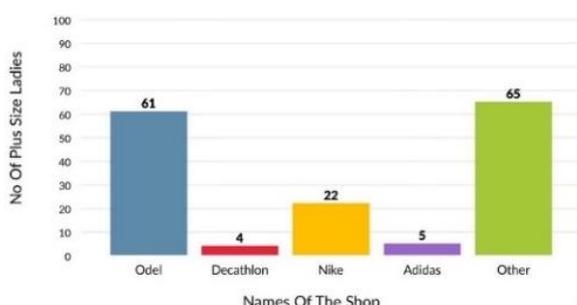
Barriers women have that stop them being active?	<p>69.0% women are busy with office work, kids and household work.</p> <p>28.6% women are busy with too much office work.</p> <p>Above two reasons are the major boundaries that plus size middle aged women are facing in the current society.</p>
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Buying Behavior

Table 4 2 Buying behavior

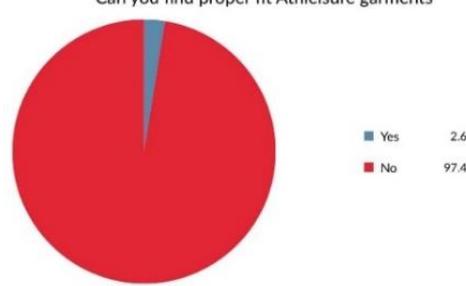
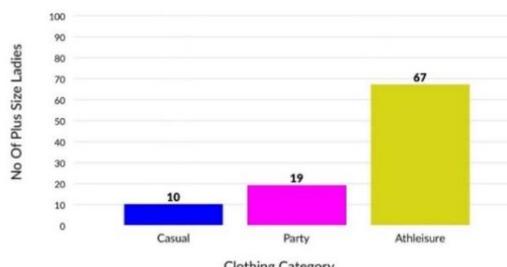
Topic	Analysis																		
Main concerns when plus size middle aged women buy athleisure wear	<p style="text-align: center;">Main two concerns when purchasing Athleisure garments</p> <table border="1"> <thead> <tr> <th>Description</th> <th>no</th> <th>% value</th> </tr> </thead> <tbody> <tr> <td>Price worthiness</td> <td>30</td> <td>38.46%</td> </tr> <tr> <td>Product quality</td> <td>48</td> <td>61.54%</td> </tr> <tr> <td>Durability</td> <td>30</td> <td>38.46%</td> </tr> <tr> <td>Functionality</td> <td>46</td> <td>58.97%</td> </tr> <tr> <td>Fashionability</td> <td>49</td> <td>62.82%</td> </tr> </tbody> </table> <p>62.82% fashionability. 61.54% product quality. 58.97% functionality. Above main 03 concerns are the most important factors when catering to plus size middle aged athleisure market.</p>	Description	no	% value	Price worthiness	30	38.46%	Product quality	48	61.54%	Durability	30	38.46%	Functionality	46	58.97%	Fashionability	49	62.82%
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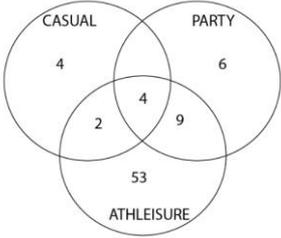
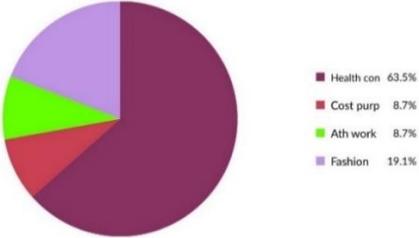
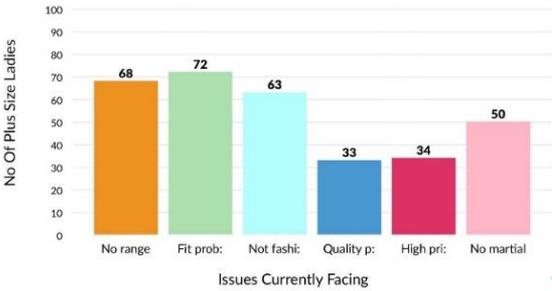
<p>How many garments buy at one time?</p>	<p style="text-align: center;">No of Athleisure garments purchase at one time</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>1-3</td> <td>80.8%</td> </tr> <tr> <td>1-5</td> <td>19.2%</td> </tr> <tr> <td>1-7</td> <td>0%</td> </tr> <tr> <td>1-10 or mo</td> <td>0.0%</td> </tr> </table> <p>80.8% women buy 1 to 3. 19.2% women buy 1 to 5. No one buy more than 5 garments at one time.</p>			1-3	80.8%	1-5	19.2%	1-7	0%	1-10 or mo	0.0%													
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<p>How much they are willing to pay for an athleisure top?</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Price range (Rs.)</th> <th>No</th> <th>% Value</th> </tr> </thead> <tbody> <tr> <td>500 – 1000</td> <td style="text-align: center;">0</td> <td style="text-align: center;">0%</td> </tr> <tr> <td style="background-color: yellow;">500 – 2000</td> <td style="text-align: center; background-color: yellow;">48</td> <td style="text-align: center; background-color: yellow;">61.54%</td> </tr> <tr> <td>500 – 3000</td> <td style="text-align: center;">22</td> <td style="text-align: center;">28.21%</td> </tr> <tr> <td>500 – 4000</td> <td style="text-align: center;">3</td> <td style="text-align: center;">3.85%</td> </tr> <tr> <td>500 – 5000 or more</td> <td style="text-align: center;">3</td> <td style="text-align: center;">3.85%</td> </tr> <tr> <td>500 - 10,000 or below</td> <td style="text-align: center;">2</td> <td style="text-align: center;">2.56%</td> </tr> </tbody> </table> <p style="text-align: right;">61.54% women are willing to pay Rs.500 – Rs.2000, which is the ideal price range for an athleisure top.</p>			Price range (Rs.)	No	% Value	500 – 1000	0	0%	500 – 2000	48	61.54%	500 – 3000	22	28.21%	500 – 4000	3	3.85%	500 – 5000 or more	3	3.85%	500 - 10,000 or below	2	2.56%
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<p>How much they are willing to pay for an athleisure bottom?</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th>Price range (Rs.)</th> <th>No</th> <th>% Value</th> </tr> </thead> <tbody> <tr> <td>500 – 1000</td> <td style="text-align: center;">0</td> <td style="text-align: center;">0%</td> </tr> <tr> <td>500 – 2000</td> <td style="text-align: center;">6</td> <td style="text-align: center;">7.7%</td> </tr> <tr> <td style="background-color: yellow;">500 – 3000</td> <td style="text-align: center; background-color: yellow;">47</td> <td style="text-align: center; background-color: yellow;">60.26%</td> </tr> <tr> <td>500 – 4000</td> <td style="text-align: center;">17</td> <td style="text-align: center;">21.8%</td> </tr> <tr> <td>500 – 5000 or more</td> <td style="text-align: center;">6</td> <td style="text-align: center;">7.7%</td> </tr> <tr> <td>500 - 10,000 or below</td> <td style="text-align: center;">2</td> <td style="text-align: center;">2.56%</td> </tr> </tbody> </table> <p>60.62% women are ready to pay Rs.500 – Rs.3000, which is the idea price range for an athleisure bottom.</p>			Price range (Rs.)	No	% Value	500 – 1000	0	0%	500 – 2000	6	7.7%	500 – 3000	47	60.26%	500 – 4000	17	21.8%	500 – 5000 or more	6	7.7%	500 - 10,000 or below	2	2.56%
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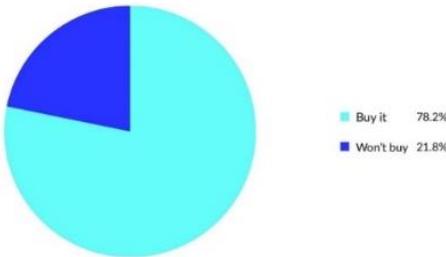
<p>Shops that offer plus size athleisure</p>	<p style="text-align: center;">Shops where plus size consumers buy Athleisure</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Names Of The Shop</th> <th>No Of Plus Size Ladies</th> </tr> </thead> <tbody> <tr> <td>Odel</td> <td>61</td> </tr> <tr> <td>Decathlon</td> <td>4</td> </tr> <tr> <td>Nike</td> <td>22</td> </tr> <tr> <td>Adidas</td> <td>5</td> </tr> <tr> <td>Other</td> <td>65</td> </tr> </tbody> </table> <p>83.33% women going for ‘other shops’ rather than Decathlon, Nike and Adidas. 78.21% women are going to ODEL which can be recognised as the most plus size women visited outlet.</p>	Names Of The Shop	No Of Plus Size Ladies	Odel	61	Decathlon	4	Nike	22	Adidas	5	Other	65
Names Of The Shop	No Of Plus Size Ladies												
Odel	61												
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Expanding consumer issues

Table **Error! No text of specified style in document.**-1 Expanding consumer issues

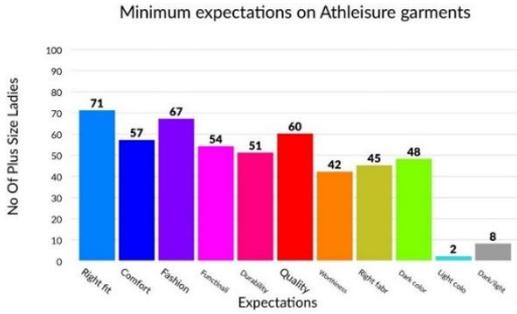
Topic	Analysis								
<p>Can you find proper fit athleisure wear in the market?</p>	<p style="text-align: center;">Can you find proper fit Athleisure garments</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Yes</td> <td>2.6%</td> </tr> <tr> <td>No</td> <td>97.4%</td> </tr> </tbody> </table> <p>97.4% women said ‘No’ and that proves the gap in plus size middle aged athleisure market.</p>	Response	Percentage	Yes	2.6%	No	97.4%		
Response	Percentage								
Yes	2.6%								
No	97.4%								
<p>Most hardest to find PS clothing category</p>	<p style="text-align: center;">Hardest to find plus size clothing category</p>  <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Clothing Category</th> <th>No Of Plus Size Ladies</th> </tr> </thead> <tbody> <tr> <td>Casual</td> <td>10</td> </tr> <tr> <td>Party</td> <td>19</td> </tr> <tr> <td>Athleisure</td> <td>67</td> </tr> </tbody> </table>	Clothing Category	No Of Plus Size Ladies	Casual	10	Party	19	Athleisure	67
Clothing Category	No Of Plus Size Ladies								
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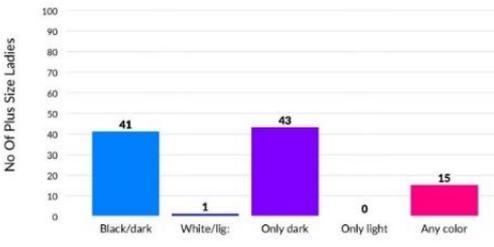
	 <p>‘Athleisure’ is the hardest to find plus size clothing category with 85.9% respondents.</p>
<p>The need of athleisure for plus size of middle aged women.</p>	<p>Reasons for the demand of plus size athleisure garments</p>  <p>According to above chart details, 63.5% ladies are requesting athleisure wear because they are health conscious which is the main concern of this research. 19.1% ladies requesting it for fashionable and stylish lifestyle.</p>
<p>What are the Main problems plus size middle aged women are currently facing in the industry?</p>	<p>Issues plus size consumers currently facing</p>  <p>‘Fit problems’ is the main problem - 92.31%. ‘Not having enough plus size range’ - 87.18%. ‘Not fashionable enough’ - 80.77%.</p> <p>Face-to-face discussions have highlighted 2 main key problems. Plus size women love to wear both Functional + Fashionable athleisure wear garments which are currently unavailable in the market.</p> <p>In the current market, all most all of the products are in low quality and high price which cannot fulfil consumer requirements and also breaking consumer trust about the garment quality.</p>

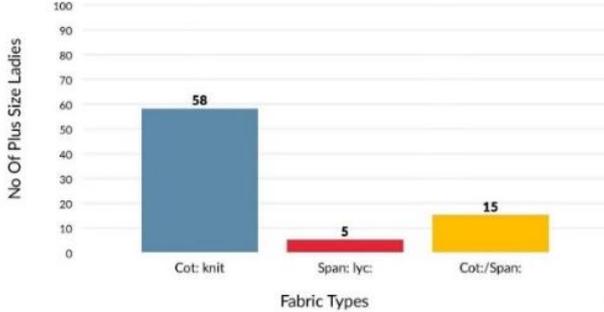
<p>Which factor motivates plus size middle aged women to choose athleisure wear over other clothing categories?</p>	<p style="text-align: center;">Why you choose Athleisure wear ?</p>  <p style="text-align: center;">Showing the body shape (expressive), feel comfortable & supportive (functional) and look fashionable (aesthetic) are the main expectations of 89.8% women.</p>
<p>If it is a fashionable and functional garment BUT expensive. What you would rather do?</p>	<p style="text-align: center;">Good looking but expensive. What would you do?</p>  <p style="text-align: center;">The effect of the high income and health conscious lifestyle motivates ladies to buy the garment that fulfil their requirements neglecting the cost.</p>

Consumer Preferences

Table **Error! No text of specified style in document.**-2 Consumer preferences

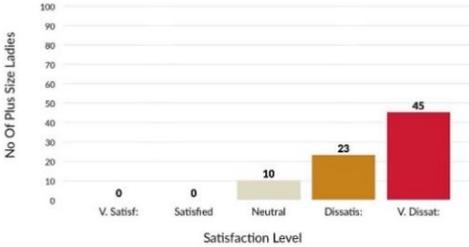
Topic	Analysis
<p>Minimum expectations on athleisure garments</p>	<p style="text-align: center;">Minimum expectations on Athleisure garments</p> 

	<table border="1"> <thead> <tr> <th>Expectation</th> <th>No</th> <th>% Value</th> </tr> </thead> <tbody> <tr> <td>Correct fit</td> <td>71</td> <td>91.03%</td> </tr> <tr> <td>Comfortability</td> <td>57</td> <td>73.08%</td> </tr> <tr> <td>Fashionability</td> <td>67</td> <td>85.90%</td> </tr> <tr> <td>Functionality</td> <td>54</td> <td>69.23%</td> </tr> <tr> <td>Durability</td> <td>51</td> <td>65.38%</td> </tr> <tr> <td>Quality</td> <td>60</td> <td>76.92%</td> </tr> <tr> <td>Worth to the price</td> <td>42</td> <td>53.85%</td> </tr> <tr> <td>Correct fabrication</td> <td>45</td> <td>57.69%</td> </tr> <tr> <td>Dark colors</td> <td>48</td> <td>61.54%</td> </tr> <tr> <td>Light colors</td> <td>2</td> <td>2.56%</td> </tr> <tr> <td>Both dark & light shades</td> <td>8</td> <td>10.26%</td> </tr> </tbody> </table> <p> Fashionability – 85.90% Quality – 76.92% Comfortability – 73.08% Functionality – 69.23% </p>	Expectation	No	% Value	Correct fit	71	91.03%	Comfortability	57	73.08%	Fashionability	67	85.90%	Functionality	54	69.23%	Durability	51	65.38%	Quality	60	76.92%	Worth to the price	42	53.85%	Correct fabrication	45	57.69%	Dark colors	48	61.54%	Light colors	2	2.56%	Both dark & light shades	8	10.26%	Correct fit – 91.03%
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Color preferences	<p style="text-align: center;">Color preferences</p>  <table border="1"> <caption>Color Preferences Data</caption> <thead> <tr> <th>Color Category</th> <th>No. of Plus Size Ladies</th> </tr> </thead> <tbody> <tr> <td>Black/dark</td> <td>41</td> </tr> <tr> <td>White/lig:</td> <td>1</td> </tr> <tr> <td>Only dark</td> <td>43</td> </tr> <tr> <td>Only light</td> <td>0</td> </tr> <tr> <td>Any color</td> <td>15</td> </tr> </tbody> </table> <p> Any dark color only – 55.13% Black and darker shades – 52.56% </p>		Color Category	No. of Plus Size Ladies	Black/dark	41	White/lig:	1	Only dark	43	Only light	0	Any color	15																								
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<p>Fabric preferences</p>	<p style="text-align: center;">Fabric preferences</p>  <p>Cotton knitted fabric only – 74. 36% Spandex, Lycra knitted only – 6. 41% Cotton or synthetic any fabric – 19. 23%</p>																																																			
<p>Style preferences according to FEA consumer needs model.</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Style description</th> <th style="text-align: center;">No</th> <th style="text-align: center;">% Value</th> <th style="text-align: left;">Reason according to FEA consumer needs</th> </tr> </thead> <tbody> <tr> <td>Plain color</td> <td style="text-align: center;">71</td> <td style="text-align: center;">91.03%</td> <td>Expressive</td> </tr> <tr> <td>Body mapping</td> <td style="text-align: center;">06</td> <td style="text-align: center;">7.70%</td> <td>Functional</td> </tr> <tr> <td>Color blocking</td> <td style="text-align: center;">63</td> <td style="text-align: center;">80.77%</td> <td>Aesthetic</td> </tr> <tr> <td>Fully bonded</td> <td style="text-align: center;">09</td> <td style="text-align: center;">11.54%</td> <td>Functional</td> </tr> <tr> <td>Seamless knitted</td> <td style="text-align: center;">06</td> <td style="text-align: center;">7.69%</td> <td>Functional</td> </tr> <tr> <td>Laser cut</td> <td style="text-align: center;">46</td> <td style="text-align: center;">58.97%</td> <td>Aesthetic</td> </tr> <tr> <td>Printed</td> <td style="text-align: center;">60</td> <td style="text-align: center;">76.92%</td> <td>Aesthetic</td> </tr> <tr> <td>Camó</td> <td style="text-align: center;">35</td> <td style="text-align: center;">44.87%</td> <td>Aesthetic & Expressive</td> </tr> <tr> <td>Rhinestones</td> <td style="text-align: center;">16</td> <td style="text-align: center;">20.51%</td> <td>Aesthetic</td> </tr> <tr> <td>Ombre</td> <td style="text-align: center;">46</td> <td style="text-align: center;">58.97%</td> <td>Aesthetic</td> </tr> <tr> <td>Fabric and mesh bonded</td> <td style="text-align: center;">54</td> <td style="text-align: center;">69.23%</td> <td>Functional & Aesthetic</td> </tr> </tbody> </table> <p><i>Plus size women style choices has highlighted the need of functional and aesthetic mixed athleisure garment requirement that can express who they are to the world.</i></p>				Style description	No	% Value	Reason according to FEA consumer needs	Plain color	71	91.03%	Expressive	Body mapping	06	7.70%	Functional	Color blocking	63	80.77%	Aesthetic	Fully bonded	09	11.54%	Functional	Seamless knitted	06	7.69%	Functional	Laser cut	46	58.97%	Aesthetic	Printed	60	76.92%	Aesthetic	Camó	35	44.87%	Aesthetic & Expressive	Rhinestones	16	20.51%	Aesthetic	Ombre	46	58.97%	Aesthetic	Fabric and mesh bonded	54	69.23%	Functional & Aesthetic
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Consumer Satisfaction

Table **Error! No text of specified style in document.**-3 Consumer satisfaction

Topic	Analysis												
The Satisfaction	<p data-bbox="522 274 927 293">Satisfaction level of available plus size Athleisure products</p>  <table border="1" data-bbox="458 312 927 559"> <thead> <tr> <th>Satisfaction Level</th> <th>No Of Plus Size Ladies</th> </tr> </thead> <tbody> <tr> <td>V. Satisf.</td> <td>0</td> </tr> <tr> <td>Satisfied</td> <td>0</td> </tr> <tr> <td>Neutral</td> <td>10</td> </tr> <tr> <td>Dissatis.</td> <td>23</td> </tr> <tr> <td>V. Dissat.</td> <td>45</td> </tr> </tbody> </table> <ul data-bbox="502 578 1185 658" style="list-style-type: none"> 57.7% women are very dissatisfied. It highlights the market issue / need of plus size middle aged athleisure wear market. 	Satisfaction Level	No Of Plus Size Ladies	V. Satisf.	0	Satisfied	0	Neutral	10	Dissatis.	23	V. Dissat.	45
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Requirement Analysis for the plus size athleisure wear product design & development

This section discuss what are the target market segment’s product attributes requirements according to FEA model.

Table **Error! No text of specified style in document.**-4production requirement analysis according to FEA model

Functional	Expressive	Aesthetic
<ol style="list-style-type: none"> 1. Not enough size range for enough extend. 2. Fir Problems. 3. Quality issues. 4. Not Suitable fabrics for plus size women. 5. Need for functional garments. 6. Durability. 7. Quality need. 8. health conscious lifestyle 9. Need of correct fabric. 10. Comfortability. 11. 74.36% cotton knit fabric demand. 12. 19.23% cotton or synthetic fabric demand. 13. feel comfortable and help body functions while looking fashionable. 	<ol style="list-style-type: none"> 1. Look good with the outfit to have self-esteem. 2. Fashionability. 3. Color selection shows personality. 4. Shows the body shape give confidence and give the massage that the wearer is active person. 	<ol style="list-style-type: none"> 1. Problem is not fashionable / old fashion / basic silhouettes. 2. Not suitable colors and styles for PS middle aged women. 3. Fashionability need. 4. Dark colors demand / dark shades. 5. Fashionable + functional need. 6. 41% dark shades, 43% any dark color only, 15% any color.

DISCUSSION

Introduction

This chapter consists of the discussion, according to research analysis findings.

Research findings

Research has confirmed the plus size athleisure wear market gap created by the working middle aged women due to health conscious lifestyle.

Discussion

Main survey and face-to-face interviews have carried out to explore more data about the initial data collected from two pilot surveys and market research. Consumer exploration has identified that 55% out of ladies are belongs to age 30-41 which can consider as the most common middle women age range. Data has showed 96.2% of ladies are working women and out of that sample, 82.1% of ladies are in obese level according to BMI calculations which is having high risk to get non-communicable diseases. All most all women are willing to do an activity to live healthy life and out of that sample 96.2% of ladies prefer jogging, yoga and cycling type activity to maintain their lifestyle. Furthermore, results has showed UK size 18 is the most common plus size. 47.8% of ladies are having diabetes that can consider as most common NCD and also blood pressure and cholesterol are some major health issues. The research has highlighted that fashionability (62.82%), product quality (61.54%) and functionality (58.97%) are the main 03 concerns when plus size women purchasing athleisure garments. 80.8% of ladies would buy 1-3 garments at one time from most commonly from ODEL and 'other shops' category because high end brands do not cater to plus size women. 97.4% of the sample has responded as they cannot find proper fitting plus size athleisure garments in the

market that can take as a major loop hole in the market as athleisure is the most hardest to find clothing category. 63.5% of ladies have mentioned health consciousness as the main reason to their athleisure wear demand but not only that but also being an acceptable garment category at work places, fashionable lifestyle and cost effective lifestyle are some other reasons. Fit problems, not having enough PS range and not fashionable are the 03 main issues PS ladies are facing. Face-to-face interviews have highlighted target market segment like to wear both functional and fashionable athleisure wear and the other major problem is available products are low quality and high priced. 89.8% of ladies choose athleisure wear over other clothing category because they can fulfil their functional, expressive and aesthetic needs in one garment. Correct fitting (91.03%), fashionability (85.90%), quality (76.92%), comfortability (73.08%) are the minimum expectations of a garment. All most all of the ladies like to wear black or darker shades with cotton knitted fabrics.

Product design and development analysis has done according to FEA model which is exploring consumer needs (showing the body shape (expressive), feel comfortable & supportive (functional) and look fashionable (aesthetic) are the main expectations of this market segment) that can be useful for future researchers, fashion business people etc.

Recommendations for future studies

- Compression garments for plus size women to increase muscle functions.
- Athleisure demand in other age categories like teenagers, elder women, pregnant women etc.
- Other plus size clothing category demand such as casual and party wear.

CONCLUSION

Summary

World's Plus Size fashion market is getting larger due to constant growth of positive mindset of plus size women. Even though they are above size 12 they are conscious about health. The study focus on two subjects;

1. Explore plus size athleisure market gap

The research had found out there is a market gap for plus size athleisure category created by the middle aged women (age 30 – 45) because of health consciousness (63.5%).

2. Present the requirement analysis for such product design & development

Research findings has revealed that middle aged working women from age 30 - 45 have created a demand for plus size athleisure wear because athleisure is the most hardest to find plus size clothing category in the market. Since most of the high end brands do not cater to plus size range because of the more time consumption and cost issues 97.4% ladies are not satisfied with plus size athleisure market. They are willing to do jogging, cycling and yoga type activities even though 69% of them are busy with office work, kids and household work because 85.9% ladies are in the obese level in BMI rate. 50% of ladies are having diabetes. 4/5 of the sample buy 1 to 3 garments at one time. Fear of getting NCD is their major motivation to jogging track but not only that but also being an accepted garment category at work places, fashionability and cost effectiveness are some of the other motivations. Fit problem is the main problem while not having size range to enough extend and not fashionable enough garments are the top 3 issues middle aged PS women are currently facing. Women like 'functional, fashionable and quality athleisure wear in black or any dark color with cotton knitted fabrics' is the brief idea

about the consumer requirement in this market segment.

This research has investigated a market segment with a market gap and have presented the requirements of the product they want according to FEA consumer needs model and according to that, plus size middle aged women's demand for athleisure wear is to show the body shape (expressive), feel comfortable & support (functional) and look fashionable (aesthetic) are the main expectations of 89.8% women.

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