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The Impact of BMI, Body Fat, Hydration Level and Stress on Fatigue State of Indian Females - A Study Based on Futrex NIR Technology

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ABSTRACT

Technology is very well-advanced today. Humans should be active and advanced to match up with the technology. To be active, one needs to maintain their mental and physical health well. Fatigue is an important parameter that results in the mental health of an individual. Fatigue is a common symptom, even among healthy individuals, but only a few knew about it. Most research on fatigue has been oriented towards work or performance of tasks. It has involved laboratory studies of healthy individuals, while the study of fatigue as encountered in clinical settings has received minimal attention from investigators. A person's physical condition can be calculated separately by different technologies like PPG, HRV, and NIR in the modern world. Fatigue is calculated using the frequency domain analysis of HRV technology. Heart rate variability or HRV is the physiological phenomenon of the variation in the time interval between consecutive heartbeats in milliseconds. A normal, healthy heart does not tick evenly like a metronome, but instead, when looking at the milliseconds between heartbeats, there is constant variation. An FDA-approved HRV monitoring device is used to measure the Fatigue levels for this study. Fatigue state is divided into five called Excellent, Good, Normal, Bad, and Very Bad. Excellent, Good, and Normal states are the acceptable levels of fatigue, and one needs to maintain these levels for a good and healthy body and mind. Those in Bad and Very Bad levels need to work on this. If not, it may lead to chronic fatigue syndrome over a while. It can be debilitating, difficult to diagnose, and complicated to treat. Body fat percentage and body water content are measured using a device manufactured by Futrex, which uses NIR technology. Stress score was calculated from the same FDA-approved HRV monitoring device mentioned above. The purpose of this study is to examine the effect of BMI, body fat, and water percentage on fatigue. For BMI and BFP, only the overweight and obese categories are considered as both can impact the fatigue level. For body water, the following classifications were considered: Sub-optimal (<55%), Normal (55%-65%). The current study is based upon 735 Indian females, ages ranging from 18 to 60. The analysis showed a strong relationship between BMI, BFP, BW, and stress with fatigue state.

KEYWORDS

Fatigue State; Body Fat Percentage; Body Mass Index; Body Water; Stress Score; Heart Rate Variability; Near Infrared; Photoplethysmography

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PURPOSE

Fatigue is a term used to describe an overall feeling of tiredness or lack of energy. Fatigue can affect a person both mentally and physically. This study was conducted to know the impact of body mass index, body fat percentage, hydration level, and stress on the Fatigue State of an individual.

MATERIALS AND METHOD

The data for the study was taken from a device using a non-invasive technology called Futrex from 2016 October to 2020 March. We found the relationship between body mass index, body fat, hydration level, stress with fatigue score using regression analysis. The Correlation coefficient between the parameter classification and fatigue score classification was found by correlogram. A one-way ANOVA test was used to find the p-value for each parameter and fatigue. For the statistical analysis, PSPPIRE software was used.

RESULT

A total of 735 data was used for the study. Indian female candidates aged between 18 to 70 were taken into consideration. The r square value of the regression analysis showed a relation of 61%. The significant value was less than 0.05 for body mass index (BMI), body fat percentage (BFP), body water (BW) content, and stress score (SS) with the ANOVA test. A significant relationship was shown by the correlogram diagram with the parameters mentioned above and fatigue score.

CONCLUSION

Body mass index, body fat percentage, body water, and stress score are valid parameters that can affect the fatigue state of an individual.

INTRODUCTION

Fatigue is a common complaint in healthy individuals and numerous patient groups such as those with depression, rheumatoid disorders, multiple sclerosis, congestive heart failure, and cancer. Its more than just tiredness [1]. Fatigue can make it hard to get out of bed in the morning and prevent a person from fulfilling their daily tasks. Fatigue is conceptually ambiguous and may manifest itself with physical/neuromuscular, emotional/affective, and mental/cognitive symptoms. Physical and mental fatigue are different, but they often occur together [1-3]. Repeated physical exhaustion can lead to mental fatigue over time. A person with physical fatigue may find it physically hard to do the things they usually do, such as climbing the stairs. Fatigue is also a common component of mood disorders and is one of the diagnostic symptoms of major depression. There is a substantial body of research that examines the interplay of fatigue and mood in chronic illnesses [4]. One might assume that fatigue and mood would worsen in tandem as disease severity progresses.

Symptoms include muscle weakness, and diagnosis may involve completing a strength test [4]. With mental fatigue, a person may find it harder to concentrate on things and stay focused. They may feel sleepy or have difficulty staying awake while working. Overweight increases fatigue risk by increasing the risk of conditions that have fatigue as a common symptom, such as diabetes or sleep apnea. Carrying more weight and experiencing joint or muscle pain can lead to or exacerbate fatigue. Similarly, underweight people may get tired easily, depending on the cause of their condition. Eating disorders, cancer, chronic diseases, and an overactive thyroid can all cause weight loss, as well as excessive tiredness and fatigue.

The main symptom of fatigue is exhaustion from physical or mental activity. A person does not feel refreshed after resting or sleeping. It might also be hard for them to carry out their daily activities, including work, household chores, and caring for others. The symptoms of fatigue may be physical, mental, or emotional.

Common symptoms associated with fatigue can include:

- Aching or sore muscles.
- Apathy and a lack of motivation.
- Daytime drowsiness.
- Difficulty concentrating or learning new tasks.
- Gastrointestinal problems, such as bloating, abdominal pain, constipation, or diarrhea.
- Headache.
- Irritability or moodiness.
- Slowed response time.
- Vision problems, such as blurriness.

Symptoms tend to get worse after exertion. They may appear a few hours after activity or exercise, or possibly on the next day Table 1.

Table 1 shows the different body fat percentages, BMI, body water percentages, stress score, and fatigue of female individuals. The ranges differ between males and females for body fat percentage, though we have taken on female individuals for the study, while for BMI, body water, and stress score, it is common between males and females. For fatigue, we have taken excellent as one and good as two and very bad as five and as such.

Under Weight	0 to 21	**Under Weight**	<18.5
Normal	21.01-33	**Healthy Weight**	18.5-24.9
Overweight	33.01-39	**Overweight**	25-29.9
Obese	>39	**Obese**	>30
Sub-Optimal	<55	**Not Stressed**	0-30
Good	55 to 65	**Under Control**	30.01-50
		Stressed	50.01-80
		Highly Stressed	80.01-100
Excellent	81-100	1	
Good	61-80	2	
Normal	41-60	3	
Bad	21-40	4	
Very Bad	0-20	5	

Table 1: Ranges for body fat, BMI, body water, stress score and fatigue.

It is a known fact that exercise is important in preventing obesity, type-2 diabetes, and other disorders characterized by metabolic disturbances. Also, since overweight people are less active than lean people, it’s often assumed that the relationship between physical activity levels and body mass index goes in one direction, in the sense that inactivity leads to weight gain. Lack of self-control and “mental weakness” are often considered the primary reasons people have trouble getting off the couch and into the gym. The general belief is that folks with excess body fat are less active simply because they lack the willpower and discipline to start exercising. But what if it’s not that easy? Correlation doesn’t imply causation. Although a sedentary lifestyle obviously can contribute to metabolic deregulation and weight gain, it’s becoming increasingly clear that it also works the other way around; that weight gain can make you tired and sedentary. This means that on average, the more fat you carry, the more sedentary you are.

The factors such as discipline, willpower, and the perceived benefits of exercise, certainly play an important role. Several hormones, neurotransmitters, genes, inflammatory mediators, and other factors can also impact how physically active we are by influencing our energy, fitness, and spontaneous physical activity levels. This explains why overweight and obesity, which are often characterized by hormonal dysregulation and certain genetic predispositions, can cause inactivity. The reason why fatigue and weight gain go hand in hand is easy to understand. When you burn one gram of fat, you produce two-and-a-half times more energy than when you burn a gram of protein or carbohydrates. It's also important to remember that psychological factors play a role, as many people with excess body fat (and many lean people) find it uncomfortable to exercise at a gym [5].

Weight gain and inactivity are linked through a vicious cycle. A sedentary lifestyle contributes to poor metabolic health, low-grade inflammation, excess fat storage, and weight gain, which further contributes to inactivity. Inactivity isn't just a cause of weight gain but also a consequence. It is important to have in the back of the mind when dealing with weight regulation and obesity.

While it's often believed that exercise is just a matter of willpower and discipline, science clearly shows that other factors also play a significant role. While some people have no problem exercising every day and find physical activity highly rewarding, genetic predispositions, poor metabolic health, mental barriers, and low-grade chronic inflammation can make exercise seem like hell to others. This doesn't mean that we don't have control over our actions and that people who carry excess fat don't have a choice except to stay sedentary - it just means that individual differences play an important role.

The expanding view of the relationship between activity levels and body composition has implications for people who lack the desire to exercise and trainers, health practitioners, and other personnel that work with health and fitness. People who feel fatigued and tired have been keeping them back from having an active lifestyle. It might come as a relief that it's not just a lack of discipline that makes the trip to the gym seem like a nightmare.

The study aimed to show the impact of BMI, BFP, BW, and Stress on an individual's fatigue. The findings showed promising results.

Technology Explanation

HRV

Assessment of the beat-to-beat variability or heart rate variability (HRV) can be an indicator of "stress" (physical and mental) on the body [6]. Fatigue state is measured using Fast Fourier Transform (FFT) or Frequency Domain Analysis of Heart rate variability (HRV). HRV represents the variations of normal RR intervals (the time elapsed between two successive R-waves). The frequency domains are a non-invasive tool used to assess the autonomic nervous system control the heart rate [7]. Particularly, in the time domain, the standard deviation of normal RR intervals (SDNN), the Root Mean Square Successive Differences (RMSSD), and the percentage of adjacent cycles that are greater than 50 ms (pNN50) are considered as indices of vagal activity. In the frequency domain, the high frequency (HF: 0.15 Hz - 0.40 Hz) power characterizes the parasympathetic control and the low frequency (LF: 0.04 Hz -0.15 Hz) both the sympathetic and parasympathetic activities [8].

Frequency domain analysis is a complex analysis technique that shows how much of a signal lies within one or more frequency bands. Regarding heart rate variability, research has identified certain frequency bands that correlate with certain physiological phenomena, such as parasympathetic nervous system activity [8]. Figure 1 shows the frequency spectrum showing HRV frequencies. Common frequency domain HRV metrics include [7]:

- High Frequency power (HF): Frequency activity in the 0.15 Hz - 0.40 Hz range.
- Low Frequency power (LF): Frequency activity in the 0.04 Hz - 0.15 Hz range.

- LF/HF Ratio: A ratio of low frequency to high frequency.

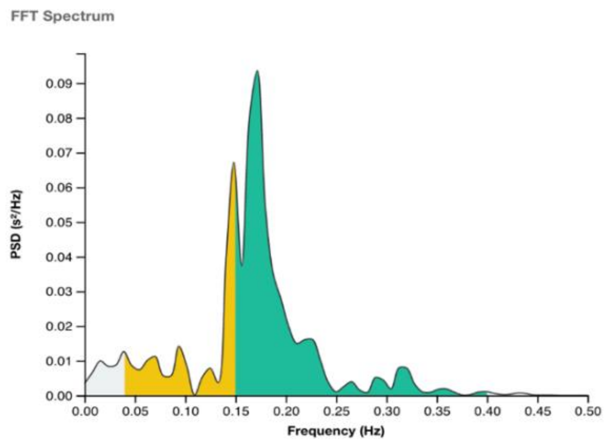

Figure 1: FFT spectrum showing HRV frequencies [8].

NIR

Body fat and body water are measured using the NIR technology. NIR fat measurement technology is based on non-invasive probes that contain a near infra-red-light source and near infra-red-light detector. The near-infra-red ray penetrates the body tissues. The reflected infra-red light that gets detected is then mathematically calculated to get the body fat percentage. This measurement is generally done in biceps to get more accurate readings. Figure 2 shows the NIR sensor for reading body fat, and body water content.

Figure 2: NIR device used to measure the body fat.

METHOD

The device sends a low-energy beam of near-infrared light at about 900 nanometres into the biceps area that penetrates the underlying tissue to a depth of one centimeter. The energy is either reflected, absorbed, or transmitted, depending on the scattering and absorption properties of the biceps. A detector within the wand measures the intensity of the reflected light. Shifts in the wavelength of the reflected beam and a prediction equation are used to compute the percent body fat [8]. The NIR data are entered into a prediction equation with the person's height, weight, age, gender, frame size, and level of physical activity.

The body water is also calculated by entering the NIR data into a prediction equation. The stress score is calculated using data from the FDA-approved device using different equations.

Data Collection

The data set for the study was acquired from a health monitoring device called K-350 Health Kiosk, and it uses an HG865 Body composition analyzer, which uses NIR technology for calculating vital parameters of the body like blood pressure, body fat percentage, and body water percentage. Stress score was calculated from the FDA-approved device. Fatigue is calculated by the frequency domain analysis of heart rate variability (HRV) technology, an FDA-approved device. A total of 735 female candidates, whose ages ranged from 18 to 70, were taken to obtain the data. Before the screening, the below conditions were met to get precise measurements. The candidates were allowed to take rest, 10 minutes to 15 minutes before the measurement.

- They were asked not to smoke, exercise, take medicines, or drink beverages 45 minutes before the screening.

- All personal belongings (watch, mobile, etc.) were moved out from the kiosk to avoid electronic interference and avoid extra weight.
- The left index finger was cleaned with a spirit swab to remove oil stains and dirt just before the screening to ensure PPG measurement accuracy.
- The candidates were advised not to move or talk during the screening.

Analysis

For the fatigue analysis, mean and standard deviations of the data set were considered against age, body mass index, body fat percentage, body water and stress score. One-way ANOVA test and Regression analysis were also plotted using the PSPPIRE software to find the influence of age, body mass index, body fat percentage, body water percentage and stress score on five states of fatigue.

RESULTS

Analysis of Data Taken

Tend 2 shows the mean and standard deviation of the BMI samples. From table 2, it is clear that the average BMI lies in the range of 18.03 to 18.16 for the underweight category (BMI: 0 to 18.5). The mean BMI varies between 21.65 to 24.59 for the normal category (BMI: 18.51 to 24.99) and the BMI variation, 25.95 to 27.74 for the overweight category (BMI: 25 to 29.99). For the obese category (BMI >30) the mean varies between 25.91 to 27.89.

S. No.	Age	BMI Range	Fatigue	Mean	Std. Deviation
Under Weight					
1	18 to 70	0 to 18.5	Excellent	18.16	0
2	18 to 70	0 to 18.5	Good	18.03	0.25
3	18 to 70	0 to 18.5	Normal	18.04	0.39
4	18 to 70	0 to 18.5	Bad	0	0
5	18 to 70	0 to 18.5	Very Bad	0	0
Healthy Weight					
1	18 to 70	18.51 to 24.99	Excellent	21.65	1.46
2	18 to 70	18.51 to 24.99	Good	22.57	1.67
3	18 to 70	18.51 to 24.99	Normal	22.29	1.72
4	18 to 70	18.51 to 24.99	Bad	24.57	0.29
5	18 to 70	18.51 to 24.99	Very Bad	24.59	0
Overweight					
1	18 to 70	25 to 29.99	Excellent	0	0
2	18 to 70	25 to 29.99	Good	25.96	0.7
3	18 to 70	25 to 29.99	Normal	25.95	0.54
4	18 to 70	25 to 29.99	Bad	27.19	1.36
5	18 to 70	25 to 29.99	Very Bad	27.74	1.06
Obese					
1	18 to 70	>30	Excellent	0	0
2	18 to 70	>30	Good	25.91	0.7
3	18 to 70	>30	Normal	25.95	0.55
4	18 to 70	>30	Bad	27.55	1.7
5	18 to 70	>30	Very Bad	27.89	1.6

Table 2: Mean and standard deviation of BMI data (N = 735).

Table 3 shows the mean and standard deviation of the BFP samples. From table 3, it is understood that the average BFP lies in the range of 20.4 to 20.43 for the underweight category (BFP: 0 to 21). The mean BFP varies between 24.71 to 31.93 for the healthy weight category (BFP: 21.01 to 33) and the BMI variation, 35.54 to 35.67 for the overweight category (BFP: 33.01 to 39). For the obese category (BMI >39) the mean varies between 40.59 to 41.56.

S. No.	Age	BFP Range	FS	Mean	Std. Deviation
Under Weight					
1	18 to 70	0 to 21	Excellent	20.4	0.1
2	18 to 70	0 to 21	Good	20.43	0.43
3	18 to 70	0 to 21	Normal	20.39	0.28
4	18 to 70	0 to 21	Bad	0	0
5	18 to 70	0 to 21	Very Bad	0	0
Healthy Weight					
1	18 to 70	21.01 to 33	Excellent	24.71	1.88
2	18 to 70	21.01 to 33	Good	26.32	2.35
3	18 to 70	21.01 to 33	Normal	27.12	3.02
4	18 to 70	21.01 to 33	Bad	30.98	1.1
5	18 to 70	21.01 to 33	Very Bad	31.93	0.5
Overweight					
1	18 to 70	33.01 to 39	Excellent	0	0
2	18 to 70	33.01 to 39	Good	0	0
3	18 to 70	33.01 to 39	Normal	0	0
4	18 to 70	33.01 to 39	Bad	35.54	1.59
5	18 to 70	33.01 to 39	Very Bad	35.67	1.44
Obese					
1	18 to 70	>39	Excellent	0	0
2	18 to 70	>39	Good	0	0
3	18 to 70	>39	Normal	0	0
4	18 to 70	>39	Bad	40.59	1.28
5	18 to 70	>39	Very Bad	41.56	1.96

Table 3: Mean and standard deviation of BFP data collected (N = 735).

S. No.	Age	BW Range	FS	Mean	Std. Deviation
Sub-Optimal					
1	18 to 70	0 to 55	Excellent	55	0
2	18 to 70	0 to 55	Good	54.13	0.54
3	18 to 70	0 to 55	Normal	53.61	0.85
4	18 to 70	0 to 55	Bad	51.13	2.04
5	18 to 70	0 to 55	Very Bad	48.97	2.39
Good					
1	18 to 70	55 to 65	Excellent	57.17	1.32
2	18 to 70	55 to 65	Good	56.94	1.37
3	18 to 70	55 to 65	Normal	57.08	1.28
4	18 to 70	55 to 65	Bad	0	0
5	18 to 70	55 to 65	Very Bad	0	0

Table 4: Mean and standard deviation of BW data collected (N = 735).

Table 4 shows the mean and standard deviation of the BW samples. From table 4, it is obvious that the average BW lies in the range of 48.97 to 55 for the sub optimal category (BW: 0 to 55). The mean BW varies between 56.94 to 57.17 for the good category (BW: 55 to 65).

Table 5 shows the mean and standard deviation of the stress score samples. From table 5, it is clear that the average SS lies in the range of 23.2 to 24.82 for not stressed (SS: 0 to 30). The mean SS varies between 42.08 to 50 for the under control (SS: 30.01 to 50) and the SS variation, 52 to 65.13 for the stressed (SS: 50.01 to 80). For the highly stressed (SS: 80.01 to 100) the mean varies between 83.56 to 85.44.

S. No.	Age	Stress Score Range	FS	Mean	Std. Deviation
Not Stressed					
1	18 to 70	0 to 30	1	24.33	2.49
2	18 to 70	0 to 30	2	23.2	4.17
3	18 to 70	0 to 30	3	24.82	2.17
4	18 to 70	0 to 30	4	0	0
5	18 to 70	0 to 30	5	0	0
Under Control					
1	18 to 70	30.01 to 50	1	42.08	3.88
2	18 to 70	30.01 to 50	2	43.41	4.65
3	18 to 70	30.01 to 50	3	45.11	4.38
4	18 to 70	30.01 to 50	4	50	0
5	18 to 70	30.01 to 50	5	50	0
Stressed					
1	18 to 70	50.01 to 80	1	52	1.22
2	18 to 70	50.01 to 80	2	52.73	1.14
3	18 to 70	50.01 to 80	3	54.38	3.34
4	18 to 70	50.01 to 80	4	61.47	7.54
5	18 to 70	50.01 to 80	5	65.13	8.26
Highly Stressed					
1	18 to 70	80.01 to 100	1	0	0
2	18 to 70	80.01 to 100	2	0	0
3	18 to 70	80.01 to 100	3	0	0
4	18 to 70	80.01 to 100	4	83.56	2.36
5	18 to 70	80.01 to 100	5	85.44	2.09

Table 5: Mean and standard deviation of stress score data collected (N = 735).

Table 6 shows the regression analysis of BFP, BW, BMI, SS with Fatigue Score. The linear regression table will establish the significant relationship between Fatigue (dependent variable) and BFP, BW, BMI, SS (independent variables). From table 6, we can see that the 'r square' value showing the amount of variation in the dependent variable and the independent variables as 0.61. The dependency percentage between BFP, BW, BMI, SS to Fatigue is 61% from the analysis. The remaining 39% will depend on some other hidden parameters: clinical or family history.

REGRESSION/VARIABLES = AGE BFP BW BMI SS

REGRESSION/DEPENDENT = FS

REGRESSION/METHOD = ENTER

REGRESSION/STATSTICS = COEFF R ANOVA

Model Summary (FS)					
R	R Square	Adjusted R Square	Std. Error of the Estimate		
0.78	0.61	0.61	10.71		
ANOVA (FS)					
	Sum of Squares	df	Mean Square	F	Sig.
Regression	131767.5	5	26353.51	229.61	.000
Residual	83671.40	729	114.78		
Total	215438.9	734			
Coefficients (FS)					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	1627.46	1388.27	.00	1.17	.241
AGE	-.13	0.07	-.06	-1.89	.059
BFP	-14.33	12.34	-4.08	-1.16	.246
BW	-20.56	19.02	-3.81	-1.08	.280
BMI	-.55	0.33	-.11	-1.65	.099
SS	-.67	0.04	-.46	-16.02	.000

Table 6: Regression analysis for BFP, BW, BMI, SS with fatigue score.

Analysis of Fatigue State with Respect to BMI

BMI result analysis of FS

The figure 3 shows the Fatigue distribution (Excellent, Good, Normal, Bad, Very Bad) on Indian females with BMI (underweight, healthy weight, overweight & obese) classification. Body composition is a powerful predictor of mortality and morbidity in humans. The most common estimate of body composition in populations has been the body mass index, which was developed as a measure of weight independent of height and not as an index of obesity [10,11]. It's an applicable rule used widely to categorise a person as underweight, normal weight, overweight, or obese based on tissue mass and height. The value is derived from the weight and height of a person. It can be calculated by dividing the weight by the square of the body height. BMI shows a numeric measure of a person's thickness and thinness. Here the body mass is compared with the fatigue state.

Figure 3 shows the comparison of BMI category and Fatigue states. In the underweight category, we can see the fatigue states of excellent, good and normal. Good is elevated in the underweight category. When in a healthy weight, we could see all the five states of fatigue. Excellent, good, normal, bad and very bad is seen. However, the bad and very bad is seen the least. Excellent is seen more following good and normal states. We can see a clear decline of the good and normal state in the overweight category, and excellent is nowhere in the picture. Bad is seen more followed by very bad. In the obese category, the bad and very bad states of fatigue can only be seen. Excellent, good and normal is nowhere seen in the picture. A clear indication of BMI's influence on fatigue. In both the overweight and obese category of BMI, we could see a strong influence of bad and very bad states.

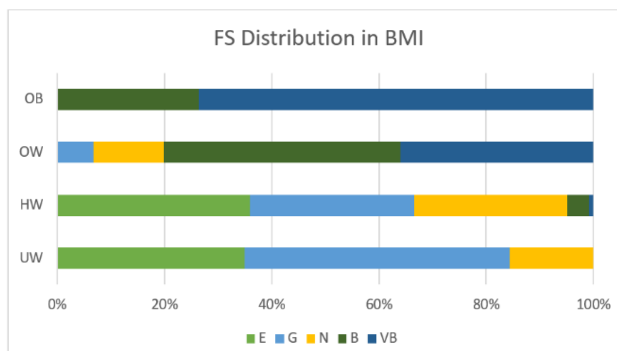

Figure 3: Stacked Bar plot showing the fatigue state on BMI.

ONEWAY/VARIABLES = BMI BY FI

ONEWAY/STATSTICS = DESCRIPTIVES

Descriptives									
						95% Confidence Interval for Mean			
	FI	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BMI	1	34	21.44	1.66	0.29	20.86	22.02	18.16	24.83
	2	60	22.58	2.33	0.30	21.98	23.19	17.73	26.92
	3	380	23.01	2.31	0.12	22.78	23.25	17.07	26.97
	4	213	27.38	1.99	0.14	27.11	27.65	24.03	31.97
	5	48	29.55	3.05	0.44	28.67	30.44	24.59	38.34
	Total	735	24.60	3.32	0.12	24.36	24.84	17.07	38.34
ANOVA									
		Sum of Squares	df	Mean Square	F	Sig.			
BMI	Between Groups	4366.23	4	1091.56	215.18	.000			
	Within Groups	3703.17	730	5.07					
	Total	8069.40	734						

Table 7: ANOVA table for fatigue state and BMI.

BMI - ANOVA Test Results

The ANOVA test result for finding the relation between BMI and Fatigue is shown in table 7. As per the ANOVA, it is clear that there is correlation between the BMI and Fatigue as the p-value for this interaction is lower than 0.05. The p value less than 0.05 has been taken as significant in this paper.

BMI - Fatigue Correlogram Analysis

A correlogram is a graphical representation of data where values are depicted by color. It visualizes the most popular and unpopular elements of a dataset using colors on a scale from dark to light. Here we have used green color for representation. By aggregating behavior of data, correlogram facilitate data analysis and give an at-a-glance understanding of how data is distributed [12].

The correlogram given in figure 4 shows BMI's Obese influence on determining the subject's Fatigue. According to the figure, healthy weight category of BMI has great chance of falling in fatigue's excellent, normal and good category. Same as in overweight it shows a high chance of falling in bad and very bad category of fatigue. Obese category shows a chance of falling in very bad category of fatigue. Hence once again we can see an influence of BMI on fatigue states.

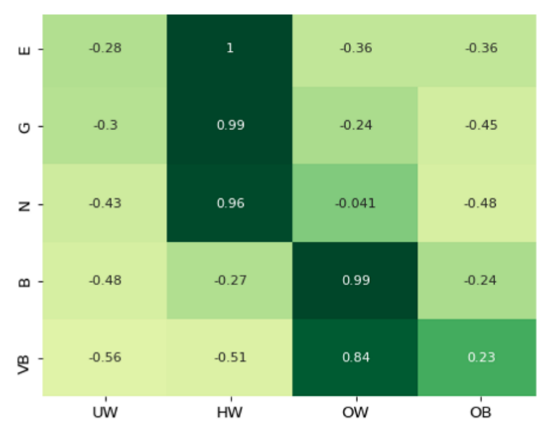

Figure 4: Correlogram showing the influence of BMI on fatigue.

Analysis of Fatigue State with Respect to Body Fat Percentage

BFP based result analysis of FS

The figure 5 shows the Fatigue distribution (Excellent, Good, Normal, Bad, Very Bad) on Indian females with BFP (Underweight, Normal, Overweight & Obese) classification.

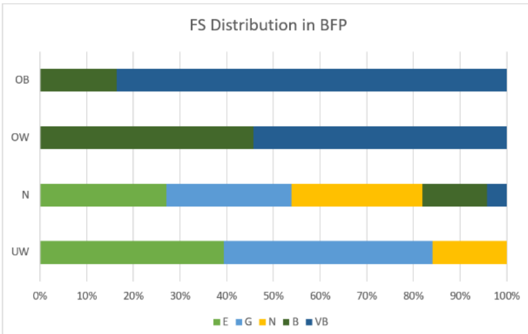

Figure 5: Graph showing the fatigue state on BFP.

The graph in figure 5 shows the comparison of the BFP category with Fatigue states. In the first underweight category, the fatigue states of excellent, good and normal could be seen. There is no sign of bad and very bad states of fatigue in this category. When moving to the normal category, the presence of five states of five fatigue could be seen. Though in this category of bad and very bad have a little presence and excellent, good and normal shares equally. Overweight and obesity are defined as abnormal or excessive fat accumulation in the body that may impair health [13]. Preventing and managing overweight and obesity are complex problems with no easy answers. Numerous methods for estimating these figures are available, and each has its limitation, be it technical or biological [14]. The overweight category only bad and very bad states of fatigue. No indication of excellent, good and normal categories. We can see that the very bad category is more than bad in overweight itself. At present, obesity is well recognized as one of the major public health issues worldwide [15]. The obese category has the worst fatigue sates of bad and very bad, in which the latter has the majority. If a person is in the obese category of body fat percentage, has a very high possibility of her fatigue being very bad or at least bad.

Body composition refers to the proportion of fat you have relative to lean tissue (muscles, bones, body water, organs, etc.). This measurement is a clearer indicator of your fitness. No matter what you weigh, the higher percentage of body fat you have, the more likely you are to develop obesity-related diseases, including heart disease, high blood pressure, stroke, and type 2 diabetes [16]. It is the only body measurement that directly calculates a person's body composition without considering height or weight. Body fat percentage is calculated by total fat mass divided by total body mass and multiplying by 100. There will be a total of three types of body fat in the human body. Essential, storage, and excess body fat. Essential body fat is important to maintain daily life functions, while stored body fat is stored and used for emergencies. Excess body fat is a clear indicator of unnecessary body storage. Several methods are available to determine the body fat percentage. Here we use NIR technology to determine the body fat.

BFP - ANOVA Test Results

The ANOVA test result for finding the relation between BFP and Fatigue is shown in table 8. As per the ANOVA, it is obvious that there is a correlation between the BFP and Fatigue as the p-value for this interaction is lower than 0.05. The p value less than 0.05 has been taken as significant.

ONEWAY/VARIABLES = BFP BY FI

ONEWAY/STATSTICS = DESCRIPTIVES

Descriptives									
						95% Confidence Interval for Mean			
	FI	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BMI	1	34	24.45	2.12	.36	23.71	25.19	20.30	27.70
	2	60	25.93	2.73	.35	25.22	26.63	19.70	30.70
	3	380	26.97	3.16	.16	26.65	27.28	20.00	32.30
	4	213	33.64	3.15	.22	33.22	34.07	29.00	43.00
	5	48	36.96	3.72	.54	35.88	38.05	31.00	45.00
	Total	735	29.35	4.88	.18	29.00	29.71	19.70	45.00
ANOVA									
		Sum of Squares	df	Mean Square	F	Sig.			
BMI	Between Groups	10391.00	4	2597.75	266.25	.000			
	Within Groups	7122.35	730	9.76					
	Total	17513.35	734						

Table 8: ANOVA table for fatigue state and BFP.

BFP - Heatmap Analysis

A correlation heatmap uses coloured cells, typically in a monochromatic scale, to show a 2D correlation matrix (table) between two discrete dimensions or event types. Correlation heatmaps are ideal for comparing the measurement for each pair of dimension values. The figure above shows the relation between BFP and Fatigue. There's a clear indication of excellent, good and normal states of fatigue in the healthy weight category. Same as in overweight it shows the chance of fatigue state falling to bad state and then to a very bad state. In the obese category a high chance of falling to a very bad state and bad state of fatigue. If the correlation value comes as 1, then it's possible to say a 100% percentage correlation between the two. Hence, we could say that there's a great influence of body fat percentage in the fatigue state of individuals (Figure 6).

Figure 6: Heatmap showing the influence of BFP on fatigue.

Analysis of Fatigue State with Respect to Body Water Percentage

Water is essential for life. From the time that ancient species ventured from the oceans to live on land, a major key to survival was dehydration. The necessary adaptations cross an array of species, including man. Without water, humans can survive only for days. Water comprises 75% body weight in infants to 55% in the elderly and is essential for cellular homeostasis and life [17]. It acts as a building material, as a solvent, reaction medium and reactant, as a carrier for nutrients and waste products, thermoregulation, and a lubricant and shock absorber [18]. Body water percentage is defined as the water content in a human body. It is the total amount of fluid in the human body. This water could be at tissues, blood, bones or anywhere in the body. It is one of the important measures of a healthy body. The human body needs water to function. It is the primary building block for cells. Helps to regulate the internal body temperature, strengthen the muscle and keep the skin moisturized. How much water we need depends on water functions and the mechanisms of daily water balance regulation [17]. Body water percentage is divided into two categories. Below 55 is sub-optimal. Between 55 to 65 is normal. It is always advised to keep the range between 55 to 65. The human body's 60% weight is water content.

Figure 7 shows the comparison between body water categories sub-optimal and good with fatigue state. Normal, Bad and Very Bad are the major portions in all three categories. We can see in the good category there is no very bad and bad states of fatigue. Inadequate hydration in the elderly is associated with increased morbidity and mortality [19]. When you have less body water percentage and fall in the sub-optimal category, you have high chances of falling in the very bad and bad category. We could see that very bad and bad states cover the major portion of the sub-optimal category. Sub-optimal has a little of the excellent and good state, while the good category has a major portion of excellent and good. With this, it can be related that low body water can have a major role in the fatigue state of an individual.

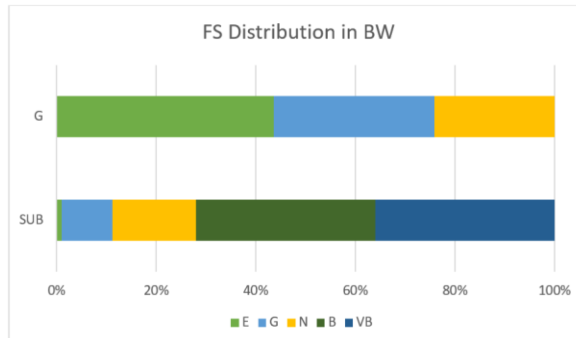

Figure 7: Graph showing the fatigue state on BW.

BW - ANOVA Test Results

The ANOVA test result for finding the relation between BW and Fatigue is shown in table 9. As per the ANOVA, it is clear that there is a correlation between the BW and Fatigue as the p-value for this interaction is lower than 0.05. The p value less than 0.05 has been taken as significant.

ONEWAY/VARIABLES = BW BY FI

ONEWAY/STATSTICS = DESCRIPTIVES

Descriptives									
						95% Confidence Interval for Mean			
	FI	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
BMI	1	34	57.11	1.37	.24	56.63	57.59	55.00	59.80
	2	60	56.14	1.76	.23	55.69	56.60	53.04	59.80
	3	380	55.47	2.05	.11	55.26	55.68	52.00	59.94
	4	213	51.13	2.05	.14	50.85	51.41	45.05	54.15
	5	48	48.97	2.42	.35	48.27	49.68	43.75	52.85
	Total	735	53.92	3.17	.12	53.69	54.15	43.75	59.94
ANOVA									
		Sum of Squares	df	Mean Square	F	Sig.			
BMI	Between Groups	4386.41	4	1096.60	266.58	.000			
	Within Groups	3002.95	730	4.11					
	Total	7389.36	734						

Table 9: ANOVA test table for fatigue state and BW.

BW - Correlogram Analysis

The correlogram in figure 8 shows the relation between BW and Fatigue. The figure shows when an individual falls in the Sub-optimal condition of body water; there's a chance of falling into a very bad and bad category, the heatmap value shown as 1. The correlogram shows that normal, good and excellent could fall in the good category of body water. If the correlation value comes as 1, then it's possible to say a 100% percentage correlation between the two. Hence, we could say that there's a great influence of body water on the fatigue state of individuals.

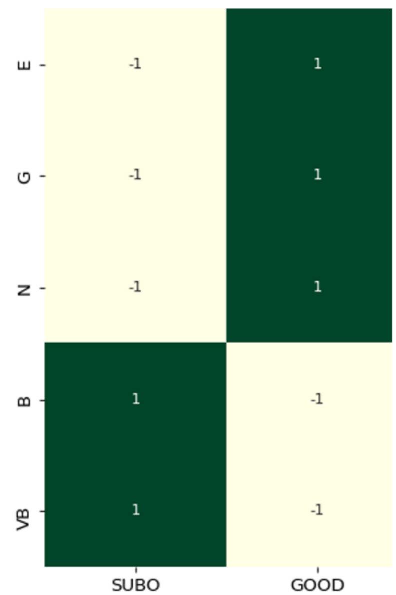

Figure 8: Correlogram showing the influence of BW on fatigue.

Analysis of Fatigue State with Respect to Stress Score

Stress is your body's reaction to a challenge or demand. In short bursts, stress can be positive, such as when it helps you avoid danger or meet a deadline. But when stress lasts for a long time, it may harm your health [20]. Stress could affect a person physically or mentally. Long-time stress is a severe health issue and could lead to many other health problems, including fatigue. Fatigue-related disorders (e.g., Chronic fatigue syndrome) are often associated with elevated levels of psychological distress. Evidence suggests a bidirectional association between fatigue and stress [21]. Stress-related psychological disorders (e.g., posttraumatic stress disorder and depression) have fatigue as a core characteristic [21].

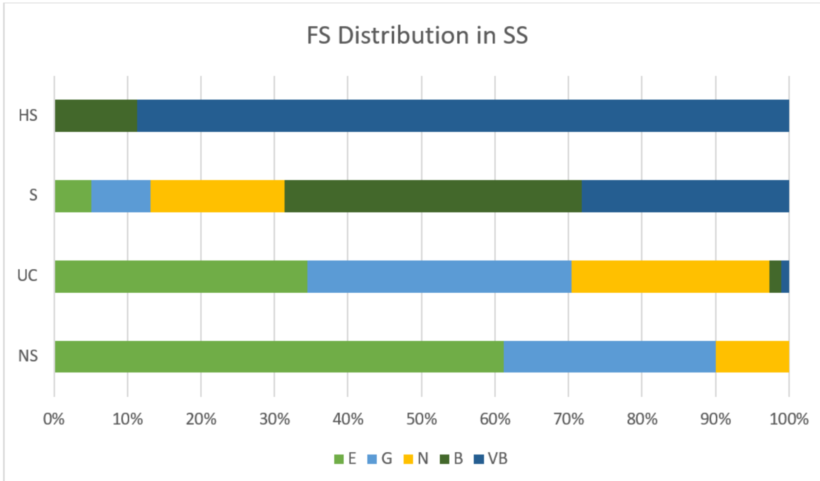

Figure 9: Graph showing the fatigue state on stress score.

Stress is a feeling of emotional or physical tension. It can come from any event or thought that makes you feel frustrated, angry, or nervous [20]. Figure 9 shows the comparison of stress score states with Fatigue states. The stress score states are classified into four: not stressed, under control, stressed, and highly stressed. From the above figure, the not stressed category only contains an excellent, good and normal category of fatigue state, and the excellent state has the major portion followed by good. In the under-control category of stress state, one can see all the five states of fatigue, though the bad and very bad states are very little. In this category also the excellent and good category has the majority followed by normal. Again, in the stressed category, we could see five states of fatigue, but it has taken a reverse form compared to the under-control category. Bad and very bad has the majority in the stressed category, while little of excellent, good and normal also shows their presence. In the highly stressed category, only a bad and very bad state could be seen. In that, more than 85% is covered by very bad state and rest by bad state. A clear indication of stress's influence on fatigue. In both the stressed and highly stressed category, we could see a strong influence of bad and very bad states.

Stress Score - ANOVA Test Results

The ANOVA test result for finding the relation between stress and fatigue is shown in table 10. As per the ANOVA, it is clear that there is correlation between the stress score and fatigue state as the p-value for this interaction is lower than 0.05. The p value less than 0.05 has been taken as significant.

Stress Score - Correlogram Analysis

The correlogram in figure 10 shows the relation between stress score and fatigue states. When an individual falls in the under-control category, the figure shows that the candidate can fall to excellent, good, and normal fatigue states. There's a high chance of an individual falling into the bad, very bad and normal category; the value shown is 1. If the correlation value comes as 1, then it's possible to say a 100% percentage correlation between the two. Hence, we could say that there's an influence of stress in the fatigue state of individuals.

ONEWAY/VARIABLES = SS BY FI

ONEWAY/STATSTICS = DESCRIPTIVES

Descriptives									
						95% Confidence Interval for Mean			
	FI	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
SS	1	34	40.12	8.80	1.51	37.05	43.19	21.00	54.00
	2	60	43.43	8.29	1.07	41.29	45.57	18.00	55.00
	3	380	48.40	7.25	.37	47.67	49.13	21.00	69.00
	4	213	62.03	8.82	.60	60.84	63.22	50.00	88.00
	5	48	71.58	12.22	1.76	68.04	75.13	50.00	89.00
	Total	735	53.08	11.85	.44	52.22	53.93	18.00	89.00
ANOVA									
		Sum of Squares	df	Mean Square	F	Sig.			
SS	Between Groups	53098.58	4	13274.64	193.68	.000			
	Within Groups	50033.16	730	68.54					
	Total	103131.7	734						

Table 10: ANOVA test table for fatigue state and stress score.

Figure 10: Correlogram showing the influence of stress score on fatigue.

CONCLUSION

A little is understood about fatigue's symptomatology, biological mechanisms, and treatment. Furthermore, fatigue is difficult to classify by a study; as a subjective experience, it is identifiable only by patients' self-reports [22]. Fatigue is conceptually ambiguous and may manifest itself with physical/neuromuscular, emotional/affective, and mental/cognitive symptoms. The multiple ways fatigue may be expressed suggest that it might be measured by assessing a range of symptom domains [22].

Our paper was aimed to study the effects of BMI, BFP, Body water and stress on fatigue.

- For body mass index vs fatigue, the interaction in the ANOVA result was less than 0.05, and thus conclude that there's a strong relation of BMI with fatigue. The correlogram analysis shows a high chance of an individual falling under the fatigue - very bad category if the BMI comes in obese and falls in the fatigue-bad if it comes in BMI-overweight.
- For body fat vs fatigue, also the interaction in the ANOVA result was less than 0.05, and thus it shows a strong relationship between body fat and fatigue. The heatmap analysis gives strong support to ANOVA findings. When an individual's BFP falls in the overweight category, there's a high chance of falling under the fatigue-normal or fatigue-bad category. If the individual falls in the obese category, the fatigue category would be very bad.

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- The body water also shows a strong relation with FS. Again, the ANOVA result of interaction falls below 0.05. If the water content is low, it can cause dryness in the body, and the fatigue state can be bad or very bad. If the body water level falls suboptimal, the fatigue could be bad or very bad; likewise, if the water percentage is good, there's a high chance of falling under good and normal.
- The stress score showed a good relation to fatigue. ANOVA result of the interaction falls below 0.05. If an individual is highly stressed or stressed, the fatigue state of that individual could be very bad or bad.

From this study, it's obvious that all the four factors, body mass index, body fat percentage, body water percentage and stress score, play an important role in a female's fatigue state. To maintain a good fatigue state, one should maintain a good fat percentage and body mass index and try to reduce the stress with day to day and activities and drink the right amount of water to keep the body water percentage in a normal state.

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