# ADD-ON EFFECTS OF DIFFERENT YOGA MAT MATERIALS ON THE AUTONOMIC FUNCTIONS OUTCOMES OF YOGA PRACTICES

Dissertation submitted by

**Sridhar R**

Under the guidance of

**Dr.B. Ragavendrasamy**

**Dr. Rajesh S.K**

Towards the partial fulfillment of

*Master of Science in Yoga Therapy*

**MSc (YT)**

**June 2019**

Swami Vivekananda Yoga Anusandhana Samsthana (Deemed to be University)
No.19, Eknath Bhavan, Gavipuram Circle, Kempegowdanagar, Bangalore-560019
India.
http://www.svyasa.edu.in/

# CERTIFICATE

This is to certify that Sridhar. R who registered for the degree of Master of Science in Yoga Therapy at **Swami Vivekananda Yoga Anusandhana Samsthana (S-VYASA University)** Bengaluru, under the division of Yoga and Life Sciences, has completed the required training in acquiring the relevant knowledge of Yoga Therapy and has successfully carried out the research project titled "**Add-on effects of different yoga mat materials on the autonomic functions outcomes of yoga practices**" in partial fulfilment of the course as per the regulation of the University.

Date: **Dr.B. Ragavendrasamy**

Place: Bengaluru

# DECLARATION

I, Sridhar. R, hereby declare that this study was conducted by me at **Swami Vivekananda Yoga Anusandhana Samsthaana, Bangalore**, under the guidance of **Dr. B. Raghavendrasamy** of S-VYASA University, Bengaluru.

I also declare that the subject matter of my dissertation titled "**Add-on effects of different yoga mat materials on the autonomic functions outcomes of yoga practices"** has not previously formed the basis of the award of any degree, diploma, associateship, fellowship or similar titles.

Date: **Sridhar. R**

Place: Bengaluru

## ACKNOWLEDGEMENT

First of all, I am thankful to all the people, who directly or indirectly, showed me the right path through their words of wisdom and blessings. I am thankful to the Almighty for selecting me to perform this work at this esteemed University. I would like to express my deepest gratitude to **B. Ragavendrasamy** for his continuous guidance and encouragement throughout this project.

I thank all the faculty and staff of S-VYASA, especially the team of Yoga Therapy for their help and co-operation at different stages of this work. I am grateful to all the friends for their immense help in data collection.

I am grateful to **Swami Vivekananda Yoga Anusandhana Samsthana (S-VYASA)** for giving me an opportunity to work on this dissertation. I am indebted to my family and friends for their continued inspiration and support. I don't have words to express their immense contribution to my development.

Date: **Sridhar. R**

Place: Bengaluru

# ABSTRACT

## Background

In order to practice yoga sadhana, a yoga mat is often recommended to provide some level the characteristics such as grip, balance and comfort (the mat must allow the user to practice without feeling the ground). And often biomechanical investigations are conducted to assess grip, balance and comfort. However, yoga mats have never researched upon from the perspective of its add-on effects.

## Aim

The aim is to study the influence of various yoga mats made of Cotton, Rubber and Kuça grass on the outcomes of yoga practice.

## Materials and Methods

Sixteen self-declared healthy male volunteers, with six or more months of practice to undergo two experimental states i.e., *nadi-shudhi* pranayama and breath awareness on three different yoga mat types: Rubber, *Kuça* and Cotton on consecutive six days. The autonomic variables were assessed in the six sessions. Frequency domain and time domain analysis of HRV data was carried out.

## Results and Discussion

The results indicate that, Kuça grass mat appear to offer better change across the HRV spectrum. Autonomic nervous system is more stable when one uses *Kuça* mat compared to cotton and rubber mat. The results indicate a significant increase in LF-HF ratio during and immediately after performing the pranayama while seated on cotton and rubber mat. Interestingly, no significant changes were noted in the *Kuça* grass mat.

## Conclusion

There is definitely a positive change in the HRV spectrum after performing pranayama while seated on Kuça grass mat compared to rubber & cotton mat.



## Keywords

yoga mat, cotton, Kuça, pranayama, alternate nostril breathing, *nadi-shuddhi* pranayama, HRV, eco-friendly.

**STANDARD INTERNATIONAL TRANSLITERATION CODE USED TO TRANSLITERATE SANSKRIT WORDS**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| a | = | अ | ṅa | = | ङ | pa | = | प |
| ā | = | आ | ca | = | च | pha | = | फ |
| i | = | इ | cha | = | छ | ba | = | ब |
| ī | = | ई | ja | = | ज | bha | = | भ |
| u | = | उ | jha | = | झ | ma | = | म |
| ū | = | ऊ | ñ | = | ञ | ya | = | य |
| ṛ | = | ऋ | ṭa | = | ट | ra | = | र |
| ṝ | = | ॠ | ṭha | = | ठ | la | = | ल |
| e | = | ए | ḍa | = | ड | va | = | व |
| ai | = | ऐ | ḍha | = | ढ | śa | = | श |
| o | = | ओ | ṇa | = | ण | ṣa | = | ष |
| au | = | औ | ta | = | त | sa | = | स |
| ṁ | = | अं | tha | = | थ | ha | = | ह |
| ḥ | = | अः | da | = | द | kṣa | = | क्ष |
| ka | = | क | dha | = | ध | tra | = | त्र |
| kha | = | ख | na | = | न | jña | = | ज्ञ |
| ga | = | ग | gha | = | घ | | | |

# Table of Contents

# 1. INTRODUCTION

## 1.1 Introduction

A journey into yoga means dissolving the identity of the self and learning to experience expansiveness awareness rather than being caught up in a restrictive and skin-limited understanding of the self. However, yoga is currently observed by many who want to have a better posture and improved physical and mental health.

To start the practice is quite simple and we do this from the confines of our personalized, brightly colored, private rectangular yoga spaces called *yoga mats*. It usually involves execution of complicated yoga movements and a yoga mat is of utmost importance during those sessions. Are we assuming that we need a mat to practice yoga or is it possible to practice yoga without a mat?

## 1.2 Role of yoga mat in yoga practice – a common perspective

Most often, people are advised to practice yoga on a mat instead of on a bare floor. In order to practice yoga, one does not require other equipment, but a mat, it is necessary to invest in it. In fact, yoga practice can be much more effective with a mat. In order to execute complicated yoga movements more conveniently, a yoga mat is of importance during the practice. It serves as protection and cushion for yoga practices which are often performed on the ground. The benefits of the use can be felt when you are forced to perform extreme poses.

Yoga mats can prevent possible injuries that can occur when practicing yoga on a surface that may be slippery. A yoga mat will keep your body warm and will keep your energy that you are generating flowing through your body instead of it being passed. If you are not using a mat, you are exposing yourself to anything and everything and using your own yoga mat limits your exposure to these germs and bacteria.

A yoga mat defines your space. It serves as a fence and gives a sense of space so that you can practice freely in all the movements necessary during each session. Therefore, you have to assess your skill level when choosing a yoga mat and your choice of yoga mat to use mainly depends on the intensity of your yoga activities.

Traditional guidance for the yoga practices recommend using various types of mats for different purposes. And there is a wide variety of yoga mats that are available. Yoga mats are produced using diverse materials like elastic based, synthetic based, Cotton floor covering based and so forth. However, in the present scenario, yoga mats made of rubber, cotton and Kuça grass are being widely used by yoga practitioners round the globe.

## 1.3 Requisite for yoga practice

### 1.3.1 Dress

A loose & comfortable outfit is suitable to wear in order to properly perform yoga, particularly asanas (yoga poses). It is recommended to wear basic, comfortable, breathable something with a loose fit, giving freedom of movement. If clothes are poorly chosen, they can restrict the ability to move freely. One must avoid clothes that are too tight that interfere with both breathing and circulation because it is important to allow as much light and air as possible to have access to the body, and to offer as few obstacles as possible to the transpiration of the skin.

### 1.3.2 Timing

The very best time to practice yoga is upon waking up early in the morning after emptying the bowels and the second most conducive time is early evening around sunset before eating. Early morning means an hour and a half before sunrise and it is called *Brahmamuhurta*, 'the period of Brahma.' Evening, around the time of sunset, is called Sandhya. Sandhya is the meeting of day and night. These specified times for practice are important because of correlation to body rhythms and solar/lunar activities. The external influences of the sun rising or the evening commencing affect body rhythms and functions, making it conducive for yoga practice. And most importantly, it is recommended that practice of yoga be done every day at the same time.

### 1.3.3 Environment

Yoga traditionally was practiced in retreat in nature, in the mountains and forests or by the river banks and sea shores. However, in the context of modern times, one may do yoga practice anywhere, but there are certain places that are better and certain places that one should avoid if possible. The place of practice must be very clean with availability of fresh air. It is recommended to choose the quietest place possible. In order to reap maximum benefits, an atmosphere to practice yoga would be an environment that is comfortable and convenient to your enjoyment.

### 1.3.4 Food/Diet

There is a general misconception that a large quantity of food is necessary for health and strength. However, care must be taken from becoming too food conscious because many people indulge in food as a means of escape for the mind. It is important to eat what is necessary to maintain bodily requirements and a diet which will be most conducive for yoga practice.

Moderation in diet in recommended, moderation in diet means neither overeating nor under eating. It means eating sparingly but comfortably filling the stomach and meeting the requirements of the body. Thus, body and mind remain healthy and balanced. The stomach should never be overloaded, it should be half filled with food, one quarter with water and one quarter with air.

## 1.4 Types of Yoga mat in Yogic tradition

It's prescribed in Ayurveda not to sit on bare floors because of the risk of *Vata*. And for this reason yogis usually use some kind of separation between themselves and the floor/rock etc. Traditional guidance for the yoga practices recommend using various types of mats for different purposes. However, in the present scenario, yoga mats made of rubber, cotton and Kuça grass are being widely used by yoga practitioners round the globe.

Rubber mats appear to be one of the commonest choices for yoga practices as they offer cushioning, and are slip-resistant. While cotton yoga mats are another alternative which gives good cushioning for yoga exercise because of soft texture & they absorb sweat easily.

They are also easy to maintain since they can be regularly washed after use. It is this particular quality which makes them more hygienic. But they are not long lasting as rubber yoga mats.

### 1.4.1 Mats – It's relevance – Effects if any

#### 1.4.1.1 Kuça

*Kuça* grass is scientifically known as panic grass and of genus borage species. *Kuça* grass mat is mainly used for sitting and doing meditation, yoga, puja like *hoomam*, praying god in home, etc,. In Ayurveda, Kuça grass is also used as a medicine to treat dysentery and menorrhagia and to promote free flow of urine. Mats made of *Kuça* grass make very good meditation seats and sages often sit on *Kuça* grass mats when they do their meditation.

Kuça grass has been mentioned in the Rig Veda for use in sacred ceremonies and also to prepare a seat for priests. Kuça grass is specifically mentioned in the Bhagavad Gita as part of the ideal seat for meditation for a sadhaka. According to early Buddhist accounts, Kuça grass was used by Buddha for his meditation seat when he attained enlightenment.

And it is believed that Kuça grass blocks energy generated during meditation from being discharged through our body (mostly through legs and toes) into ground. Kuça grass can also be used to help shield people from the negative and scientific radiations.

#### 1.4.1.2 Tiger Skin

Animal skins, whether sheep, yak or carnivorous beast, have been used for survival from the elements, comfort, convenience and status since humans could hunt or domesticate animals. Because of their easy availability, they were a readily available source of material to create clothing, dwellings and furnishings. Skins and furs form a natural mat or rudimentary carpet, and have been used in this way from prehistory up to our present technological age. Thus, using animal skin as a seat for meditation dates back to the earliest times.

Often yogis chose tiger skin and it is evident from the pictures of yogis sitting on animal skin. Basically, they used what was available. For forest yogis it was natural to use a dry, tanned skin, like the non-conducting gloves when handling electricity.

It is believed that if you sit on a tiger skin, it was possible to acquire all the siddhis and supernatural powers. And that it brings power because the skin has its own vibration, provided the animal has died naturally, then the skin is believed to retain the natural quality or the nature of the animal.

#### 1.4.1.3 Silk

Silk is an animal fiber produced by certain insects to build their cocoons and webs, and is the only natural fiber that occurs in filament form. And silk of all other fibers known to mankind, is considered as one of the oldest. Silk has been used and regarded as a highly valued textile fiber for over 4000 years. Silk has outstanding mechanical properties and biocompatibility. They displaying unusual mechanical properties, such as being strong, extensible, and mechanically compressible (Yin et al., 2018).

Silk is one of the most beautiful fabrics available, with a long and colourful history and changing applications in the world today. Silk's capacity to absorb water makes it comfortable to wear in warm weather and whilst engaged in activity. However, it is equally good in cold weather, as its low conductivity keeps warm air close to the skin.

#### 1.4.1.4 Deer skin

In olden days, the deer was always a part of the ancient Ashrams of sannyasins and maharishis and sages used to live in forests and there used to be many deer. When the deer died its natural death, their skin was used to made seats. Besides, Yogis and Sanyasis are usually found to be away from human society and man-made fabric, it leads to the use of more natural and available 'fabric' of animal skin. They should have found the skin of the deer an easily procurable material for their yoga practice (Asan).

It is traditional for many kundalini Yoga practitioners to use sheepskins on which they do their yoga. Many yogis have recommended the sheepskin for meditation, as it creates an insulation between the yogi and the magnetic pull of the Earth. It is believed that they conserve the energy generated by meditation.

The sages found that doing for spiritual sadhana from a spiritual perspective, seated on a deer-skin was highly conducive to Siddhi. As the subtle power generated through their sadhana was well preserved by the use of skin. It is believed that sitting on a deerskin and meditating will help acquire all the aesthetic beauties, the charms of life, and liberation too. Using a deerskin also gave the soft or gentle nature of the deer.


**Fig. 1** Yoga mats made of different raw materials

## 1.5 Physiology of Yoga practice

Yoga is an ancient technique intended to stabilize and recondition the psycho-physiological make-up in an individual. Any mode of exercise or physical activity leads to a state of physical stress on the different systems that changes the homeostasis.

Yoga offers a unique combination of mild to moderate physical exercise (suryanamaskar and asana), cleansing process (kriya), breathing control (pranayama) and meditation (dhyana). And It has not only been used by healthy individuals for health maintenance and disease prevention but used as a treatment for a range of health conditions.

### 1.5.1 Yoga on Cardiac Autonomic regulation

There are many studies that report changes associated with yoga practice on autonomic regulation. Studies suggest that yoga affects cardiac autonomic regulation with increased heart rate variability and vagal dominance during yoga practice (Tyagi & Cohen, 2016). And previously, research has shown increased vagal activity during and after the practice of alternate nostril breathing along with systematic reduction in blood pressure, breath rate and subsequently in HRV (Balkrishna, 2014). After yoga practice there was a significant reduction in the resting heart rate, systolic blood pressure, diastolic blood pressure, and mean blood pressure of the participants.

### 1.5.2 Yoga on Metabolic functions/Metabolism

The practice of yoga generally leads to a more efficient functioning of the psycho-neuro-endocrine and immune system. Before the development of Western Medical science, yoga was believed to alter the neuroendocrine system which was vital to health.

A set of practices were developed in order to maintain healthy glands and the body's metabolism. There are strong evidences that suggests yoga has a positive impact on hormone regulation. Findings of such studies show there's improved glucose tolerance and insulin sensitivity after regular asana practice among type 2 diabetics. And clinically significant among the sample were noted in fasting plasma glucose and postprandial plasma glucose after yoga practice. (C. McCall, 2013).

### 1.5.3 Yoga on stress

A number of research studies exist on the effectiveness of yoga in stress management. Yoga practices are recognized for its effectiveness in helping people reduce psychological stress. Various aspects of the yoga intervention, such as physical exercise (*suryanamaskar* and *asana*), breathing control (*pranayama*) and meditation (*dhyana*) accounts for the observed beneficial effects on stress, mood and wellbeing. And another study shows that yoga intervention decreased the perceived stress significantly among the participants. It was observed that yoga induced stress reduction, as the salivary cortisol concentrations after a yoga class among the study sample, further revealing the potential mechanisms. Analysis showed that there was a decrease of mean cortisol levels, hormone responsible for sympathetic activation.

Stress, in general increases anxiety and depression, a state of chronic sympathetic activation and thereby activation of the HPA axis. Regular practice of yoga shows a immediate decrease in salivary cortisol concentrations, pointing to a direct effect on HPA axis. Furthermore, initial findings from the study has shown an improved indices of cardiac autonomic function following yoga practice. Yoga may also induce the relaxation response, for which a decrease in cortisol levels and sympathetic nervous system responsivity has been demonstrated.(Chatterjee & Mondal, 2017).

## 1.6 Role of earthing the human body

Historically, humans have been mostly walking barefoot or use footwear made of animal leather. They slept on the ground or on skins. Earthing (also known as grounding) refers to contact with the Earth's surface electrons by walking barefoot outside or sitting, working, or sleeping indoors connected to conductive systems, that transfer the energy from the ground into the body.

### 1.6.1 Principle underlying earthing the human body

There are evidences that suggest Earth's negative potential to create a stable internal bio-electrical environment which helps with normal functioning of all body systems. It is proven that electrons from antioxidant molecules neutralize the free radicals in the body's immune and inflammatory responses.

Studies suggest the concept that the Earth's electrons influence multiple physiological changes which are of clinical significance, with respect to pain, sleep, and a shift from sympathetic to parasympathetic tone in the autonomic nervous system (ANS), and a blood-thinning effect. (Sokal, Sokal, Chevalier, Sinatra, & Oschman, 2012)

### 1.6.2 Earthing & stress, sleep & pain

Grounding appears to be affecting positively the morning fatigue levels, daytime energy, and nighttime pain levels. Results indicate that grounding the human body to earth ("earthing") during sleep reduces night-time levels of cortisol and re synchronizes cortisol hormone secretion more in alignment with the natural 24-hour circadian rhythm profile. Changes were most apparent in females. And subjects reported that improvements in these conditions as well as improvements in sleep, pain, and stress— often occurred rapidly within the first few days of grounding rather than gradually over. (Sokal et al., 2012)

### 1.6.3 Earthing & cardiac autonomic regulation.

Living in direct with earth ground the body inducing favorable physiological and electro-physiological changes that promote health. Any physiological states in body corresponds the changes in the autonomic nervous system (ANS). And any stress response is directly linked to ANS stimulation, a situation with increased sympathetic tone and research findings have demonstrated that subjects experienced reduction in stress and a normalization of autonomic nervous system function after grounding. There are strong association between cardiac autonomic events and symptoms of emotional instability among healthy as well as patients with cardiovascular diseases. And in all instances, there is strong evidence that grounding has the potential to help support HRV by reducing the excessive sympathetic stimulation, balancing the autonomic stimulation.

# 2. REVIEW OF LITERATURE

## 2.1 Ancient literature review

According to Patanjali, pranayama is a necessary preparatory practice for meditation. In traditional texts, there are various rules and regulations to practice pranayama. It must be practiced by either sitting in Padmasana or Siddhasana / Siddha Yoni asana because they are considered best in avoiding any strain & discomfort. It keeps the body relaxed & focused for long duration making it ideal for meditation. One must be in loose, comfortable clothes made of natural fibres and more importantly, it is advised to be seated on a suitable material made of natural fibre to ensure maximum conduction of energy during the practice of meditation.

Kuça is a grass which is distributed throughout India. There are some symbolic references to Kuça for its healing properties and there are various ancient texts that describe its utilities. According to Ayurveda, Kuça is used for treating asthma, jaundice, dysentery, menorrhagia and for skin eruptions. And in Bhagavadgita it is suggested for a meditator to be seated on Kuça to practice yoga (meditation). And according to some of the early Buddhist accounts, it was used by Buddha himself to make the meditation seat on which he attained enlightenment.

### 2.1.1 Timing for pranayama

प्रातर्मध्यदिने सायमर्धरात्रे च कुंभकान्।

शनैरशीतिपर्यन्तं चतुर्वारं समभ्यसेत्॥११॥

prātarmadhyadine sāyamardharātre ca kumbhakān।

śanairaśītiparyantaṁ caturvāraṁ samabhyaset ||11|| (H.Y.P)

Retention should be practiced perfectly four times a day: early morning, midday, evening and midnight, so that retention is gradually held up to eighty (counts in one sitting).

### 2.1.2 Environment

Ideal environment as per Bhagavadgita

शुचौ देशे प्रतिष्ठाप्य स्थिरमासनमात्मनः ।

नात्युच्छृतं नातिनीचं चेलाजिनकुशोत्तरम् ॥६ ॥११ ॥

śucau deśe pratiṣṭhāpya sthiramāsanamātmanaḥ ।
nātyucchṛitaṁ nātinīcaṁ celājinakuśottaram ।।6.11।। (B.G -6.11)

Establishing a firm seat for himself in a clean place, not too high, not too low, Covered with a cloth, an antelope skin, and Kuça grass.

Ideal environment from Hatha yoga praddipika

सुराज्ये धार्मिके देशे सुभिक्षे निरुपद्रवे ।

धनुः प्रमाणपर्यन्तं शिलाग्निजलवर्जिते ।

एकान्ते मठिकामध्ये स्थातव्यं हठयोगिना ॥१२ ॥

surājye dhārmike deśe subhikṣe nirupadrave ।
dhanuḥ pramāṇaparyantaṁ śilāgnijalavarjite ।
ekānte maṭhikāmadhye sthātavyaṁ haṭhayoginā ।।12।। (H.Y.P)

The hatha yogi should live alone in a hermitage and practice in a place the length of a bow (one and a half meters), where there is no exposure from hazard such as rock, fire or water, and must be well-administered and virtuous kingdom (nation or town) where good alms can be easily attained.

### 2.1.3 Food/Diet

Food and diet in Bhagavadgita

युक्ताहारविहारस्य युक्तचेष्टस्य कर्मसु ।

युक्तस्वप्नावबोधस्य योगो भवति दुःखहा ॥६ ।१७ ॥

yuktāhāravihārasya yuktaceṣṭasya karmasu ।
yuktasvapnāvabodhasya yogo bhavati duḥkhahā ।।6।17।। (B.G)

For him who is moderate in food and diversion, whose actions are disciplined, who is moderate in sleep and waking, Yoga destroys all sorrow ‘Moderation in diet’ means neither overeating nor under eating.

It means eating sparingly but comfortably filling the stomach and meeting the requirements of the body. Thus, body and mind remain healthy and balanced. A weak body cannot support a strong mind. A strong and healthy body reflects the nature of the mind.

Overeating and craving for food shows an uncontrolled mind. A yogi's diet should be sattvic, pure and not over spiced. Eat what is necessary to maintain your bodily requirements and choose a diet which will be most conducive for your sadhana. However, do not become too food conscious.

Food on Hatha yoga praddipika

ब्रह्मचारी मिताहारी त्यागी योगपरायणः ।

अब्दादूर्ध्वं भवेत्सिद्धो नात्र कार्या विचारणा ॥५७ ।

brahmacārī mitāhārī tyāgī yogaparāyaṇaḥ ।
abdādūrdhvaṁ bhavetsiddho nātra kāryā vicāraṇā ।।57। (H.Y.P)

One who is *brahmachari*, takes moderate and pure food, is regular and intent on yoga and renounces (attachment to sensual experience) becomes perfected (*siddha*) after a year.

So, one who keeps his mind above the existence of duality and sex, takes agreeable and sweet (*mitahara*) food, practices his sadhana regularly and maintains detachment from the affairs of mundane life, will definitely achieve perfection within a short period of time.

सुस्निग्धमधुराहारश्चतुर्थांशविवर्जितः ।

भुज्यते शिवसंप्रित्यै मितहारः स उच्यते ॥५८ ॥

susnigdhamadhurāhāraścaturthāṁśavivarjitaḥ ।
bhujyate śivasamprityai mitahāraḥ sa ucyate ।।58।। (H.Y.P)

*Mitahara* is defined as agreeable and sweet food, leaving one fourth of the stomach free, and eaten (as an offering to please Shiva).

### 2.1.4 KUÇA

*Darbha* or *kuça* grass is also known as Desmostachya bipinnata bipinnate which is its botanical name (Murthy & Mahajan, 2017). The word 'kuça' is derived from the sànskråt word 'kuçala' meaning sharp, intelligent and wise, because of the sharp nature of the tip of the grass. It is considered the second most sacred herb in the vedäs after soma (Gorkeshava, 1995). The history of its use in vaidika times is estimated to be more than 3,500 years ago.

The unique feature of kuça grass is that it has sharp edges and that of kuça that it is a hardy plant and, therefore, is a great survivor; its roots go deep in search of water (Pattanaik, 2011). Buddha also used this meterial for his meditation seat when he attained enlightenment under Bodhi tree.

Various names and properties of kuśa in rasaśāstra

कुशो दर्भस्तथा बर्हिः सूच्यग्रों यज्ञभूषणः ।
ततोऽन्यो दीर्ढ्पत्रः स्यात्क्षुरपत्रस्तथैव च ॥१६५॥
दर्भद्वयं त्रिदोषघ्नं मधुरं तुवरं हिमम् ।
मूत्रक्रृच्दाश्मरीतृष्णाबस्तिरुक्प्रदरास्रजित् ॥१६६॥

kuśo darbhastathā barhiḥ sūcyargo yajñabhūṣaṇaḥ ।
tatoa′nyo dīrghapatraḥ syātkṣurapatrastathaiva ca ||165||
darbhadvayaṁ tridoṣaghnaṁ madhuraṁ tuvaraṁ himam ।
mūtrakrṛcchāśmarītṛṣṇābastirukpradarāsrajit ||166||

Kuça, darbha, barhi, sücyarga and yajïabhüñaëa all these are names of kuça and dérghapartra and kñurapatra are the names of Däbha. These two (Däbha & Kuça) are tridoña remover, sweet, astringent and cooling in nature. They help to cure problems of difficulty in urination, stones, thirst, bladder related diseases & also in metrorrhagia (Angadi, 2014).

Kuça in Atharva Veda çamhita

पञ्च राज्यानि विरुधां सोम श्रेष्ठानि ब्रूमः ।
दर्भो भह्लगो यवः ते नो मुञ्चन्त्व् अंहसः ॥

Pañca rājyāni virudhāṁ soma śreṣṭhāni brūmaḥ ।
darbho bhaṅġou yavaḥ te no muñcantv aṁhasaḥ || A.V.S. 11.6.15 ||

There are five sacred plants including darbha, bhäìga (cannabis), barley and saha and soma.Among whom, soma reigns supreme. These sacred herbs provide relief from all woes (Gaud, 2011).

अयं दर्भो विमन्न्युकः स्वाय चारणाय च ।

मन्योर्विमन्युकस्यायं मन्युशमन्  उच्यते ॥

Ayaṁ darbho vimannyukaḥ svāya cāraṇāya ca ।
manyorvimanyukasyāyaṁ manyuśaman  ucyate ।। A.V.S.6.43.1 ।।

should sit on a firm seat, that which is neither too high nor too low, covered with sacredkuça grass, a deerskin, and a cloth, one over the other, in a clean spot (Goenka, 2011).

**2.1.5 Meditation**

शुचौ देशे प्रथिष्टाप्य स्थिरमासनमात्मनः ।

नात्युच्छ्रितं नातिनीचं चैलाजिनकुशोत्तरम् ।६ ११ ।

śucau deśe prathiṣṭāpya sthiramāsanamātmanaḥ ।

nātyucchritaṁ nātinīcaṁ cailājinakuśottaram ।6 11।

समं कयशिरोग्रीवं धारक्यन्नचलं स्थिरः ।

संप्रेक्ष्य नासिकाग्रं स्वं दिशश्चानवलोकयन् ॥६-१३ ॥

samaṁ kayaśirogrīvaṁ dhārakyannacalaṁ sthiraḥ।
samprekṣya nāsikāgraṁ svaṁ diśaścānavalokayan।।6.13।।

Holding the body, head and neck erect, Motionless and steady, Gazing at the tip of his own nose And not looking in any direction.

**2.1.6 Nadisuddhi Pranayama (ANB)**

बद्धपद्मसना योगी प्राणं चंद्रेण पूरयेत् ।

धारयित्वा यथाशक्ति भूयः सूर्येण् रेचयेत् ॥७ ॥

baddhapadmasanā yogī prāṇaṁ candreṇa pūrayet।

dhārayitvā yathāśakti bhūyaḥ sūryeṇ recayet।।7।।(H.Y.P)

Sitting in baddha padmasana, the yogi should inhale through the left nostril and hold the breath to capacity, and then exhale through the right nostril. Then inhaling through the right nostril,gradually fill the abdomen, perform, kumbhaka as before, then exhale completely through the left nostril.

**2.1.7 Padmasana (Lotus pose)**

वामोरुपरि दक्षिणं च चरणं संस्थाप्य वामं तथा

दक्षोरुपरि पश्चिमेन विधिना धृत्वा कराभ्यां दृढम्।

अंगुष्टौ हृदये निधाय चिबुकं नासाग्रमालोकयेत

एतद्व्याधिविनाशकारि यमिनां पद्मासनं प्रोच्यते ॥४४।

vāmoarupari dakṣiaṇaṁ ca caraṇaṁ saṁsthāpya vāmaṁ tathā

dakṣoarupari paścimena vidhinā dhṛtvā karābhyāṁ dṛḍham|

aṅguṣṭau hradaye nidhāya cibukaṁ nāsāgramālokayet

etadvayādhivināśakāri yamināṁ padmāsanaṁ procyate||44|(H.Y.P)

Place the right foot on the left thigh and the left foot on the right thigh, cross the hands behind the back and firmly hold the toes. Press the chin against the chest and look at the tip of the nose. This is called padmasana, the destroyer of a yogi's diseases.

**2.1.8 Regulated breathing**

अपाने जुह्वति प्राणं प्रणे ऽपानं तथापरे।

प्रणापानगती रुद्ध्वा प्राणायामपरायणाः ॥४-३१॥

apāne juhvati prāṇaṁ praṇe ' paanaṁ tathāpare|
praṇāpānagatī ruddhvā prāṇāyāmaparāyaṇāḥ||4-31||

Some offer inhalation into exhalation, And others exhalation into inhalation, Restraining the path of inhalation and exhalation, Intent on control of the vital breath

## 2.2. Scientific literature review

### 2.2.1 Alternate nostril breathing on heart rate variability

Alternate nostril breathing causes differential physiological and psychological effects. An investigation on autonomic effects of alternate nostril breathing & paced breathing at the same respiratory rate suggests that both breathing practices increases the autonomic modulation without much changes in sympatho-vagal balance and autonomic changes are largely mediated by breathing rate in individuals (Lee & Ghiya, 2012). And another study suggests that vagal activity increased during & after the practice of alternate nostril breathing. And it could contribute to decrease in blood pressure and changes in heart rate variability(Telles, Singh, & Balakrishna, 2014) .

### 2.2.2 Meditation among meditators and non-meditators

Mental and emotional states play a role in mental capacity of an individual to concentrate on ongoing tasks (Ehring et al., 2011). Two groups of similar socio-economic characteristics were examined and their results suggest that mindfulness meditators have greater respiratory interoceptive accuracy compared to non-meditators(Daubenmier, Sze, Kerr, Kemeny, & Mehling, 2013)

### 2.2.3 New light on well being

Results of volunteers involved in three experimental conditions (orthostatic test, exercise tests, chocolate test) were assessed to find a correlation among the variables of HRV and GDV. Measures taken before & after following the three experimental conditions demonstrate that stress index and area of GDV parameters correlate strongly with HRV measure of sympatho-vagal balance. A Low Frequency which corresponds to sympathetic component correlates with stress index parameter of GDV (Gh, Giacomoni, & Rein, 2004)

### 2.2.4 Measuring Chi after yoga practice

Health depends on levels and balance of energy. Traditional Indian system of prana has two forms (*prana & shakthi*) which corresponds to the two forms recognized by the Chinese system (Yin & yang). AcuGraph measures acupuncture points and specific recordings at Tsing points of 24 acupuncture meridians reveal that after yoga practice there was an increase in the levels of Qi and

a significant improvement in regulation of Qi. It has shown certain similarities with concept of Qi and Prana, making it a useful analytic tool for studying general effects of interventions on groups (Nagilla, Hankey, & Nagendra, 2013). According to Traditional Chinese medicine, joints & spinal movements involved in asana stimulate meridian points. Results of a study on *padmasana* suggest that it is more suitable for meditation as there was an increase in subtle energy levels of experimental group compared to the control group that sat on a chair which had completely different effects (Ghosh, Hankey, & Srinivasan, 2017) .

## 2.3. Summary of Scientific Literature Review

| AUTHORS | SAMPLE SIZE | INTERVENTION | RESULTS & CONCLUSION |
|---|---|---|---|

### 2.3.1 Alternate nostril breathing & HRV:

| | | | |
|---|---|---|---|
| (Lee & Ghiya, 2012) | Twenty healthy individuals<br>(22.3 ± 2.9 years)<br>8 males,<br>12 females<br>Age Range: 19 - 29 years (non-practitioner) | Participants performed Anulom-Vilom &Paced Breathing in a random order for 30 min, preceded & followed by 5 min of seated rest. | An increase in TP, LF, and HF following ANB & PB suggest that both conditions increased cardiac autonomic modulation. Data suggests that both ANB & PB increase autonomic modulation without causing a significant shift in Sympathovagal balance. |
| (Telles et al., 2014) | 20 male experience of yoga breathing practices for more than three months. | Alternate nostril yoga breathing (nadisuddhi pranayama) & a session of Breath awareness of equal duration. | ANYB seems to be positively influencing cognitive functions required for sustained attention at different scalp sites (frontal, vertex and parietal), while breath awareness showed changes at the vertex alone. |
| (Raghuraj & Telles, 2008) | Twenty one experienced male volunteers with ages between 18 and 45 years were recruited to measure autonomic and | Thirty minutes of breathing practice, preceded and followed by five min of quiet sitting. | Following RNYB there was a significant increase in systolic, diastolic and mean pressure. In contrast, the systolic and diastolic pressure decreased after ANYB and the systolic and mean pressure were lower after LNYB. It is evident that the practice of unilateral nostril yoga breathing |

| | | | |
|---|---|---|---|
| | respiratory variables. | | appears to influence the BP in different ways. Opening possibility for future therapeutic applications. |
| (Balkrishna, 2014) | Twenty six male subjects (group mean age ±SD, 23.8±3.5 years). | a) ANYB and (b) breath awareness (BAW) sessions. | During ANYB there was a significant decrease (repeated measures ANOVA) in systolic BP and respiration rate while RMSSD and NN50 significantly increased.<br>ANYB and BAW were significantly different (2-factor ANOVA) in RMSSD and respiration rate.<br>The results suggest that vagal activity increased during and after ANYB, which could have contributed to the decrease in BP and changes in the HRV. |
| (Gh et al., 2004) | Control subjects (n=24) from that study were volunteers from the State Medical Academy in Russia and were used for the Orthostatic test. Fourty-three | For the Orthostatic test, subjects were asked to deep breathe in a supine position for 5 minutes. Exercise test involved 10 minutes of strenuous physical exercise. Third experimental condition | In situations where either the sympathetic or the parasympathetic nervous systems were activated, the HRV parameter corresponding to sympathetic regulation of heart rate was correlated with GDV. In a situation inducing a positive emotional state, the HRV parameter which correlates with |

| | | | |
|---|---|---|---|
| | athletes (age 19-24) from the State Research Institute of Sport in Russia volunteered for the exercise tests. Twelve volunteers from the same institute participated in the chocolate test. | was the consumption of dark chocolate | GDV is the balance between the sympathetic and parasympathetic nervous systems. In all cases, GDV entropy correlated with the different HRV parameters. |

### 2.3.2 Meditation

| | | | |
|---|---|---|---|
| (Daubenmier et al., 2013) | Vipassana meditation practitioners, Nonmeditators | Mind-Body Awareness/ Mindfulness based meditation among meditators and non-meditators. | Mindfulness meditators have greater respiratory interoceptive accuracy compared to nonmeditators, at least under specific task conditions. |

### 2.3.3 Padmasana & AcuGraph

| | | | |
|---|---|---|---|
| (Ghosh et al., 2017) | Fifty two male Yoga practitioners (with mean age in years 23.03 ± 3.23), with a minimum of 1 year experience of Yoga practices. | Participants were alternately divided into two different groups, One group was to sit in Lotus Posture and the other on a chair. Each condition was measured on 3 successive days. | Result shows that sitting in Lotus Posture strongly stimulates the subtle Energy Levels, agreeing with the experimental hypothesis. And decreases in Energy Levels of group sitting in a chair were surprising as the rest might be expected to have no effect inspite of sitting on chair. Yoga seems to improve regulation of subtle |

| | | | |
|---|---|---|---|
| | | | energy levels in meridian as well as increasing them. |

**2.3.4 GDV**

| | | | |
|---|---|---|---|
| (Luiza Ciesielska-Wróbel, Szadkowska, Masajtis, & Goch, 2010) | The control subjects (n=24) from that study were volunteers from the State Medical Academy in Russia and were used for the Orthostatic test. Fourty-three athletes (age 19-24) from the State Research Institute of Sport in Russia volunteered for the exercise tests. Twelve volunteers from the same institute participated in the chocolate test. | The intervention was orthostatic test consisting of deep breathing followed by rapid standing; ten minutes of strenuous exercise and consumption of chocolate. | The study shows a significant change in EPI parameters between groups, the most prominent being the average intensity and the immune organs. Between groups, the immune organs showed significant change. Therefore, it is clear that yoga intervention results in change in overall health. |

| | | | |
|---|---|---|---|
| (Rate, 2016) | 11 Male & 27 Female | A 15-minute resting Baseline condition, the first portion of the Trier Social Stress Test (which served as a 10-minute anticipation condition), the second portion of the Trier Social Stress Test (which served as a 10-minute social performance stressor), and a 10-minute recovery period. Heart rate data was collected throughout the experiment. During | Result promotes the idea that mindfulness is associated with better cardiovascular health, even before a stressor takes place. Additionally, the result that mindfulness is associated with reduced reactivity and increased recovery also promotes the idea that mindfulness is a healthy coping strategy for chronic stress as well as acute stress. |

**2.3.5 Kuça Grass**

| | | | |
|---|---|---|---|
| (Raj,Sushmetha, & Jayashree, 2015) | Six tropical grasses, namely Darbha, Lemongrass, Bermuda grass ,Mauritian Grass, Bamboo and,Windmill grass. SASTRA University campus, Thanjavur, | fermentable food items like curd during lunar and solar eclipse<br>Experiments on the interaction of the grass with cow's curd indicate that the Desmotachya bipinnata. | The morphology and disinfecting ability of Darbha is compared with five other tropical grasses. |

| | | | |
|---|---|---|---|
| | Tamil Nadu, India. | | |

**2.3.6 Yoga & Gym Mat**

| | | | |
|---|---|---|---|
| (Flao, Imbert, Wloch, & Gueguen, 2015) | Fourteen healthy yogi participated in the study (2 males and 12 females, age: 36.0 ± 6.9 years old). | Grip was assessed with the downward-facing dog pose repeated three times with identical starting position.<br><br>The posture of the tree was repeated five times during 20s to evaluate balance.<br><br>With the knees on a pressure mapping system held for 60s, was performed for the evaluation of comfort.<br><br>After each series of postures, the participants were asked to answer questions about their perception of the mat on scales ranging from 1 (no grip, balance or comfort) to 9 (extreme grip, balance or comfort). | The study brought new information on the measurable factors that can describe grip, balance and comfort perception of yoga and gym mats. Strong correlations exist between reliable biomechanical measurements, mechanical tests and perception, allowing developing predictive models. |

# 3. AIMS & OBJECTIVES

## 3.1 Aim

The aim is to study the influence of various yoga mats made of Cotton, Rubber and Kuça grass on the outcomes of yoga practice.

## 3.2 Objectives

To showcase the impact of various yoga mats used for yoga practice (Pranayama)

To validate the effect of traditional mat (Kuça) used for meditation with scientific evidences.

The objective of this study is to measure the changes in heart rate variability, before, during and after fifteen minutes intervention of guided breath awareness, guided alternate nostril breathing & self-regulated breathing practice of equal duration on various yoga mats (Rubber, Kuça Grass, Cotton).

## 3.3 Research Question

Whether mats used for meditation be backed with scientific evidence for its influences?

Whether the impact of traditionally used Kuça grass mat be showcased?

Will it create awareness among people to use traditional resources to modern scenarios?

## 3.4 Research Hypothesis

1. Rubber yoga mat used for practicing yoga might influence the outcomes following yoga practice.
2. Cotton yoga mat used for practicing yoga might influence the outcomes following yoga practice.
3. Kuça yoga mat used for practicing yoga might influence the outcomes following yoga practice.

## 3.5 Null Hypothesis

1. Rubber yoga mat used for practicing yoga might not influence the outcomes following yoga practice.

2. Cotton yoga mat used for practicing yoga might not influence the outcomes following yoga practice.

3. *Kuça* yoga mat used for practicing yoga might not influence the outcomes following yoga practice.

# 4. METHODS

## 4.1 Source of Subject

Sixteen self-declared healthy male volunteers, with six or more months of practice, ages ranging from 18 to 33 years (group mean age – SD, 23.1 ± 3.5 years) residing at S-VYASA University of Bangalore and Maharshi Dayanand Saraswati University of Ajmer were recruited as subjects for the study following obtaining written informed consent. All the subjects were not under any medication for any ailment or debility.

Male volunteers alone were selected as autonomic and respiratory variables are known to vary with the phases of the menstrual cycle. All the subjects recruited had been practicing various forms of meditation in the past 6 months. Apart from their prior experience of meditation, they were given a 3-day orientation program under our guidance.

All participants expressed their willingness to take part in the experiment. The study was approved by the institution's ethics committee. The study design was explained to the volunteers of the study, and their signed consent was obtained.

## 4.2 Design

The research study involved the subjects to undergo two experimental states i.e., nadi shudhi pranayama and breath awareness on three different yoga mat types: Rubber, Kuça and no mat on consecutive six days. The order of the intervention was randomized.

The participants were assigned randomly to different mats on different days for 6 days. Each session included three sequences. These were (i) Sequence 1: Guided regulated breathing with 5 second to inhale and 5 seconds to exhale for 5 minutes (ratio of inhalation: exhalation [1:1]). (ii) Sequence 2: Alternate Nostril Yoga Breathing (ANB) for 5 minutes in 1:2 ratio for inhalation and exhalation respectively (5 seconds to inhale and 10 seconds to exhale). (iii) Sequence 3: Self-regulated Breath Awareness for 5 minutes. Each of these 3 sessions on 6 days consisted 3 states: pre (5 minutes), during (15 minutes) and post (5 minutes) to collect HRV readings.

Each session consisted of 25 min in total and during which subjects were made to practice on any one of the three yoga mats using recorded instructions. The instructions to perform practices were recorded to avoid any instructor or time bias. In that 25 min duration first 5min and last 5mis was idle sitting. This was for 6 days keeping the time of the day constant for each subject. Participants were assigned randomly to these 6 possible sequences using a random number table. Hence, each participant was assessed on six different days at the same time of the day, with the assignment of participants to different mats being random.

**Fig. 1** Schematic presentation of the Control and Experiment condition

| Variable | Description |
|---|---|
| *YMS01_* | *YogaMatStudy (YMS), 01/02 corresponds to participant serial number, _followed by K (C/E), C (C/E), R (C/E)* |
| *K(c)* | *Kuça Control* |
| *C(c)* | *Cotton Control* |
| *R(c)* | *Rubber Control* |
| *R(e)* | *Rubber Experimental* |
| *C(e)* | *Cotton Experimental* |
| *K(e)* | *Kuça Experimental* |

| Code | Day 1 | Day 2 | Day 3 | Day 4 | Day 5 | Day 6 |
|---|---|---|---|---|---|---|
| YMS01_ | K(c) | C(c) | R(c) | R(e) | C(e) | K(e) |
| YMS02_ | K(e) | K(c) | C(c) | R(c) | R(e) | C(e) |
| YMS03_ | K(e) | C(e) | K(c) | C(c) | R(c) | R(e) |
| YMS09_ | R(c) | C(c) | K(c) | R(e) | C(e) | K(e) |
| YMS010_ | C(c) | R(c) | K(e) | C(e) | R(e) | K(c) |
| YMS011_ | K(c) | C(c) | R(c) | K(e) | C(e) | R(e) |
| YMS012_ | K(e) | K(c) | C(c) | R(c) | R(e) | C(e) |
| YMS013_ | C(e) | R(e) | K(c) | C(c) | R(c) | K(e) |
| YMS015_ | K(e) | R(e) | C(e) | R(c) | K(c) | C(c) |
| YMS017_ | C(e) | K(e) | R(c) | C(c) | K(c) | R(e) |
| YMS018_ | K(e) | R(c) | C(c) | K(c) | R(e) | C(e) |
| YMS020_ | C(c) | R(c) | R(e) | C(e) | K(e) | K(c) |
| YMS024_ | R(e) | K(e) | C(e) | K(c) | C(c) | R(c) |
| YMS025_ | K(c) | C(e) | K(e) | R(e) | K(c) | C(c) |
| YMS027_ | R(e) | C(e) | R(c) | C(c) | K(c) | K(e) |
| YMS028_ | K(e) | R(c) | C(c) | K(c) | C(e) | R(e) |
| YMS030_ | C(e) | K(c) | C(c) | R(c) | K(e) | R(e) |

**Fig. 2** Schematic presentation of the random table

## 4.3 Inclusion Criteria

Yoga Practitioner for 6 months or more, in normal health and not on any medication during the study were chosen as samples. (Inclusion criteria based on previous studies :(Deo, Kumar, Srinivasan, & Kushwah, 2016) (Ghosh et al., 2017)

## 4.4 Exclusion Criteria

Individuals with any physical disability, mental instability, or inability to sit in Padmasana (Lotus Posture) for 15 minutes or more were excluded from participating in the study.

## 4.5 Assessment

### 4.5.1 Heart Rate Variability

Autonomic variables were acquired using electrodes with conducting gel, fixed at mid-clavicular points bilaterally and with a third electrode 1 cm above the left lower costal margin.

These three positions were selected to simulate standard electrode positions to record the three limb leads with minimal risk of movement artifact (Thakor & Webster, 1985). This precaution was needed as participants used their right hand to manipulate the nostrils.

The autonomic variables were assessed in the six sessions using a Polyrite D (a simple to record ECG device which is noninvasive) to evaluate time domain analysis, frequency domain analysis and non-linear domain analysis during the intervention. Assessments were done throughout the session. HRV data were recorded in 5 min duration. Five minutes of each epoch were analyzed for HRV. In each epoch of 5 min, HRV data were recorded. Each session lasted for 25 min of which 15 min was spent in the respective breathing practices, preceded and followed by 5 min of sitting quiet for pre and post readings. The assessments schedule during a session has been presented schematically in Fig 2.

| Pre | During 1 | During 2 | During 3 | Post |
|---|---|---|---|---|
| 5 minutes | 5 minutes | 5 minutes | 5 minutes | 5 minutes |
| Simple Sitting | Guided regulated breathing | Alternate Nostril Yoga Breathing | Self-regulated Breath Awareness | Simple Sitting |

**Fig. 3** Schematic presentation of the timing of the assessment during a session.

## 4.6 Intervention

The subjects were asked to come to the laboratory for 6 consecutive days at the same time of the day so as to maintain similar diet and physical activity levels of all the subjects. Throughout all sessions participants sat in *Padmasana* and kept their eyes closed following prerecorded instructions.

An emphasis was placed on carrying out the practices slowly, with awareness of physical and mental sensations and relaxation. Participants were given a 3-day meditation orientation program under our guidance. The purpose of this orientation was for all participants to practice based on specific instructions. The experiment was conducted in a sound attenuated, temperature-controlled environment.

Participants were randomly made to sit on a mat made of cotton, rubber or Kuça and they were allowed to wander freely as they listened to a pre-recorded audio consisting of brief periods of instructions. The instruction was meant to induce a non-meditative relaxed state before the intervention.

Participants were then asked to follow the audio instructions for the practice of guided regulated breathing for 5 minutes which involves conscious effort to keep the breathing pattern restricted to 5 seconds to inhale and 5 seconds to exhale as per the instructions given in the audio.

Participants were then asked to follow the audio instruction for the practice of guided ANB in 1:2 ratio of inhalation & exhalation with 5 seconds to inhale and 10 seconds to exhale. They were supposed to be aware of and be absorbed with the breath. And finally, participants were asked to follow self-regulated breathing as per their ability to comply with the ratio of 1:1 breathing.

## 4.7. Data Collection

The following data were extracted from the polygraph records. Frequency domain and time domain analysis of HRV data was carried out for 5-minute recordings for each of the following sessions (Pre, During 1, During 2, Post). These 5-minute epochs were recorded for pre, during, and post sessions. Pre and post sessions had one epoch of 5 minutes each, whereas during had 2 similar epochs (viz. D1, D2).

The energy in the HRV series in the following specific frequency bands was studied viz., the very low frequency band (0.0–.05 Hz), low frequency (LF) band (0.05– 0.15 Hz), and high frequency (HF) band (0.15–0.5 Hz). The LF and HF ratio [Ratio LF ($ms^2$)/HF ($ms^2$)], Heart Rate and RMSSD (The square root of the mean of the sum of the squares of differences between adjacent NN intervals), NN50, (Number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording), pNN50 (NN50 count divided by the total number of all NN intervals) were also included.

Time domain and Frequency domain analysis of the heart rate variability data was carried out for 5 min recordings, in the following 5-min epochs for each of the four sessions: Pre, epoch 2 (D1), epoch 3 (D2), and Post. The following components of time domain HRV were analyzed: (1) mean RR interval (the mean of the intervals between adjacent QRS complexes or the instantaneous heart rate), (2) RMSSD (the square root of the mean of the sum of the squares of differences between adjacent NN intervals), (3) NN50 (the number of interval differences of successive NN intervals greater than 50 milliseconds), and (4) pNN50 (the proportion derived by dividing NN50 by the total number of NN intervals). And following components of frequncy domain HRV were analysed : the very low frequency band (0.0–.05 Hz), low frequency (LF) band (0.05– 0.15 Hz), and high frequency (HF) band (0.15–0.5 Hz). The LF and HF ratio [Ratio LF ($ms^2$)/HF ($ms^2$)]

## 4.9. Data Analysis

All the data were extracted as per the standard procedure recommended for the respective tool. The data recorded were visually inspected off-line and HRV records which had artifacts were not included for analysis. In the records of sixteen participants, the HRV record in the third during state had muscle artifact. However. it was not seen in the other during state as they were noise-free in all subjects and hence were used for analysis.

The data were manually inspected for completeness and any incomplete data were removed from data analysis. The data was checked for normality. And based on the distribution of the data, statistical analysis was done to measure the changes in autonomic variables. The data collected were then analyzed with an HRV analysis program (Kubios).

Repeated measures analysis of variance (RMANOVA) were performed with two ‘‘within/between subjects’’ factors (i.e., Factor 1: Condition; Cotton, Rubber, Kuça and Factor 2: Time; Pre, During [D1, D2] and Post). This was followed by a post hoc analysis with Bonferroni adjustment for multiple comparisons between the mean values of different states (Pre, During and Post) and all comparisons were made with the respective Pre state.

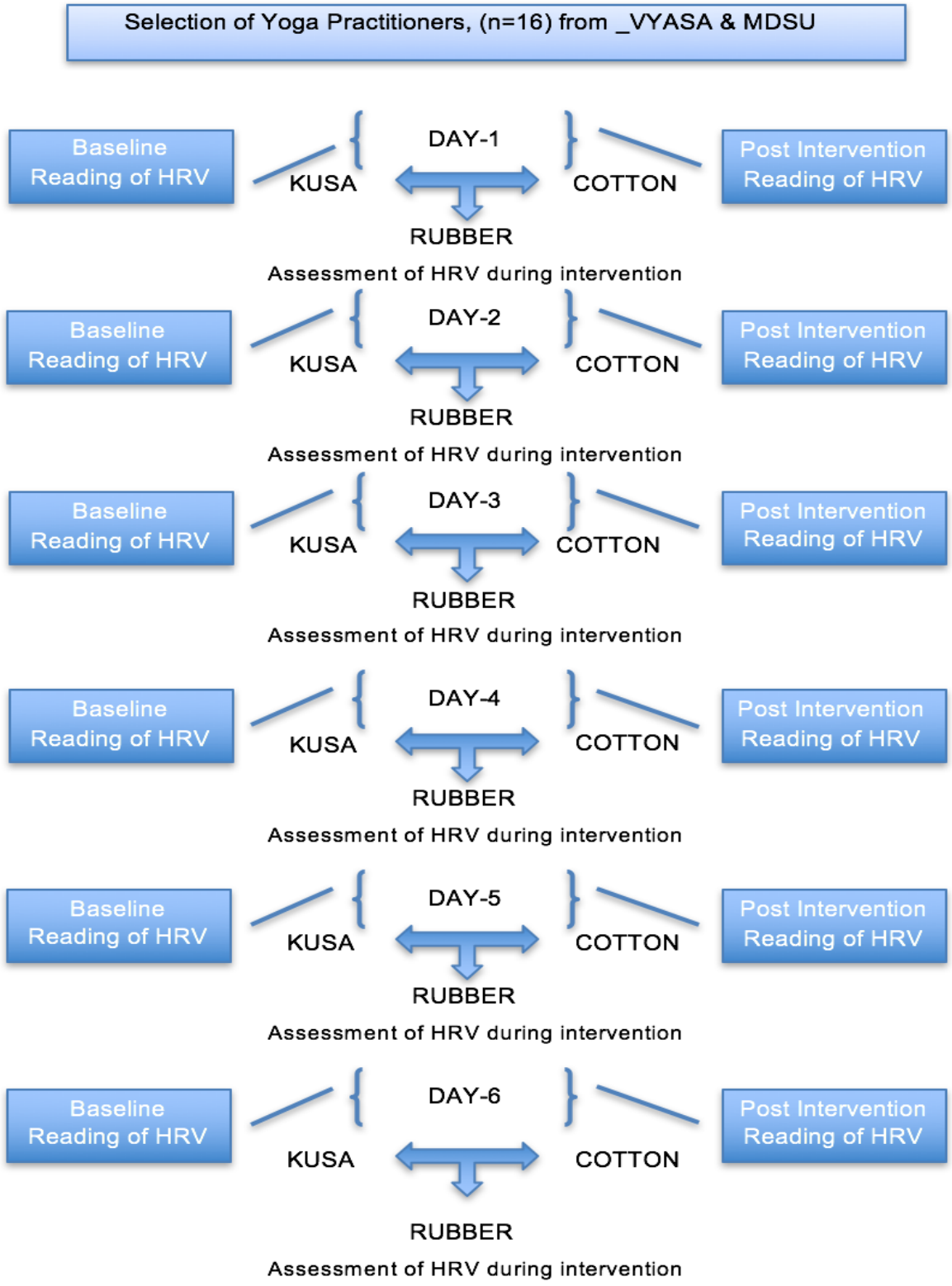



**Fig. 4** Schematic presentation of the Study Design

# 5. RESULTS

**Table. 1** Schematic presentation of the High Frequency spectrum in HRV across mat conditions

| STATISTICAL TEST | HF_Hz | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 0.22±0.07 | 0.26±0.07# | 0.23±0.07 | 0.24±0.07# |
| CE | 0.19±0.06 | 0.18±0.03# | 0.18±0.04 | 0.18±0.04# |
| KC | 0.23±0.06 | 0.24±0.07 | 0.23±0.07# | 0.23±0.07 |
| KE | 0.23±0.08 | 0.21±0.04** | 0.18±0.02# | 0.17±0.03** |
| RC | 0.23±0.07 | 0.24±0.08 | 0.23±0.08 | 0.22±0.08 |
| RE | 0.21±0.06 | 0.2±0.05 | 0.17±0.02# | 0.2±0.08 |

**Graph. 1** Schematic presentation of the High Frequency spectrum in HRV across mat conditions

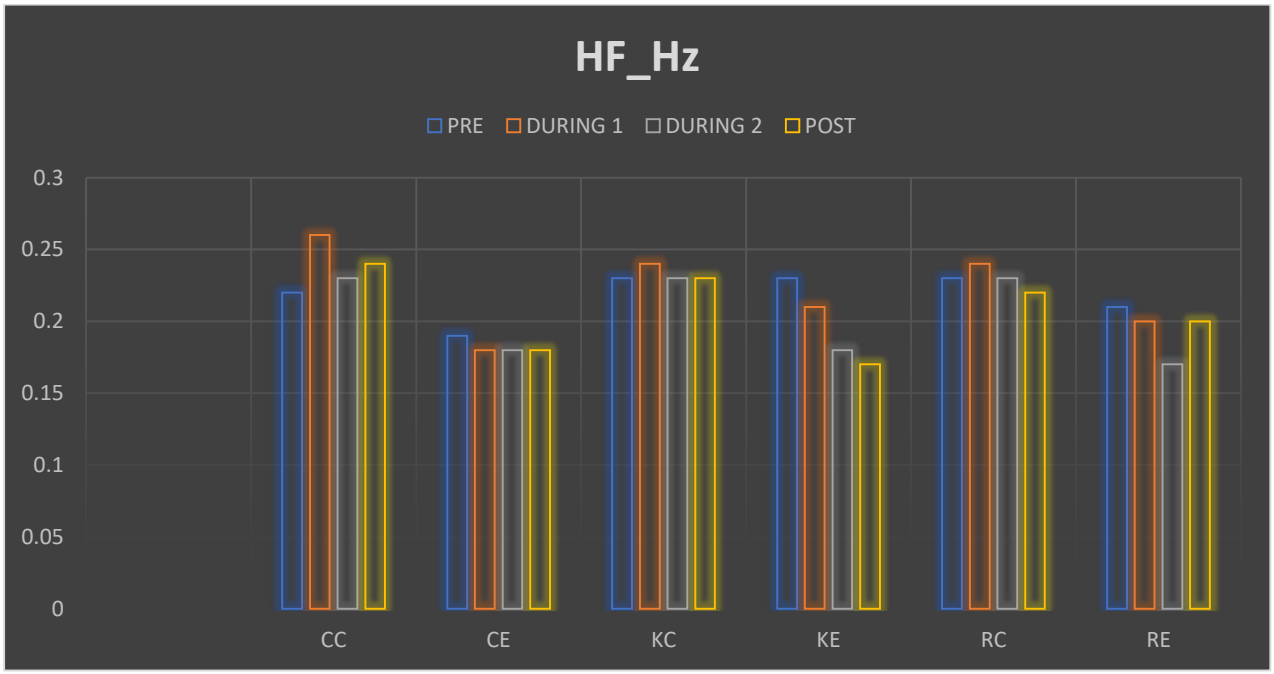


**Table. 2** Schematic presentation of the Low Frequency spectrum in HRV across mat conditions

| STATISTICAL TEST | LF_Hz | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 0.09±0.02 | 0.09±0.02 | 0.09±0.02 | 0.09±0.03 |
| CE | 0.1±0.03 | 0.09±0.03 | 0.09±0.02 | 0.08±0.02 |
| KC | 0.09±0.03 | 0.08±0.03 | 0.09±0.02 | 0.08±0.02 |
| KE | 0.09±0.02 | 0.11±0.02* | 0.09±0.02 | 0.08±0.02* |
| RC | 0.08±0.03 | 0.09±0.02 | 0.08±0.02 | 0.08±0.03 |
| RE | 0.09±0.02 | 0.1±0.02 | 0.08±0.02 | 0.1±0.02 |

**Graph. 2** Schematic presentation of the Low Frequency spectrum in HRV across mat conditions

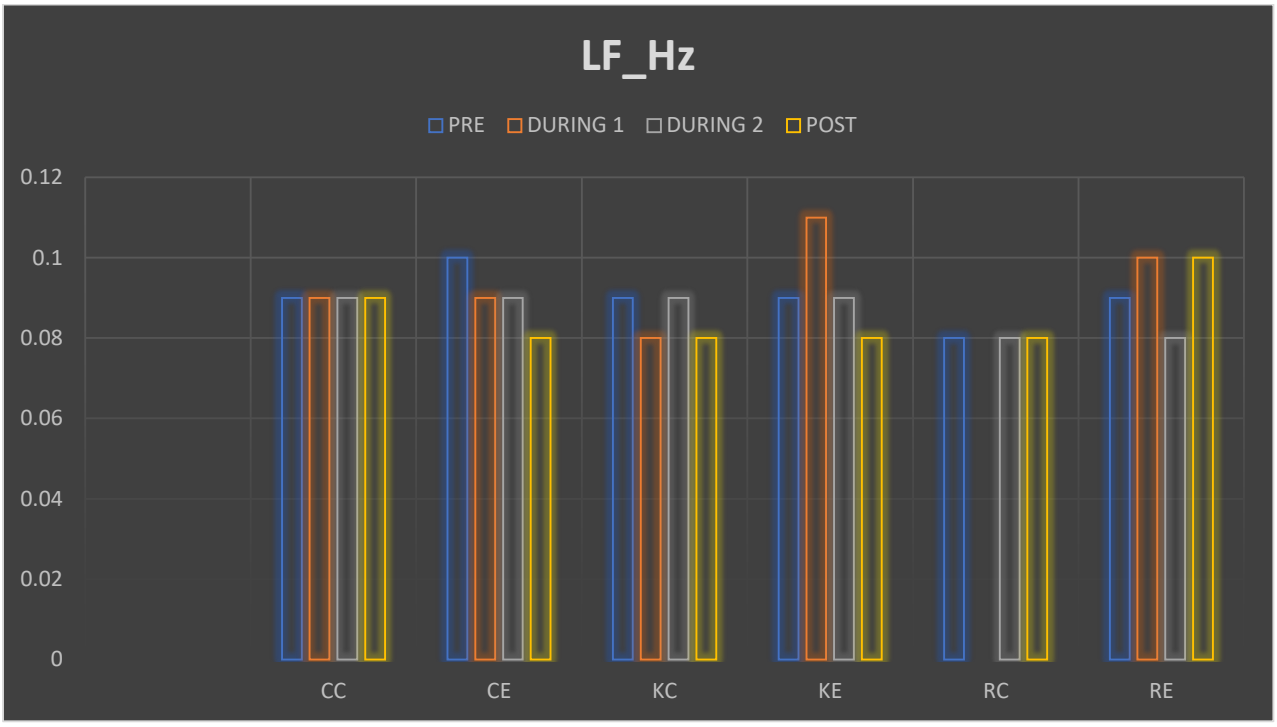


**Table. 3** Schematic presentation of the LF_HF Ratio in HRV across mat conditions

| STATISTICAL TEST | LF_HF ratio | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 1.85±1.89 | 1.65±1.22$^{\#\#}$ | 1.64±0.86$^{\#}$ | 1.92±0.96$^{\#\#}$ |
| CE | 2.45±1.32 | 5.21±3.65$^{\#\#}$ | 7.57±5.56$^{\#}$ | 5.11±3.76$^{\#\#}$ |
| KC | 1.96±1.44 | 2.73±2.42 | 3.02±3.29 | 2.86±2.28 |
| KE | 2.05±1.17 | 3.35±1.44 | 10.83±15.94 | 3.74±3.63 |
| RC | 2.32±2.69 | 3.18±3.34 | 2.94±2.3$^{\#\#}$ | 2.68±1.94 |
| RE | 2.97±2.95 | 4.75±3.21$^{\#}$ | 6.71±2.95$^{\#\#(*)}$ | 3.66±3.01* |

**Graph. 3** Schematic presentation of the LF_HF Ratio spectrum in HRV across mat conditions

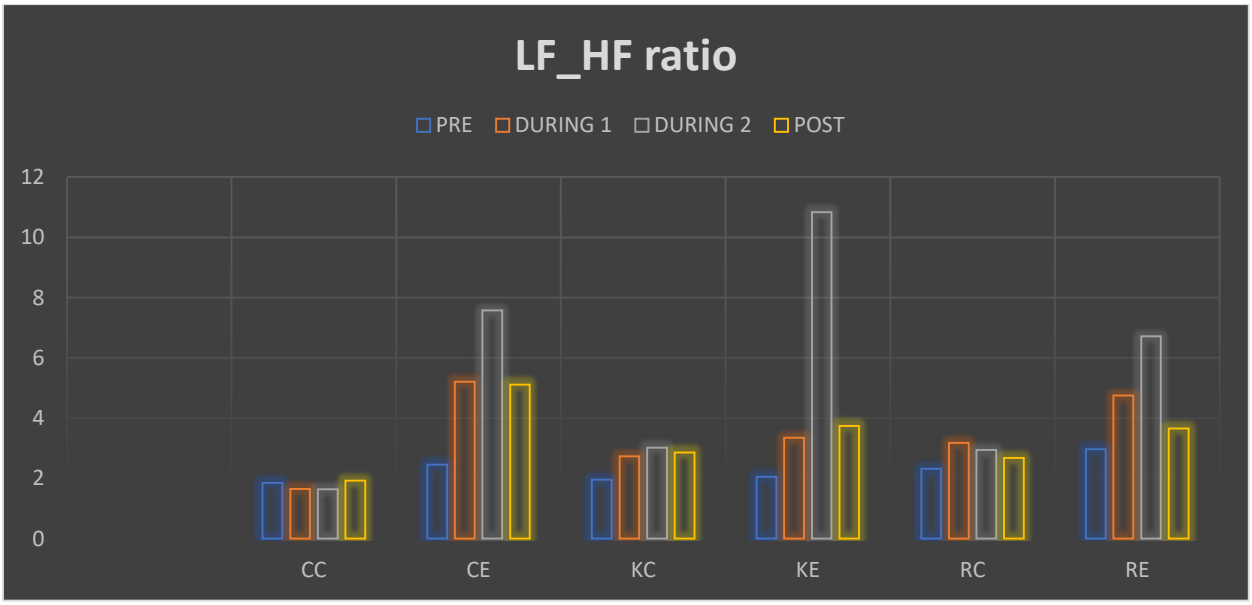


**Table. 4** Schematic presentation of the Mean Heart Rate per minute across mat conditions

| STATISTICAL TEST | MeanHR_beats_min | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 74.51±10.59 | 74.31±9.8 | 74.64±9.63 | 74.8±8.56 |
| CE | 78.71±9.94 | 79.23±10.04 | 80.63±9.75 | 77.7±10.34 |
| KC | 76.61±11.05 | 76.86±11.04 | 76.65±10.8 | 77.8±9.32 |
| KE | 77.32±5.89** | 79.39±6.93 | 80.74±6.78** | 77.32±7.51* |
| RC | 76.59±10.2 | 77.58±10.33 | 76.67±10.19 | 75.92±11.35 |
| RE | 75.34±8.85 | 77.18±9.26* | 79.6±8.37* | 76.5±8.58* |

**Graph. 4** Schematic presentation of the Mean Heart Rate per minute across mat conditions

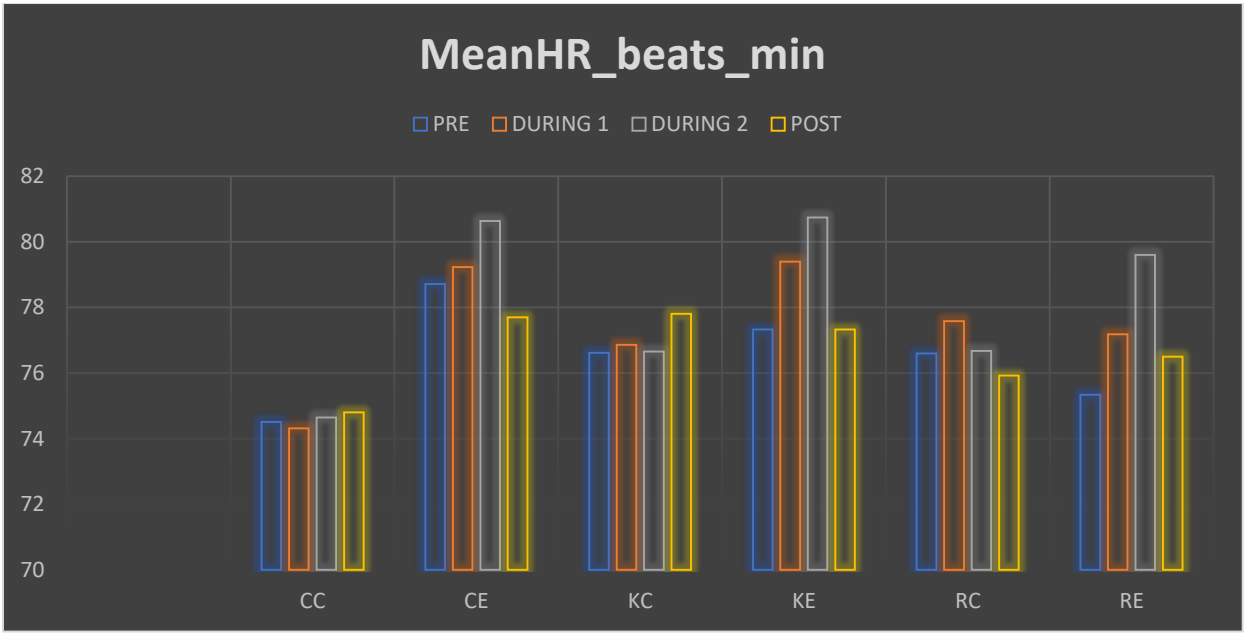


**Table. 5** Schematic presentation of the NN50 in HRV across mat conditions

| STATISTICAL TEST | NN50 | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 76.53±53.79 | 73.24±53.03 | 78.94±54.48 | 71.94±42.68 |
| CE | 60.35±44.33 | 78.59±41.54 | 76.35±37.03 | 68.29±34.4 |
| KC | 71.18±53.12 | 64±58.97 | 60.06±51.92 | 58.29±49.2 |
| KE | 60.94±39.85 | 76.59±41.75 | 65±36.02 | 58.29±49.2 |
| RC | 57.41±38.63 | 56.06±50.07 | 61.12±50.78 | 58.65±50.49 |
| RE | 75.71±53.01 | 81.06±39.75 | 69.88±34.75 | 67.65±35.99 |

**Graph. 5** Schematic presentation of the NN50 in HRV across mat conditions

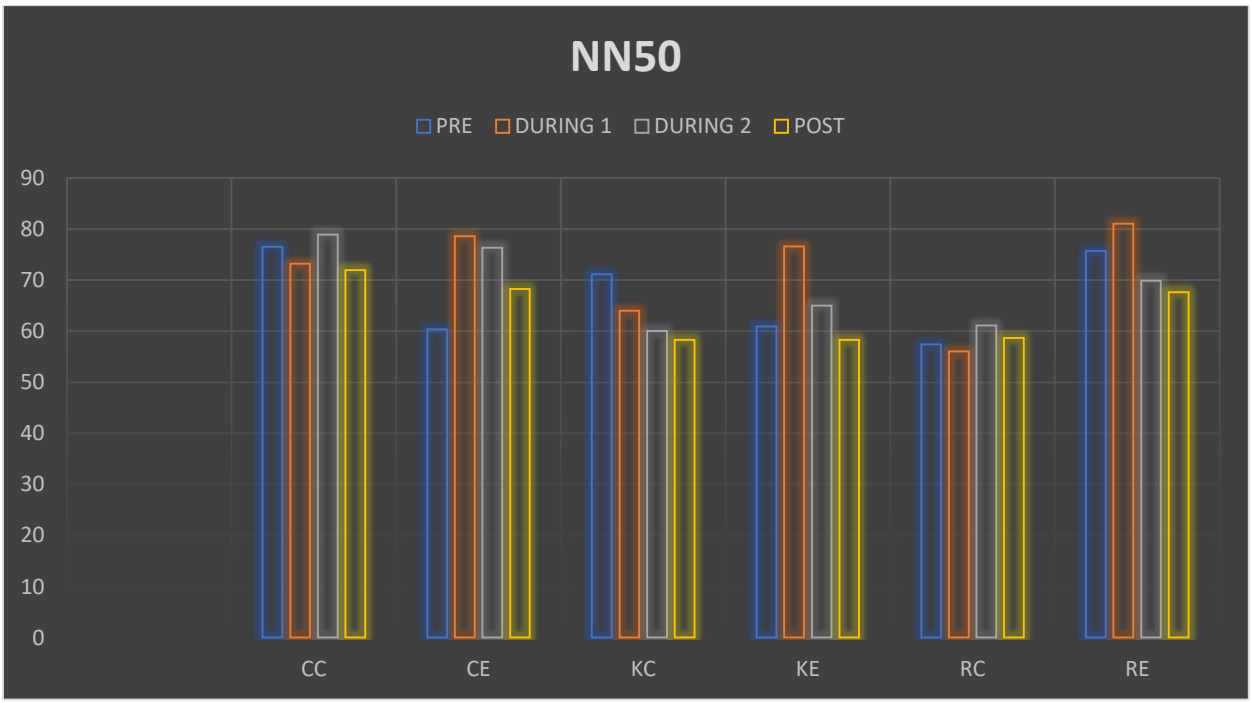


**Table. 6** Schematic presentation of the pNN50 in HRV across mat conditions

| STATISTICAL TEST | pNN50 | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 22.42±16.98 | 21.38±17.07 | 22.88±17.23 | 20.42±13.12 |
| CE | 16.62±13.8 | 21.05±12.26 | 19.97±10.62 | 18.59±10.49 |
| KC | 20.71±17.45 | 18.76±19.02 | 17.75±18.03 | 17.11±16.81 |
| KE | 16.35±11.2 | 20.16±11.96 | 16.64±9.58 | 15.72±12 |
| RC | 16.97±16.47 | 16.05±15.18 | 17.57±16.18 | 17.25±16.29 |
| RE | 21.6±16.87 | 22.04±11.81 | 18.33±9.8 | 18.37±10.1 |

**Graph. 6** Schematic presentation of the NN50 in HRV across mat conditions

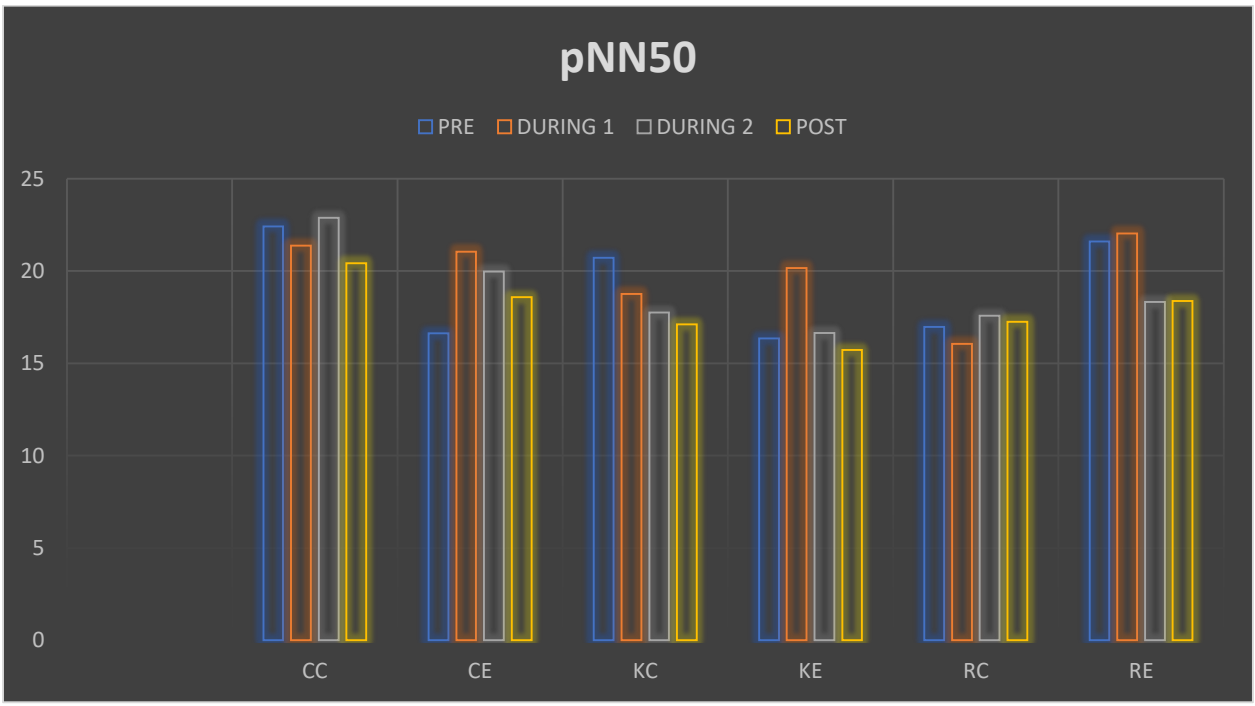


**Table. 7** Schematic presentation of the RMSSD in HRV across mat conditions

| STATISTICAL TEST | RMSSD | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 43±19 | 42.07±18.01 | 43.85±18.5 | 40.96±13 |
| CE | 41.24±17.56 | 54.18±20.46 | 62.85±23.14 | 46.8±15.86 |
| KC | 41.41±17.63 | 40.26±21.9 | 40.06±21.34 | 39.17±19.96 |
| KE | 39.8±14.2 | 53.67±23.17 | 49.67±25.9 | 40.28±14.84 |
| RC | 38.52±20.47 | 36.14±17.1 | 37.38±16.46 | 36.37±16.15 |
| RE | 47.29±25.52 | 54.92±20.33 | 49.08±15.76 | 48.54±17.02 |

**Graph. 7** Schematic presentation of the RMSSD in HRV across mat conditions

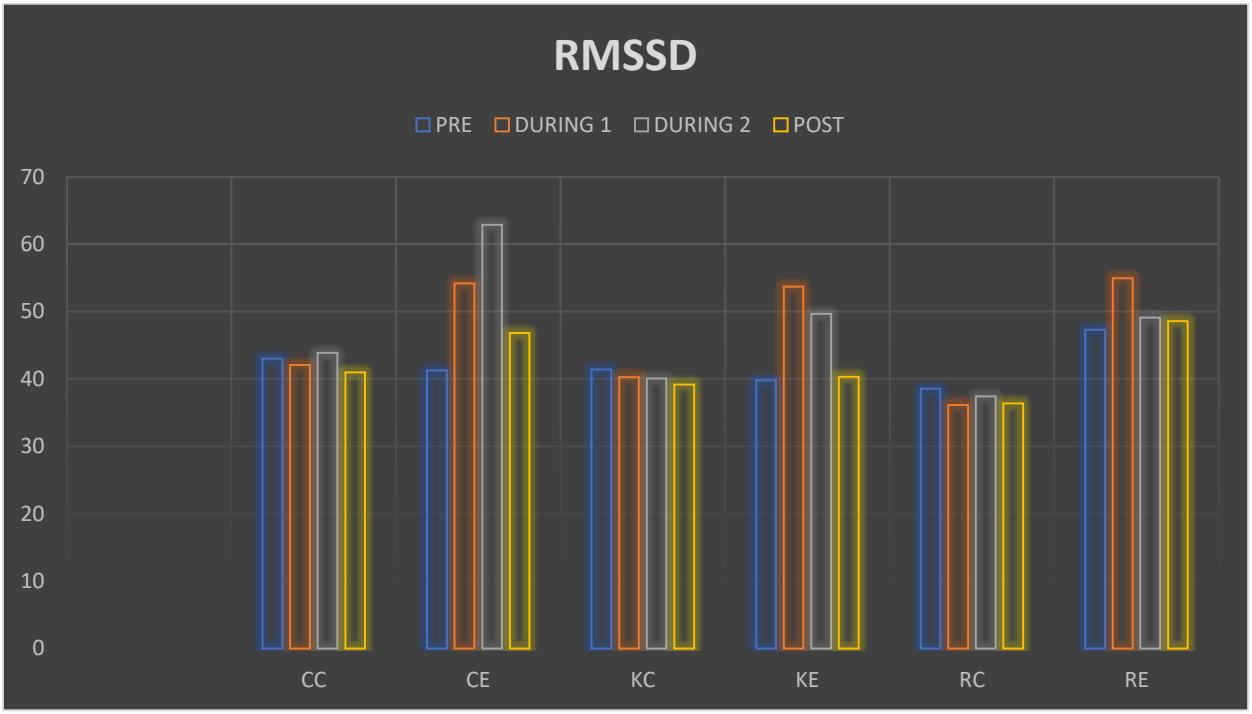


**Table. 8** Schematic presentation of the Stress Index in HRV across mat conditions

| STATISTICAL TEST | Stress Index | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 11.27±5.15 | 11.32±5.09 | 10.72±4.98 | 10.51±5.2 |
| CE | 11.42±8.35 | 8.38±5.86 | 6.24±1.66 | 8.84±5.96 |
| KC | 10.09±2.68 | 11.2±4.72 | 11.02±4.82 | 11.26±5.03 |
| KE | 10.19±2.68 | 8.88±4.47 | 8.41±4.28 | 9.88±3.53 |
| RC | 12.06±5.43 | 12.19±5.49 | 11.47±4.85 | 11.14±4.79 |
| RE | 9.23±3 | 7.78±3.21 | 7.78±2.89 | 8.61±3.17 |

**Graph. 8** Schematic presentation of the Stress Index in HRV across mat conditions

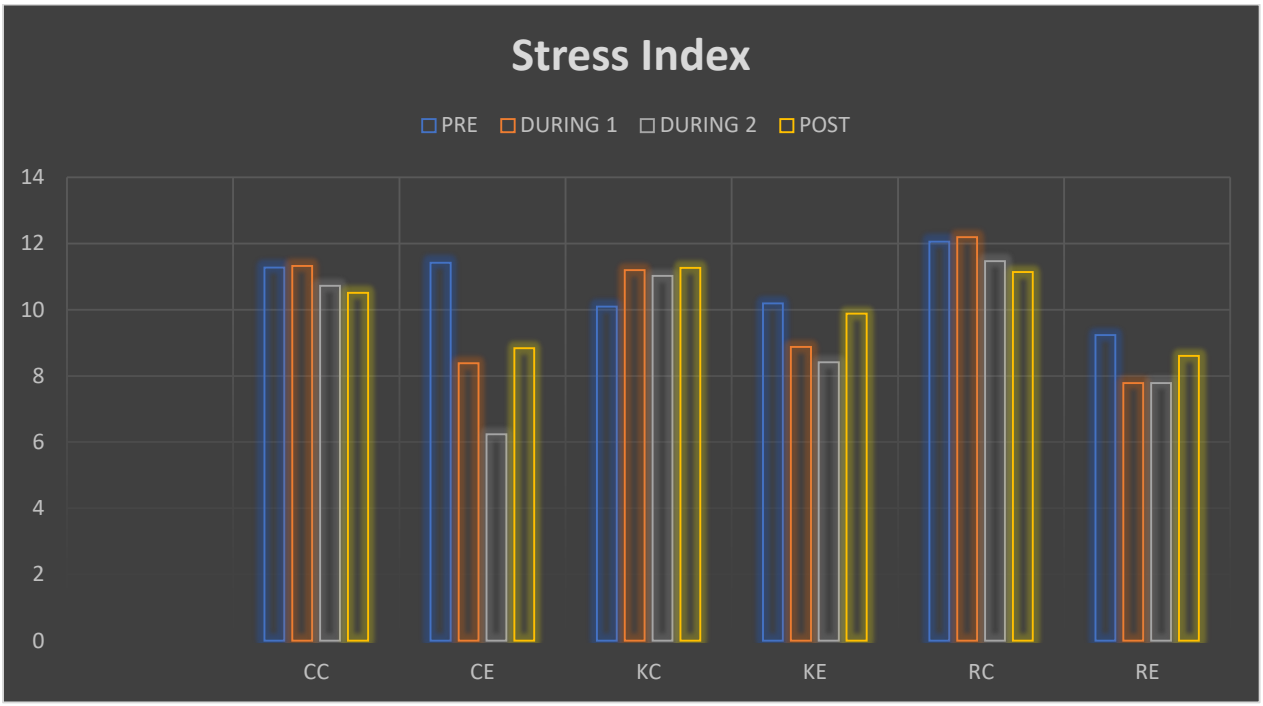
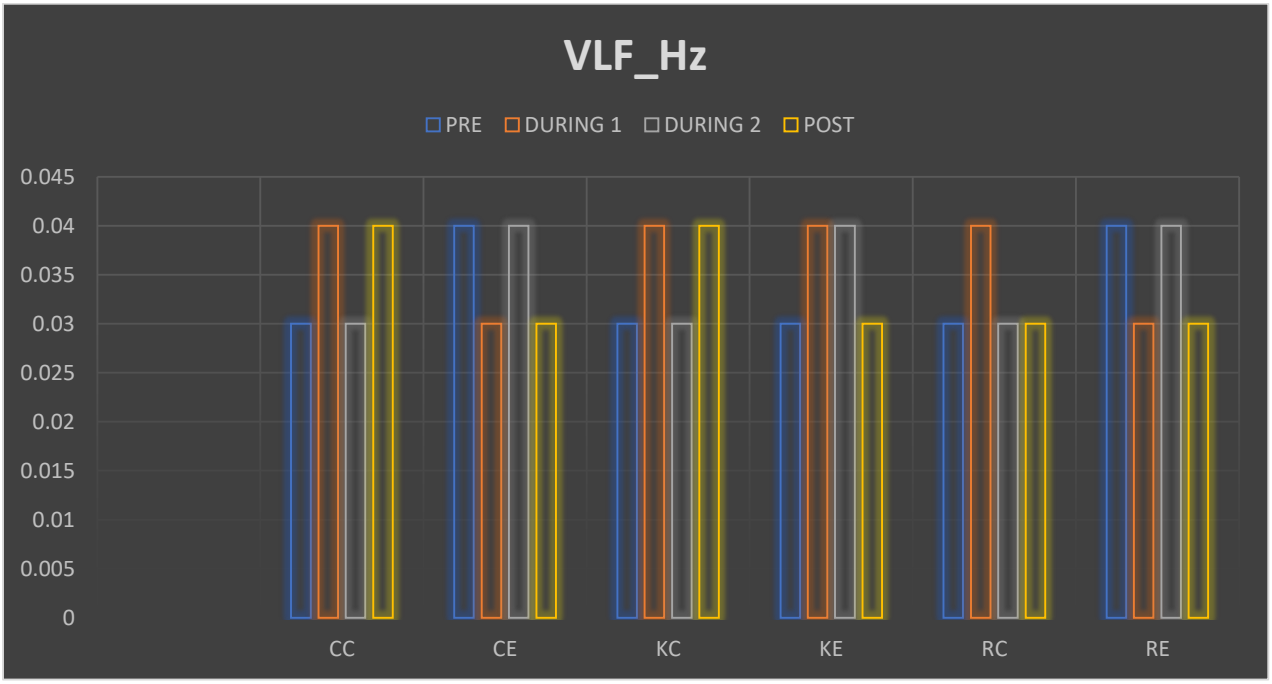


**Table. 9** Schematic presentation of the VLF spectrum in HRV across mat conditions

| STATISTICAL TEST | VLF_Hz | | | |
|---|---|---|---|---|
| | PRE | DURING 1 | DURING 2 | POST |
| CC | 0.03±0.01 | 0.04±0.01 | 0.03±0 | 0.04±0 |
| CE | 0.04±0.01 | 0.03±0.01 | 0.04±0.01 | 0.03±0 |
| KC | 0.03±0.01 | 0.04±0.01 | 0.03±0.01 | 0.04±0 |
| KE | 0.03±0 | 0.04±0.01 | 0.04±0 | 0.03±0.01 |
| RC | 0.03±0 | 0.04±0 | 0.03±0.01 | 0.03±0.01 |
| RE | 0.04±0 | 0.03±0 | 0.04±0 | 0.03±0 |

**Table. 9** Schematic presentation of the VLF in HRV across mat conditions



| STATE | VARIABLE | CC | CE | KC | KE | RC | RE |
|---|---|---|---|---|---|---|---|
| PRE | HF_Hz | 0.22±0.07 | 0.19±0.06 | 0.23±0.06 | 0.23±0.08 | 0.23±0.07 | 0.21±0.06 |
| | LF_HF ratio | 1.85±1.89 | 2.45±1.32 | 1.96±1.44 | 2.05±1.17 | 2.32±2.69 | 2.97±2.95 |
| | LF_Hz | 0.09±0.02 | 0.1±0.03 | 0.09±0.03 | 0.09±0.02 | 0.08±0.03 | 0.09±0.02 |
| | VLF_Hz | 0.03±0.01 | 0.04±0.01 | 0.03±0.01 | 0.03±0 | 0.03±0 | 0.04±0 |
| | MeanHR_beats_min | 74.51±10.59 | 78.71±9.94 | 76.61±11.05 | 77.32±5.89** | 76.59±10.2 | 75.34±8.85 |
| | NN50 | 76.53±53.79 | 60.35±44.33 | 71.18±53.12 | 60.94±39.85 | 57.41±38.63 | 75.71±53.01 |
| | pNN50 | 22.42±16.98 | 16.62±13.8 | 20.71±17.45 | 16.35±11.2 | 16.97±16.47 | 21.6±16.87 |
| | RMSSD | 43±19 | 41.24±17.56 | 41.41±17.63 | 39.8±14.2 | 38.52±20.47 | 47.29±25.52 |
| | Stress Index | 11.27±5.15 | 11.42±8.35 | 10.09±2.68 | 10.19±2.68 | 12.06±5.43 | 9.23±3 |
| DUR1 | HF_Hz | 0.26±0.07# | 0.18±0.03# | 0.24±0.07 | 0.21±0.04** | 0.24±0.08 | 0.2±0.05 |
| | LF_HF ratio | 1.65±1.22## | 5.21±3.65## | 2.73±2.42 | 3.35±1.44 | 3.18±3.34 | 4.75±3.21# |
| | LF_Hz | 0.09±0.02 | 0.09±0.03 | 0.08±0.03 | 0.11±0.02* | 0.09±0.02 | 0.1±0.02 |
| | VLF_Hz | 0.04±0.01 | 0.03±0.01 | 0.04±0.01 | 0.04±0.01 | 0.04±0 | 0.03±0 |
| | MeanHR_beats_min | 74.31±9.8 | 79.23±10.04 | 76.86±11.04 | 79.39±6.93 | 77.58±10.33 | 77.18±9.26* |
| | NN50 | 73.24±53.03 | 78.59±41.54 | 64±58.97 | 76.59±41.75 | 56.06±50.07 | 81.06±39.75 |
| | pNN50 | 21.38±17.07 | 21.05±12.26 | 18.76±19.02 | 20.16±11.96 | 16.05±15.18 | 22.04±11.81 |
| | RMSSD | 42.07±18.01 | 54.18±20.46 | 40.26±21.9 | 53.67±23.17 | 36.14±17.1 | 54.92±20.33 |
| | Stress Index | 11.32±5.09 | 8.38±5.86 | 11.2±4.72 | 8.88±4.47 | 12.19±5.49 | 7.78±3.21 |
| DUR2 | HF_Hz | 0.23±0.07 | 0.18±0.04 | 0.23±0.07# | 0.18±0.02# | 0.23±0.08 | 0.17±0.02# |
| | LF_HF ratio | 1.64±0.86# | 7.57±5.56# | 3.02±3.29 | 10.83±15.94 | 2.94±2.3## | 6.71±2.95##(*) |
| | LF_Hz | 0.09±0.02 | 0.09±0.02 | 0.09±0.02 | 0.09±0.02 | 0.08±0.02 | 0.08±0.02 |
| | VLF_Hz | 0.03±0 | 0.04±0.01 | 0.03±0.01 | 0.04±0 | 0.03±0.01 | 0.04±0 |
| | MeanHR_beats_min | 74.64±9.63 | 80.63±9.75 | 76.65±10.8 | 80.74±6.78** | 76.67±10.19 | 79.6±8.37* |
| | NN50 | 78.94±54.48 | 76.35±37.03 | 60.06±51.92 | 65±36.02 | 61.12±50.78 | 69.88±34.75 |
| | pNN50 | 22.88±17.23 | 19.97±10.62 | 17.75±18.03 | 16.64±9.58 | 17.57±16.18 | 18.33±9.8 |
| | RMSSD | 43.85±18.5 | 62.85±23.14 | 40.06±21.34 | 49.67±25.9 | 37.38±16.46 | 49.08±15.76 |
| | Stress Index | 10.72±4.98 | 6.24±1.66 | 11.02±4.82 | 8.41±4.28 | 11.47±4.85 | 7.78±2.89 |
| POST | HF_Hz | 0.24±0.07# | 0.18±0.04# | 0.23±0.07 | 0.17±0.03** | 0.22±0.08 | 0.2±0.08 |
| | LF_HF ratio | 1.92±0.96## | 5.11±3.76## | 2.86±2.28 | 3.74±3.63 | 2.68±1.94 | 3.66±3.01* |
| | LF_Hz | 0.09±0.03 | 0.08±0.02 | 0.08±0.02 | 0.08±0.02* | 0.08±0.03 | 0.1±0.02 |
| | VLF_Hz | 0.04±0 | 0.03±0 | 0.04±0 | 0.03±0.01 | 0.03±0.01 | 0.03±0 |
| | MeanHR_beats_min | 74.8±8.56 | 77.7±10.34 | 77.8±9.32 | 77.32±7.51* | 75.92±11.35 | 76.5±8.58* |
| | NN50 | 71.94±42.68 | 68.29±34.4 | 58.29±49.2 | 58.29±49.2 | 58.65±50.49 | 67.65±35.99 |
| | pNN50 | 20.42±13.12 | 18.59±10.49 | 17.11±16.81 | 15.72±12 | 17.25±16.29 | 18.37±10.1 |
| | RMSSD | 40.96±13 | 46.8±15.86 | 39.17±19.96 | 40.28±14.84 | 36.37±16.15 | 48.54±17.02 |
| | Stress Index | 10.51±5.2 | 8.84±5.96 | 11.26±5.03 | 9.88±3.53 | 11.14±4.79 | 8.61±3.17 |

(*) Indicates comparison between time intervals

(#) Indicates comparison between Mat conditions

**Table. 10** Mean and Standard Deviation Across HRV spectrum

# 6. DISCUSSION

In order to practice yoga sadhana, a yoga mat is often recommended to provide some level the characteristics such as grip, balance and comfort. And often biomechanical investigations are conducted to assess grip, balance and comfort. (Flao et al., 2015) However, yoga mats have never researched upon from the perspective of its add-on effects. Therefore, the purpose of this study was to understand the interactions between the body and the mat, and to determine the most appropriate mat to practice pranayama based on the autonomic changes after yoga practice.

The present study evaluated the changes in autonomic variables during control session which involved simple sitting compared to experimental session which included, an equal duration of breath awareness and alternate nostril yoga breathing on different mat conditions. Some of the autonomic variables assessed in the present study include established determinants of HRV, such as the very low frequency band (0.0–.05 Hz), low frequency (LF) band (0.05– 0.15 Hz), and high frequency (HF) band (0.15–0.5 Hz). The LF and HF ratio [Ratio LF (ms2)/HF (ms2)], Heart Rate and RMSSD (The square root of the mean of the sum of the squares of differences between adjacent NN intervals), NN50 (Number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording), pNN50 (NN50 count divided by the total number of all NN intervals).

In order to study the effects of pranayama techniques on different mat conditions, sixteen self-declared healthy male volunteers, with six or more months of practice, ages ranging from 18 to 33 years (group mean age – SD, 23.1 ± 3.5 years) were recruited based on their ability to perform *padmasana* for the duration of the intervention. The study protocol was explained to the subjects, and their signed consent was obtained.

As there is direct link between respiration and heart rate variability, in order to prevent changes in breath rate influencing the autonomic outcome it was ideal to have the subjects breathe as per predetermined rates during experimental conditions.

Therefore, participants were made to randomly sit on a mat made of cotton, rubber or Kuça and allowed to wander freely as they listened to a pre-recorded audio consisting of brief periods of instructions during control session, while in the experiment session, they followed pre-determined rate of guided breathing and alternate nostril yoga breathing as per the instructions. (Lehrer, Sasaki, & Saito, 1999). And because of relative ease of recording and in most commonly found HRV data, short-term measurements have been used and studied. Short-term measurement norms are based on ~5 min of HRV data. (Shaffer & Ginsberg, 2017).

Main effects showed a significant change across the conditions ($F(5,80)=11.307$, $p<0.0005$, $p\eta^2=0.414$). Simple main effects analysis showed significant changes. The baseline was normally distributed across all the conditions. Simple main effects showed significant differences in HF spectrum during the first five minutes (D1) ($p=0.03$) of the experiment and in the post session ($p=0.022$) while using cotton mat as compared to the control session using the cotton mat.

In the second five minutes of the experiment (D2), significant changes were seen while performing pranayama in the *Kuça* mat as compared to the control session on the *Kuça* mat ($p=0.043$). Within group analysis showed significant changes only in the *Kuça* mat session while performing pranayama as compared to the post data ($p=0.009$).

The results indicate that, *Kuça* grass mat appear to offer better change in the HF spectrum of the HRV as compared to any other mats. And, both cotton and *Kuça* but not rubber appear to show significant changes following *nadi shudhi* pranayama as compared to breath awareness session on the same mat type.

The condition of spherecity was not met for LF-HF ratio for both between conditions ($F(5,80)= .288$, $p<0.0005$) and within group ($p=0.005$) conditions. Hence lower bound estimates were used. Main effects showed significant changes across the conditions ($F(5,80)=6.456$, $p=0.022$) and within the groups ($F(5,80)=8.205$, $p=0.011$).

Simple main effects for between group comparisons for cotton mat showed significant changes in the experimental group in the first five minutes (D1) ($p=0.007$) and the second five minutes (D2) ($p=0.011$) of the intervention duration as compared to the breath awareness control sessions.

Interestingly, a significant increase in rubber mat intervention D2 timepoint was observed as compared to the respective control session ($p=0.007$). Also, a significant increase in LF-HF ratio

was observed in the post timepoint, immediately after the intervention duration in cotton mat between the experimental and control sessions (p=0.006). Within group analysis for rubber mat showed significant changes in the LF-HF ratio in D2 (p=0.006) and post (p=0.016) values as compared to the baseline.

The results indicate that a significant increase in LF-HF ratio during and immediately after performing the pranayama while seated on cotton and rubber mat. Interestingly, no significant changes were noted in the Kuça grass mat. (As you know that increasing LF HF ratio means increasing sympathetic predominance. Here we see that the autonomic nervous system is more stable when one uses Kuça mat). The condition for sphericity was met for both the comparisons across the conditions (p=0.225) and timepoints (p=0.11).

Main effect comparisons showed significant changes across the timepoints only (F(5,80)=3.578, p=0.02). Simple main effects showed a significant reduction in LF values between D1 and Post timepoints in the experimental group while seated on a Kuça mat (p=0.02). No significant changes were observed between the conditions. From this it appears that the Kuça grass mat might lower the sympathetic arousal.

The Mauchly's test for sphericity was met for across the condition comparisons (p=0.309) and not met for timepoint comparisons (p=0.004). Main effect comparisons showed significant changes across within group - timepoint comparisons (F (5,80)=3.167, p=0.05). Simple main effect analysis for the condition rubber mat – experimental session showed significant increase in heart rate at D1 (p<0.0005) and D2 (p=0.02) as compared to the baseline. Also, a significant reduction in heart rate was observed in the Kuça mat experimental session between the timepoints D2 and Post (p=0.02).

These findings indicate that the heart rate is effectively reduced while practicing pranayama in Kuça grass mat. Whereas, the heart rate appears to be increasing with the use of rubber mat.

The condition for sphericity was met. Main effects showed significant changes for comparison across the conditions (F(5,80)=4.234, p=0.002) and across the timepoints (F(5,80), p=0.016).

Simple main effects showed significant changes between the rubber mat control and the experimental sessions for the timepoint D1 (p=0.004). No significant changes were seen in the within group comparisons.

# 7. CONCLUSION

The present study suggests that integration of pranayama / yogic breathing practice on various mats have a favorable effect on autonomic well-being. The findings from this study suggest that vagal activity increased during and after ANYB on Kuça grass mat compared to cotton or rubber mats.

And interestingly, heart rate appears to be increasing with the use of rubber mat, in both control and experiment session. Therefore, it is an indication that autonomic nervous system is more stable when one uses *Kuça* mat. This demonstrates that simple and inexpensive mat made of natural fiber appears to offer better change in autonomic functions following pranayama/ yogic breathing as compared to breath awareness on the same mat types.

# 8. APPRAISAL

To our knowledge, this is the first study on add on effects of various yoga mats on pranayama practice contributing to several determinants of heart rate variability which is showing significant changes. Alternatively, it could be argued that the study involved only male volunteers. Hence, there is still a need for a population-based study assessing short-term HRV measurements and involving the full age spectrum across gender to help generalize the results.

Among the experiment and control session to evaluate the changes in the autonomic function, there is a need to include other widely used yoga mat materials to add including no mat condition to understand their characteristic changes after yoga practice. And it will be interesting to study how the novices respond to yoga practices in these mats and how over a period of time. (ANS gets stabilised with kusha/other mats)

Participants were randomly assigned to six possible sequences, with the six sessions on separate days. Due to these randomly fixed-session sequences, there is an inherent confounding bias in the results so that changes which occur in a session proceeding the intervention could possibly have carryover effects to the control and experimental session.

Other limitations of the study are related to the practice of yoga breathing techniques. Since all participants were right hand dominant, they all used their right hand to manipulate the nostrils. For this reason, it could be expected that using the right hand to do all the manipulations may have contributed to the changes observed during the yoga breathing techniques. There was no attempt to control for this.

.

# 9. REFERENCE


Balkrishna, A. (2014). Blood Pressure and Heart Rate Variability during Yoga-Based Alternate Nostril Breathing Practice and Breath Awareness. *Medical Science Monitor Basic Research*, *20*(2), 184–193. https://doi.org/10.12659/MSMBR.892063

C. McCall, M. (2013). How might Yoga Work? An Overview of Potential Underlying Mechanisms. *Journal of Yoga & Physical Therapy*, *03*(01). https://doi.org/10.4172/2157-7595.1000130

Chatterjee, S., & Mondal, S. (2017). Effect of combined yoga programme on blood levels of thyroid hormones: A quasi-experimental study. *Indian Journal of Traditional Knowledge*, *16*(June), S9–S16.

Daubenmier, J., Sze, J., Kerr, C. E., Kemeny, M. E., & Mehling, W. (2013). *Follow your breath : Respiratory interoceptive accuracy in experienced meditators*. *50*, 777–789. https://doi.org/10.1111/psyp.12057

Deo, G., Kumar, I. R., Srinivasan, T. M., & Kushwah, K. K. (2016). Cumulative effect of short-term and long-term meditation practice in men and women on psychophysiological parameters of electrophotonic imaging: A cross-sectional study. *Journal of Complementary and Integrative Medicine*, *13*(1), 73–82. https://doi.org/10.1515/jcim-2015-0050

Ehring, T., Zetsche, U., Weidacker, K., Wahl, K., Schönfeld, S., & Ehlers, A. (2011). The Perseverative Thinking Questionnaire (PTQ): Validation of a content-independent measure of repetitive negative thinking. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*(2), 225–232. https://doi.org/10.1016/j.jbtep.2010.12.003

Flao, E. Le, Imbert, C., Wloch, H., & Gueguen, N. (2015). Perceived grip balance and comfort of yoga and gym mats correlate with biomechanical and mechanical assessment. *Computer Methods in Biomechanics and Biomedical Engineering*. https://doi.org/10.1080/10255842.2015.1069585

Gh, C., Giacomoni, P., & Rein, G. (2004). *A CORRELATION BETWEEN GDV AND HEART RATE VARIABILITY MEASURES: A NEW MEASURE OF WELL BEING*. 59–64. Retrieved from https://pdfs.semanticscholar.org/44a6/6b4af724fff905d0b91c5c484d9b08cb3d4c.pdf?_ga=2.154367613.455772825.1524239801-718085463.1524239801

Ghosh, K., Hankey, A., & Srinivasan, T. (2017). Effect of lotus posture on acupuncture meridian energies: A controlled trial. *International Journal of Yoga*, Vol. 10, p. 88. https://doi.org/10.4103/0973-6131.205511

Lee, Cm., & Ghiya, S. (2012). Influence of alternate nostril breathing on heart rate variability in non-practitioners of yogic breathing. *International Journal of Yoga*, *5*(1), 66. https://doi.org/10.4103/0973-6131.91717

Lehrer, P., Sasaki, Y., & Saito, Y. (1999). Zazen and cardiac variability. *Psychosomatic Medicine*. https://doi.org/10.1097/00006842-199911000-00014

Luiza Ciesielska-Wróbel, I., Szadkowska, I., Masajtis, J., & Goch, J. H. (2010). IMAGES OF CORONA DISCHARGES IN PATIENTS WITH CARDIOVASCULAR DISEASES AS A PRELIMINARY ANALYSIS FOR RESEARCH OF THE INFLUENCE OF TEXTILES ON IMAGES OF CORONA DISCHARGES IN TEXTILES' USERS. *AUTEX Research Journal*, *10*. Retrieved from http://www.autexrj.org/No1-2010/

Nagilla, N., Hankey, A., & Nagendra, H. R. (2013). Effects of yoga practice on acumeridian energies: Variance reduction implies benefits for regulation. *International Journal of Yoga*, Vol. 6, pp. 61–65. https://doi.org/10.4103/0973-6131.105948

Raghuraj, P., & Telles, S. (2008). Immediate effect of specific nostril manipulating yoga breathing practices on autonomic and respiratory variables. *Applied Psychophysiology Biofeedback*, *33*(2), 65–75. https://doi.org/10.1007/s10484-008-9055-0

Raj, D. S., Sushmetha, A. M., & Jayashree, S. (2015). *Hierarchical Nanofeatures Promote Microbial Adhesion in Tropical Grasses : Nanotechnology Behind Traditional Disinfection*. https://doi.org/10.1007/s12668-015-0164-y

Rate, H. (2016). *Don't worry, be mindful: mindfulness, perseveration, and heart rate variability*. (August).

Shaffer, F., & Ginsberg, J. P. (2017). An Overview of Heart Rate Variability Metrics and Norms. *Frontiers in Public Health*, *5*(September), 1–17. https://doi.org/10.3389/fpubh.2017.00258

Sokal, P., Sokal, K., Chevalier, G., Sinatra, S. T., & Oschman, J. L. (2012). Earthing: Health Implications of Reconnecting the Human Body to the Earth's Surface Electrons. *Journal of Environmental and Public Health*. https://doi.org/10.1155/2012/291541

Telles, S., Singh, N., & Balakrishna, A. (2014). Role of Respiration in mind-body practices: concepts from contemporary science and traditional yoga texts. *Frontiers in Psychiatry- Affected Disorders and Psychosomatic Research*, *5*. https://doi.org/10.3389/fpsyt.2014.00167

Thakor, N. V., & Webster, J. G. (1985). Electrode studies for the long-term ambulatory ECG. *Medical & Biological Engineering & Computing*, *23*(2), 116–121. https://doi.org/10.1007/BF02456747

Yin, Z., Jian, M., Wang, C., Xia, K., Liu, Z., Wang, Q., … Zhang, Y. (2018). Splash-Resistant and Light-Weight Silk-Sheathed Wires for Textile Electronics. *Nano Letters*, *18*(11), 7085–7091. https://doi.org/10.1021/acs.nanolett.8b03085

# 10. APPENDIX

## APPENDIX-1 RAW DATA

| VARIABLE | YMS01_ | YMS02_ | YMS03_ | YMS09_ | YMS010_ | YMS011_ | YMS012_ | YMS013_ |
|---|---|---|---|---|---|---|---|---|
| PreCCRMSSD_ms | 51.126 | 22.4337 | 45.6217 | 29.338 | 72.5967 | 31.5991 | 68.9159 | 40.1526 |
| Dur1CCRMSSD_ms | 57.1498 | 49.9753 | 42.1172 | 25.003 | 67.0087 | 22.5922 | 78.5897 | 41.3651 |
| Dur2CCRMSSD_ms | 65.7768 | 58.887 | 40.4031 | 49.295 | 76.8137 | 23.8215 | 73.29 | 35.9341 |
| PostCCRMSSD_ms | 53.7478 | 45.2118 | 39.7653 | 48.9782 | 50.6491 | 20.4659 | 63.5903 | 37.9999 |
| PreCERMSSD_ms | 66.732 | 33.4974 | 62.7445 | 51.4984 | 29.413 | 43.395 | 67.6178 | 40.1526 |
| Dur1CERMSSD_ms | 77.5497 | 56.2904 | 69.1983 | 47.7899 | 37.3697 | 62.5608 | 86.9882 | 46.2701 |
| Dur2CERMSSD_ms | 114.2106 | 60.5782 | 55.5676 | 49.0046 | 36.9439 | 30.4494 | 86.7058 | 94.6634 |
| PostCERMSSD_ms | 50.719 | 38.8288 | 68.1439 | 38.7069 | 34.7756 | 57.4799 | 60.4861 | 59.2537 |
| PreKCRMSSD_ms | 58.1433 | 74.7562 | 34.0069 | 29.5318 | 46.9326 | 35.3376 | 73.3999 | 40.1526 |
| Dur1KCRMSSD_ms | 57.1498 | 74.0185 | 31.2871 | 23.022 | 53.1248 | 27.1522 | 81.7197 | 31.0242 |
| Dur2KCRMSSD_ms | 60.6318 | 72.4277 | 27.9009 | 21.5011 | 37.4377 | 31.9367 | 86.6956 | 28.7541 |
| PostKCRMSSD_ms | 71.3525 | 55.7097 | 29.631 | 18.1882 | 44.0654 | 29.5123 | 61.357 | 33.2453 |
| PreKERMSSD_ms | 46.4023 | 39.5332 | 28.0257 | 34.8026 | 59.1462 | 48.1312 | 58.0278 | 34.738 |
| Dur1KERMSSD_ms | 63.6138 | 39.128 | 33.3249 | 33.3249 | 50.9983 | 53.4821 | 106.3345 | 84.8537 |
| Dur2KERMSSD_ms | 43.4217 | 46.1022 | 31.9848 | 38.1726 | 43.8367 | 30.2023 | 75.2588 | 50.4267 |
| PostKERMSSD_ms | 38.6246 | 67.2595 | 26.759 | 34.104 | 47.6047 | 34.0576 | 34.8905 | 40.4951 |
| PreRCRMSSD_ms | 51.126 | 17.4021 | 53.3176 | 81.9033 | 57.1221 | 26.1544 | 73.9893 | 17.7309 |
| Dur1RCRMSSD_ms | 57.1498 | 18.145 | 47.4137 | 26.3939 | 58.1652 | 37.4567 | 69.1293 | 15.1585 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Dur2RCRMSSD_ms* | 65.7768 | 21.8366 | 41.1254 | 33.8459 | 56.5186 | 31.6455 | 69.3144 | 17.4453 |
| *PostRCRMSSD_ms* | 53.7478 | 26.0508 | 38.7713 | 22.5957 | 56.682 | 20.4524 | 74.4781 | 22.2722 |
| *PreRERMSSD_ms* | 59.6434 | 29.9592 | 42.9625 | 35.4759 | 54.8631 | 50.7464 | 74.9096 | 48.6268 |
| *Dur1RERMSSD_ms* | 57.1498 | 50.2725 | 65.3159 | 51.3768 | 59.443 | 54.2919 | 94.8295 | 45.3412 |
| *Dur2RERMSSD_ms* | 58.845 | 58.273 | 53.7727 | 52.0699 | 47.8314 | 29.247 | 80.2703 | 50.6412 |
| *PostRERMSSD_ms* | 58.3475 | 67.5393 | 52.1532 | 49.9977 | 42.8734 | 44.0591 | 51.875 | 45.3965 |

| VARIABLE | *YMS015_* | *YMS017_* | *YMS018_* | *YMS020_* | *YMS024_* | *YMS025_* | *YMS027_* | *YMS028_* |
|---|---|---|---|---|---|---|---|---|
| *PreCCRMSSD_ms* | 25.282 | 47.5732 | 37.0048 | 44.4539 | 21.9284 | 78.2757 | 52.287 | 53.3347 |
| *Dur1CCRMSSD_ms* | 20.3915 | 33.7801 | 44.8544 | 41.7605 | 28.0171 | 57.4924 | 41.8353 | 54.7238 |
| *Dur2CCRMSSD_ms* | 20.6192 | 34.7917 | 45.56 | 36.2195 | 26.2711 | 47.671 | 48.465 | 52.5779 |
| *PostCCRMSSD_ms* | 49.6722 | 34.5325 | 56.0685 | 39.5045 | 27.3502 | 37.7676 | 38.458 | 41.2161 |
| *PreCERMSSD_ms* | 18.7398 | 58.5518 | 33.4974 | 42.53 | 34.5736 | 21.3801 | 56.1038 | 34.5736 |
| *Dur1CERMSSD_ms* | 35.6866 | 71.7479 | 56.2904 | 58.4155 | 56.2084 | 23.4817 | 73.7375 | 56.2084 |
| *Dur2CERMSSD_ms* | 83.1046 | 82.5062 | 60.5782 | 55.0082 | 57.2402 | 25.0749 | 61.1782 | 57.2402 |
| *PostCERMSSD_ms* | 36.6623 | 65.6633 | 38.8288 | 34.5584 | 55.5013 | 35.8144 | 59.3994 | 55.5013 |
| *PreKCRMSSD_ms* | 31.1095 | 37.3101 | 44.4539 | 30.4349 | 39.0234 | 15.5177 | 31.1095 | 66.507 |
| *Dur1KCRMSSD_ms* | 26.4369 | 37.5372 | 41.7605 | 28.1296 | 41.4782 | 12.5949 | 26.4369 | 80.1579 |
| *Dur2KCRMSSD_ms* | 32.0054 | 37.5291 | 36.2195 | 26.2322 | 44.4217 | 18.8452 | 32.0054 | 75.7443 |
| *PostKCRMSSD_ms* | 26.0582 | 30.205 | 39.5045 | 27.4478 | 49.0525 | 19.54 | 26.0582 | 87.7646 |
| *PreKERMSSD_ms* | 20.7085 | 47.2596 | 36.4553 | 34.0881 | 30.7636 | 26.4561 | 70.6536 | 44.4008 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Dur1KERMSSD_ms* | 49.0455 | 71.3638 | 48.8922 | 42.7137 | 52.381 | 27.548 | 79.7393 | 63.7978 |
| *Dur2KERMSSD_ms* | 129.4344 | 74.5997 | 48.3263 | 49.6806 | 32.455 | 30.4289 | 55.55 | 53.1251 |
| *PostKERMSSD_ms* | 36.2276 | 64.4637 | 67.6524 | 32.2662 | 45.595 | 25.326 | 42.5555 | 33.8364 |
| *PreRCRMSSD_ms* | 12.4562 | 39.2473 | 31.8173 | 44.4539 | 23.419 | 42.0581 | 32.0898 | 39.6499 |
| *Dur1RCRMSSD_ms* | 11.0908 | 39.3007 | 42.6435 | 41.7605 | 21.1728 | 32.3838 | 35.8741 | 48.8615 |
| *Dur2RCRMSSD_ms* | 22.86 | 39.1149 | 39.4955 | 36.2195 | 23.3742 | 29.0921 | 50.24 | 46.7755 |
| *PostRCRMSSD_ms* | 33.8777 | 46.2945 | 46.5649 | 39.5045 | 23.3742 | 32.2528 | 29.2091 | 43.1311 |
| *PreRERMSSD_ms* | 18.5021 | 38.1001 | 44.4539 | 40.8897 | 43.481 | 21.8908 | 129.5901 | 46.5814 |
| *Dur1RERMSSD_ms* | 41.9275 | 62.3179 | 41.7605 | 65.8728 | 42.365 | 27.1909 | 97.5361 | 60.0658 |
| *Dur2RERMSSD_ms* | 58.9458 | 66.4288 | 36.2195 | 48.0415 | 35.2712 | 25.9563 | 54.0541 | 60.2244 |
| *PostRERMSSD_ms* | 33.4641 | 50.4933 | 39.5045 | 59.2168 | 53.924 | 18.9838 | 91.5801 | 47.2679 |

| VARIABLE | *YMS01_* | *YMS02_* | *YMS03_* | *YMS09_* | *YMS010_* | *YMS011_* | *YMS012_* | *YMS013_* |
|---|---|---|---|---|---|---|---|---|
| *PreCCNNxx_beats* | 82 | 15 | 85 | 27 | 178 | 38 | 161 | 65 |
| *Dur1CCNNxx_beats* | 80 | 94 | 77 | 19 | 169 | 14 | 184 | 43 |
| *Dur2CCNNxx_beats* | 129 | 126 | 74 | 87 | 179 | 12 | 186 | 32 |
| *PostCCNNxx_beats* | 85 | 82 | 63 | 86 | 108 | 4 | 165 | 42 |
| *PreCENNxx_beats* | 111 | 32 | 68 | 76 | 32 | 43 | 161 | 65 |
| *Dur1CENNxx_beats* | 128 | 93 | 100 | 65 | 44 | 72 | 152 | 67 |
| *Dur2CENNxx_beats* | 116 | 97 | 85 | 63 | 42 | 23 | 138 | 100 |
| *PostCENNxx_beats* | 76 | 51 | 93 | 63 | 37 | 44 | 154 | 111 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *PreKCNNxx_beats* | 102 | 147 | 59 | 27 | 128 | 55 | 175 | 65 |
| *Dur1KCNNxx_beats* | 80 | 148 | 35 | 17 | 126 | 19 | 191 | 36 |
| *Dur2KCNNxx_beats* | 106 | 110 | 24 | 11 | 59 | 47 | 189 | 27 |
| *PostKCNNxx_beats* | 132 | 87 | 33 | 4 | 85 | 34 | 145 | 35 |
| *PreKENNxx_beats* | 95 | 61 | 20 | 54 | 126 | 41 | 124 | 35 |
| *Dur1KENNxx_beats* | 132 | 35 | 53 | 53 | 96 | 64 | 167 | 92 |
| *Dur2KENNxx_beats* | 69 | 75 | 27 | 63 | 62 | 36 | 132 | 56 |
| *PostKENNxx_beats* | 132 | 87 | 33 | 4 | 85 | 34 | 145 | 35 |
| *PreRCNNxx_beats* | 51 | 123 | 14 | 56 | 110 | 29 | 54 | 51 |
| *Dur1RCNNxx_beats* | 80 | 1 | 101 | 21 | 120 | 37 | 169 | 4 |
| *Dur2RCNNxx_beats* | 129 | 9 | 62 | 48 | 125 | 28 | 180 | 6 |
| *PostRCNNxx_beats* | 85 | 17 | 60 | 16 | 109 | 8 | 191 | 18 |
| *PreRENNxx_beats* | 103 | 25 | 77 | 53 | 123 | 55 | 157 | 65 |
| *Dur1RENNxx_beats* | 80 | 72 | 96 | 55 | 118 | 56 | 165 | 69 |
| *Dur2RENNxx_beats* | 97 | 105 | 75 | 62 | 75 | 24 | 137 | 64 |
| *PostRENNxx_beats* | 72 | 109 | 69 | 41 | 64 | 37 | 119 | 54 |

| VARIABLE | *YMS015_* | *YMS017_* | *YMS018_* | *YMS020_* | *YMS024_* | *YMS025_* | *YMS027_* | *YMS028_* |
|---|---|---|---|---|---|---|---|---|
| *PreCCNNxx_beats* | 20 | 117 | 71 | 98 | 7 | 137 | 92 | 108 |
| *Dur1CCNNxx_beats* | 10 | 44 | 92 | 93 | 29 | 116 | 77 | 104 |
| *Dur2CCNNxx_beats* | 13 | 58 | 95 | 67 | 27 | 75 | 84 | 98 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *PostCCNNxx_beats* | 112 | 52 | 124 | 90 | 24 | 61 | 50 | 75 |
| *PreCENNxx_beats* | 7 | 139 | 32 | 69 | 61 | 6 | 63 | 61 |
| *Dur1CENNxx_beats* | 33 | 114 | 93 | 51 | 95 | 11 | 123 | 95 |
| *Dur2CENNxx_beats* | 110 | 104 | 97 | 59 | 83 | 16 | 76 | 83 |
| *PostCENNxx_beats* | 51 | 90 | 51 | 40 | 84 | 57 | 75 | 84 |
| *PreKCNNxx_beats* | 25 | 62 | 98 | 42 | 46 | 2 | 25 | 149 |
| *Dur1KCNNxx_beats* | 19 | 73 | 93 | 27 | 51 | 0 | 19 | 153 |
| *Dur2KCNNxx_beats* | 31 | 67 | 67 | 31 | 62 | 9 | 31 | 150 |
| *PostKCNNxx_beats* | 19 | 39 | 90 | 26 | 84 | 9 | 19 | 147 |
| *PreKENNxx_beats* | 9 | 102 | 64 | 53 | 41 | 17 | 119 | 69 |
| *Dur1KENNxx_beats* | 62 | 108 | 110 | 66 | 47 | 22 | 98 | 97 |
| *Dur2KENNxx_beats* | 122 | 98 | 103 | 62 | 28 | 19 | 75 | 78 |
| *PostKENNxx_beats* | 19 | 39 | 90 | 26 | 84 | 9 | 19 | 147 |
| *PreRCNNxx_beats* | 54 | 86 | 147 | 41 | 53 | 23 | 42 | 41 |
| *Dur1RCNNxx_beats* | 0 | 74 | 89 | 93 | 10 | 28 | 36 | 89 |
| *Dur2RCNNxx_beats* | 14 | 74 | 70 | 67 | 15 | 31 | 76 | 105 |
| *PostRCNNxx_beats* | 43 | 99 | 108 | 90 | 15 | 44 | 23 | 71 |
| *PreRENNxx_beats* | 4 | 59 | 98 | 86 | 70 | 6 | 210 | 73 |
| *Dur1RENNxx_beats* | 64 | 103 | 93 | 79 | 53 | 22 | 139 | 109 |
| *Dur2RENNxx_beats* | 77 | 101 | 67 | 47 | 44 | 19 | 81 | 108 |
| *PostRENNxx_beats* | 49 | 81 | 90 | 76 | 54 | 12 | 150 | 63 |

| VARIABLE | YMS01_ | YMS02_ | YMS03_ | YMS09_ | YMS010_ | YMS011_ | YMS012_ | YMS013_ |
|---|---|---|---|---|---|---|---|---|
| PreCCpNNxx_Per | 28.4722 | 3.6145 | 26.1538 | 7.1618 | 53.1343 | 8.6758 | 55.137 | 17.4731 |
| Dur1CCpNNxx_Per | 27.027 | 24.1026 | 22.063 | 4.9869 | 51.2121 | 3.3654 | 61.9529 | 11.5591 |
| Dur2CCpNNxx_Per | 42.2951 | 32.4742 | 22.7692 | 24.507 | 54.7401 | 2.8916 | 58.8608 | 8.2687 |
| PostCCpNNxx_Per | 29.2096 | 21.134 | 18.0516 | 22.9947 | 30.8571 | 0.9547 | 50.3049 | 10.6599 |
| PreCEpNNxx_Per | 35.5769 | 8.3117 | 19.8251 | 19.8953 | 7.1588 | 10.3614 | 51.6026 | 17.4731 |
| Dur1CEpNNxx_Per | 40.3785 | 25.6198 | 29.4118 | 16.129 | 10.1852 | 16.9811 | 44.3149 | 18.7151 |
| Dur2CEpNNxx_Per | 35.0453 | 26.0753 | 23.9437 | 16.0714 | 9.3541 | 5.5288 | 38.2271 | 29.2398 |
| PostCEpNNxx_Per | 25.2492 | 13.5279 | 26.5714 | 15.4034 | 8.8517 | 10.6024 | 46.2462 | 31.8966 |
| PreKCpNNxx_Per | 35.0515 | 45.5108 | 16.573 | 5.7203 | 35.5556 | 14.1753 | 57.0033 | 17.4731 |
| Dur1KCpNNxx_Per | 27.027 | 43.9169 | 9.3583 | 3.6017 | 34.903 | 4.8469 | 63.8796 | 10.1695 |
| Dur2KCpNNxx_Per | 36.5517 | 31.9767 | 6.5217 | 2.3256 | 15.3646 | 12.2078 | 66.0839 | 7.3973 |
| PostKCpNNxx_Per | 44.4444 | 24.0997 | 9.1922 | 0.8333 | 22.7882 | 8.8083 | 40.8451 | 9.4086 |
| PreKEpNNxx_Per | 25.8152 | 16.1376 | 4.9751 | 13.1707 | 35.7955 | 9.9515 | 35.4286 | 10.1156 |
| Dur1KEpNNxx_Per | 36.4641 | 8.5575 | 13.0221 | 13.0221 | 26.6667 | 15.4589 | 46.2604 | 26.2857 |
| Dur2KEpNNxx_Per | 18.5984 | 19.8939 | 6.3981 | 15.3285 | 16.3588 | 8.7591 | 33.9332 | 15.8192 |
| PostKEpNNxx_Per | 14.3258 | 35.2436 | 3.4826 | 13.4615 | 30.9859 | 7.0732 | 13.0435 | 14.7826 |
| PreRCpNNxx_Per | 28.4722 | 0.7353 | 32.9032 | 21.7073 | 34.0058 | 6.3452 | 61.6129 | 2.2222 |
| Dur1RCpNNxx_Per | 27.027 | 0.2445 | 29.7059 | 4.9645 | 34.9854 | 9.6104 | 51.3678 | 0.995 |
| Dur2RCpNNxx_Per | 42.2951 | 2.2167 | 18.4524 | 11.4558 | 38.8199 | 7.1611 | 55.9006 | 1.4963 |
| PostRCpNNxx_Per | 29.2096 | 4.2821 | 17.6471 | 3.5874 | 33.642 | 1.9608 | 62.623 | 4.5226 |
| PreREpNNxx_Per | 32.3899 | 6.2657 | 22.8487 | 12.0181 | 36.1765 | 13.4804 | 49.5268 | 19.9387 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Dur1REpNNxx_Per* | 27.027 | 18.2741 | 28.7425 | 12.3596 | 34.3023 | 13.6585 | 47.6879 | 21.5625 |
| *Dur2REpNNxx_Per* | 29.3051 | 28.1501 | 21.1268 | 13.9013 | 20.7182 | 5.4545 | 36.2434 | 19.8142 |
| *PostREpNNxx_Per* | 23.5294 | 29.3801 | 18.6486 | 9.0508 | 18.5507 | 8.3521 | 34.2939 | 16.7702 |

| VARIABLE | *YMS015_* | *YMS017_* | *YMS018_* | *YMS020_* | *YMS024_* | *YMS025_* | *YMS027_* | *YMS028_* |
|---|---|---|---|---|---|---|---|---|
| *PreCCpNNxx_Per* | 5.2083 | 31.6216 | 20.4023 | 25.7218 | 1.6018 | 41.018 | 25.3444 | 30.4225 |
| *Dur1CCpNNxx_Per* | 2.6042 | 11.3695 | 27.2997 | 23.9691 | 7.0048 | 33.1429 | 20.5882 | 31.2312 |
| *Dur2CCpNNxx_Per* | 3.2581 | 14.2506 | 28.8754 | 16.6667 | 6.6832 | 20.8333 | 22.9508 | 28.5714 |
| *PostCCpNNxx_Per* | 32.2767 | 13.577 | 37.8049 | 22.6131 | 6.0606 | 16.8508 | 12.9199 | 20.8914 |
| *PreCEpNNxx_Per* | 1.6908 | 37.5676 | 8.3117 | 17.7835 | 14.6988 | 1.5228 | 16.1125 | 14.6988 |
| *Dur1CEpNNxx_Per* | 8.1281 | 28.8608 | 25.6198 | 12.3487 | 23.399 | 2.6316 | 31.7829 | 23.399 |
| *Dur2CEpNNxx_Per* | 26.1905 | 25.8065 | 26.0753 | 13.7529 | 20.2439 | 3.7209 | 18.8586 | 20.2439 |
| *PostCEpNNxx_Per* | 13.3159 | 23.1959 | 13.5279 | 10.0503 | 21.5938 | 16.1017 | 18.3824 | 21.5938 |
| *PreKCpNNxx_Per* | 5.5432 | 15.8568 | 25.7218 | 10.6599 | 12.7424 | 0.4773 | 5.5432 | 47.7564 |
| *Dur1KCpNNxx_Per* | 4.3379 | 18.6224 | 23.9691 | 6.506 | 14.4886 | 0 | 4.3379 | 48.7261 |
| *Dur2KCpNNxx_Per* | 7.346 | 16.5432 | 16.6667 | 7.4519 | 17.7143 | 2.1951 | 7.346 | 48.0769 |
| *PostKCpNNxx_Per* | 4.4084 | 9.7257 | 22.6131 | 6.3882 | 22.6415 | 2.1739 | 4.4084 | 57.4219 |
| *PreKEpNNxx_Per* | 2.3077 | 26.6319 | 18.6589 | 13.8381 | 9.7156 | 4.0284 | 30.9896 | 19.0608 |
| *Dur1KEpNNxx_Per* | 16.5333 | 27.1357 | 32.9341 | 16.1369 | 10.4444 | 5.1044 | 24.0196 | 24.6819 |
| *Dur2KEpNNxx_Per* | 30.4239 | 23.6715 | 30.8383 | 14.4186 | 6.6351 | 4.3182 | 17.9856 | 19.5 |
| *PostKEpNNxx_Per* | 15.6977 | 21.5 | 47.1154 | 10.4061 | 13.5204 | 5.9585 | 9.8131 | 10.5398 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *PreRCpNNxx_Per* | 0.232 | 20.8226 | 10.5114 | 25.7218 | 1.566 | 17.663 | 6.3529 | 17.5793 |
| *Dur1RCpNNxx_Per* | 0 | 19.3717 | 26.7267 | 23.9691 | 2.1277 | 7.3107 | 8.0899 | 26.1765 |
| *Dur2RCpNNxx_Per* | 3.5714 | 19.3717 | 20.649 | 16.6667 | 3.2328 | 8.2447 | 17.2727 | 31.9149 |
| *PostRCpNNxx_Per* | 13.1098 | 29.9094 | 29.5082 | 22.6131 | 3.2328 | 12.1547 | 5.3364 | 19.8324 |
| *PreREpNNxx_Per* | 0.995 | 15.6915 | 25.7218 | 20.9756 | 18.2768 | 1.3333 | 65.0155 | 21.0983 |
| *Dur1REpNNxx_Per* | 16.0804 | 26.9634 | 23.9691 | 18.5882 | 12.297 | 4.9438 | 36.0104 | 31.0541 |
| *Dur2REpNNxx_Per* | 19.3467 | 25.3133 | 16.6667 | 10.4213 | 10.1149 | 4.2129 | 20.7161 | 28.9544 |
| *PostREpNNxx_Per* | 13.2075 | 21.2042 | 22.6131 | 19.1436 | 14.2105 | 2.7842 | 40 | 18.2609 |

| VARIABLE | *YMS01_* | *YMS02_* | *YMS03_* | *YMS09_* | *YMS010_* | *YMS011_* | *YMS012_* | *YMS013_* |
|---|---|---|---|---|---|---|---|---|
| *PreCCLF_HFratio* | 1.447 | 2.1711 | 0.8718 | 3.0932 | 0.5337 | 0.558 | 0.2914 | 3.375 |
| *Dur1CCLF_HFratio* | 1.8663 | 1.9711 | 1.5113 | 4.8055 | 0.7008 | 0.8143 | 0.3761 | 3.8321 |
| *Dur2CCLF_HFratio* | 1.3287 | 1.8365 | 1.3721 | 1.1928 | 1.2564 | 0.7263 | 0.788 | 1.9309 |
| *PostCCLF_HFratio* | 0.9901 | 1.9053 | 1.8197 | 1.8209 | 1.312 | 1.3573 | 1.5362 | 2.4625 |
| *PreCELF_HFratio* | 2.0421 | 3.0483 | 1.5354 | 1.9421 | 3.2484 | 4.0702 | 0.2383 | 3.375 |
| *Dur1CELF_HFratio* | 10.0222 | 3.3729 | 2.5891 | 3.6847 | 5.0725 | 0.4786 | 5.8622 | 15.7695 |
| *Dur2CELF_HFratio* | 1.7202 | 4.0289 | 10.2406 | 5.893 | 12.6338 | 18.6655 | 9.0332 | 5.5243 |
| *PostCELF_HFratio* | 3.6966 | 8.9857 | 3.0066 | 3.1298 | 5.6698 | 3.5309 | 1.5417 | 16.9883 |
| *PreKCLF_HFratio* | 2.4039 | 1.0985 | 2.2428 | 1.6172 | 1.1682 | 1.2572 | 0.4864 | 3.375 |
| *Dur1KCLF_HFratio* | 1.8663 | 1.7266 | 2.1359 | 6.0046 | 0.476 | 0.6473 | 0.8208 | 8.5684 |
| *Dur2KCLF_HFratio* | 1.1842 | 1.5671 | 2.9513 | 2.8691 | 1.341 | 1.0207 | 0.3279 | 13.921 |
| *PostKCLF_HFratio* | 1.123 | 1.3074 | 1.8766 | 5.4194 | 1.1205 | 2.69 | 2.0038 | 5.9448 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *PreKELF_HFratio* | 1.6187 | 2.7571 | 1.0808 | 1.9948 | 1.1959 | 4.6768 | 1.5286 | 2.9875 |
| *Dur1KELF_HFratio* | 2.7862 | 4.8552 | 1.6813 | 1.6813 | 2.9202 | 3.8361 | 2.8813 | 2.5281 |
| *Dur2KELF_HFratio* | 13.4471 | 5.5549 | 7.6708 | 2.5738 | 5.4594 | 70.6518 | 5.621 | 7.5671 |
| *PostKELF_HFratio* | 3.0801 | 2.3154 | 5.607 | 2.3229 | 0.589 | 11.3834 | 1.5633 | 10.2295 |
| *PreRCLF_HFratio* | 1.447 | 2.9169 | 1.3677 | 0.2541 | 2.0558 | 2.1712 | 0.2401 | 5.812 |
| *Dur1RCLF_HFratio* | 1.8663 | 1.7504 | 1.6048 | 3.108 | 2.3231 | 2.1824 | 0.4805 | 11.0867 |
| *Dur2RCLF_HFratio* | 1.3287 | 3.4098 | 1.7015 | 2.6151 | 1.6022 | 3.2544 | 0.5709 | 9.4993 |
| *PostRCLF_HFratio* | 0.9901 | 2.5974 | 1.7953 | 2.2692 | 2.3859 | 3.9423 | 0.4924 | 8.1063 |
| *PreRELF_HFratio* | 2.814 | 5.7953 | 2.261 | 1.4623 | 1.0521 | 3.7346 | 0.3885 | 5.3517 |
| *Dur1RELF_HFratio* | 1.8663 | 7.878 | 4.3996 | 2.1058 | 4.6447 | 1.2566 | 6.6111 | 14.5665 |
| *Dur2RELF_HFratio* | 9.4969 | 3.6766 | 7.8756 | 4.9644 | 10.1342 | 6.0185 | 6.8269 | 10.6096 |
| *PostRELF_HFratio* | 3.1227 | 1.4724 | 3.6955 | 1.6323 | 1.4464 | 4.3816 | 0.8903 | 5.9812 |

| VARIABLE | *YMS015_* | *YMS017_* | *YMS018_* | *YMS020_* | *YMS024_* | *YMS025_* | *YMS027_* | *YMS028_* |
|---|---|---|---|---|---|---|---|---|
| *PreCCLF_HFratio* | 7.8481 | 0.6334 | 1.4332 | 0.7925 | 3.9382 | 0.4187 | 1.8599 | 1.4548 |
| *Dur1CCLF_HFratio* | 2.7184 | 0.6289 | 1.4074 | 0.6992 | 2.5474 | 0.6816 | 1.1629 | 1.2678 |
| *Dur2CCLF_HFratio* | 3.5562 | 2.9716 | 2.1704 | 1.2881 | 3.1766 | 0.9657 | 1.2392 | 1.1496 |
| *PostCCLF_HFratio* | 1.8243 | 1.1141 | 2.0944 | 0.4047 | 3.9572 | 1.6611 | 4.2453 | 2.3298 |
| *PreCELF_HFratio* | 5.3771 | 0.2593 | 3.0483 | 0.8001 | 2.9707 | 2.4697 | 2.232 | 2.9707 |
| *Dur1CELF_HFratio* | 4.7916 | 6.4394 | 3.3729 | 1.9157 | 7.737 | 2.0304 | 4.4924 | 7.737 |
| *Dur2CELF_HFratio* | 3.8991 | 5.9106 | 4.0289 | 3.224 | 7.5887 | 21.2783 | 6.6701 | 7.5887 |
| *PostCELF_HFratio* | 2.8872 | 6.1819 | 8.9857 | 2.623 | 5.1322 | 1.6454 | 2.8578 | 5.1322 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *PreKCLF_HFratio* | 4.9314 | 0.3734 | 0.7925 | 1.0746 | 3.6795 | 1.8189 | 4.9314 | 0.9376 |
| *Dur1KCLF_HFratio* | 2.7907 | 1.2073 | 0.6992 | 2.1295 | 3.6522 | 2.9061 | 2.7907 | 0.6459 |
| *Dur2KCLF_HFratio* | 2.7676 | 2.287 | 1.2881 | 1.3077 | 4.7462 | 7.5955 | 2.7676 | 1.0087 |
| *PostKCLF_HFratio* | 3.4764 | 2.4624 | 0.4047 | 1.588 | 4.6636 | 9.0666 | 3.4764 | 1.1486 |
| *PreKELF_HFratio* | 3.4127 | 0.6178 | 1.728 | 0.941 | 2.5838 | 3.8084 | 0.5823 | 1.2833 |
| *Dur1KELF_HFratio* | 4.6714 | 6.8004 | 3.2655 | 1.6321 | 1.3356 | 3.1159 | 4.5619 | 4.4183 |
| *Dur2KELF_HFratio* | 1.1376 | 7.7878 | 3.169 | 7.7557 | 14.4794 | 5.4062 | 15.7235 | 5.21 |
| *PostKELF_HFratio* | 1.7082 | 11.3784 | 1.4509 | 1.8949 | 1.6534 | 1.9596 | 2.7991 | 2.3606 |
| *PreRCLF_HFratio* | 11.2014 | 0.2697 | 0.8103 | 0.7925 | 3.7261 | 1.1615 | 2.554 | 1.2678 |
| *Dur1RCLF_HFratio* | 12.0914 | 0.8389 | 1.3102 | 0.6992 | 4.1292 | 4.3992 | 1.9216 | 2.0142 |
| *Dur2RCLF_HFratio* | 5.8987 | 1.0054 | 2.3977 | 1.2881 | 3.4392 | 3.9295 | 5.6166 | 1.0588 |
| *PostRCLF_HFratio* | 3.0064 | 1.9333 | 0.2833 | 0.4047 | 3.4392 | 5.4994 | 2.5797 | 2.8658 |
| *PreRELF_HFratio* | 11.7589 | 0.6251 | 0.7925 | 0.3904 | 5.2661 | 4.8054 | 0.5571 | 2.363 |
| *Dur1RELF_HFratio* | 5.2908 | 5.4455 | 0.6992 | 2.5514 | 6.1512 | 4.9651 | 4.3139 | 4.9366 |
| *Dur2RELF_HFratio* | 7.2999 | 8.1298 | 1.2881 | 9.3934 | 11.3514 | 3.8928 | 4.3564 | 6.0602 |
| *PostRELF_HFratio* | 4.0483 | 13.2961 | 0.4047 | 0.9964 | 6.013 | 4.5154 | 3.8893 | 2.916 |

| VARIABLE | YMS01_ | YMS02_ | YMS03_ | YMS09_ | YMS010_ | YMS011_ | YMS012_ | YMS013_ |
|---|---|---|---|---|---|---|---|---|
| PreCCMeanHR_beats_min | 57.8494 | 83.386 | 65.2775 | 75.7991 | 67.327 | 87.8006 | 58.6855 | 74.6759 |
| Dur1CCMeanHR_beats_min | 59.5421 | 78.2107 | 69.9459 | 76.2371 | 66.1755 | 83.4211 | 59.5958 | 74.5478 |
| Dur2CCMeanHR_beats_min | 61.0744 | 77.7117 | 65.2272 | 71.4185 | 65.5449 | 83.3397 | 63.44 | 77.6746 |
| PostCCMeanHR_beats_min | 58.4743 | 77.9419 | 70.0567 | 75.0909 | 70.3226 | 84.0597 | 65.8261 | 79.0163 |
| PreCEMeanHR_beats_min | 62.6347 | 77.3384 | 68.8032 | 76.6347 | 89.6631 | 83.2388 | 62.6905 | 74.6759 |
| Dur1CEMeanHR_beats_min | 63.6318 | 72.751 | 68.3132 | 80.8259 | 86.6323 | 85.0031 | 68.7402 | 71.6696 |
| Dur2CEMeanHR_beats_min | 66.4317 | 74.6919 | 71.2055 | 78.6779 | 90.0141 | 83.4657 | 72.4928 | 68.5909 |
| PostCEMeanHR_beats_min | 60.4332 | 75.8019 | 70.2356 | 82.1772 | 83.901 | 83.238 | 66.8254 | 69.7819 |
| PreKCMeanHR_beats_min | 58.5301 | 64.882 | 71.5503 | 94.7813 | 72.2766 | 77.9668 | 61.7674 | 74.6759 |
| Dur1KCMeanHR_beats_min | 59.5421 | 67.5311 | 74.8438 | 94.5915 | 72.4628 | 78.5578 | 59.9239 | 71.0324 |
| Dur2KCMeanHR_beats_min | 58.212 | 69.0919 | 73.8492 | 94.7245 | 77.0056 | 77.1162 | 57.3713 | 73.3298 |
| PostKCMeanHR_beats_min | 59.6967 | 72.3899 | 72.152 | 96.1436 | 74.8195 | 77.502 | 71.2691 | 74.5098 |
| PreKEMeanHR_beats_min | 73.9328 | 75.9068 | 80.8028 | 82.2192 | 70.6601 | 82.6998 | 70.2895 | 69.4725 |
| Dur1KEMeanHR_beats_min | 72.6203 | 81.863 | 81.7731 | 81.7731 | 72.3254 | 83.0304 | 72.4485 | 70.29 |
| Dur2KEMeanHR_beats_min | 74.4978 | 75.597 | 84.5614 | 82.2383 | 75.9635 | 82.3937 | 77.8865 | 70.9189 |
| PostKEMeanHR_beats_min | 71.3177 | 70.049 | 80.685 | 83.4278 | 71.1651 | 82.1236 | 82.8933 | 69.3074 |
| PreRCMeanHR_beats_min | 57.8494 | 81.8912 | 62.3813 | 82.3012 | 69.7129 | 79.1919 | 62.3607 | 81.2699 |
| Dur1RCMeanHR_beats_min | 59.5421 | 82.026 | 68.0148 | 84.8215 | 68.761 | 77.1347 | 65.9134 | 80.6406 |
| Dur2RCMeanHR_beats_min | 61.0744 | 81.29 | 67.504 | 83.9653 | 64.6403 | 78.3071 | 64.6867 | 80.3127 |
| PostRCMeanHR_beats_min | 58.4743 | 79.4533 | 68.3504 | 89.2619 | 65.1105 | 81.9139 | 61.2098 | 79.9116 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *PreREMeanHR_beats_min* | 63.8066 | 80.0667 | 67.6327 | 88.5378 | 68.2986 | 81.8898 | 63.6981 | 65.4135 |
| *Dur1REMeanHR_beats_min* | 59.5421 | 78.975 | 67.1024 | 89.1545 | 69.1046 | 82.2754 | 69.3309 | 64.2949 |
| *Dur2REMeanHR_beats_min* | 66.3427 | 74.7791 | 71.1286 | 89.3681 | 72.5543 | 88.1947 | 75.9045 | 64.8467 |
| *PostREMeanHR_beats_min* | 61.5113 | 74.3898 | 74.0297 | 90.9182 | 69.2088 | 88.5727 | 69.6597 | 64.5645 |

| VARIABLE | *YMS015_* | *YMS017_* | *YMS018_* | *YMS020_* | *YMS024_* | *YMS025_* | *YMS027_* | *YMS028_* |
|---|---|---|---|---|---|---|---|---|
| *PreCCMeanHR_beats_min* | 77.1721 | 74.2314 | 69.8044 | 76.4704 | 87.6219 | 67.143 | 72.9825 | 71.3398 |
| *Dur1CCMeanHR_beats_min* | 76.9226 | 77.658 | 67.6534 | 77.772 | 83.018 | 70.163 | 74.9815 | 66.7978 |
| *Dur2CCMeanHR_beats_min* | 80.0726 | 81.7177 | 66.0425 | 80.5766 | 81.1626 | 72.1444 | 73.4034 | 68.7379 |
| *PostCCMeanHR_beats_min* | 69.5388 | 76.712 | 65.8303 | 79.9271 | 79.4996 | 72.6397 | 77.6549 | 72.1949 |
| *PreCEMeanHR_beats_min* | 83.0166 | 74.3475 | 77.3384 | 77.8943 | 83.2758 | 79.1295 | 78.4748 | 83.2758 |
| *Dur1CEMeanHR_beats_min* | 81.5822 | 79.2383 | 72.751 | 82.8558 | 81.4209 | 83.7927 | 77.756 | 81.4209 |
| *Dur2CEMeanHR_beats_min* | 84.1041 | 80.7341 | 74.6919 | 85.8906 | 82.304 | 86.1687 | 80.5787 | 82.304 |
| *PostCEMeanHR_beats_min* | 76.8689 | 77.8166 | 75.8019 | 79.8231 | 77.8482 | 71.0208 | 81.8674 | 77.8482 |
| *PreKCMeanHR_beats_min* | 90.4214 | 78.57 | 76.4704 | 79.0759 | 72.4531 | 84.1875 | 90.4214 | 62.6572 |
| *Dur1KCMeanHR_beats_min* | 87.8665 | 78.5081 | 77.772 | 83.1537 | 70.6749 | 84.1234 | 87.8665 | 63.0702 |
| *Dur2KCMeanHR_beats_min* | 84.5267 | 81.2731 | 80.5766 | 83.4011 | 70.233 | 82.2606 | 84.5267 | 62.5081 |
| *PostKCMeanHR_beats_min* | 86.4683 | 80.3971 | 79.9271 | 81.6651 | 74.3447 | 82.9442 | 86.4683 | 62.1323 |
| *PreKEMeanHR_beats_min* | 78.3986 | 76.8438 | 68.8581 | 76.957 | 84.6011 | 84.666 | 77.1479 | 72.7518 |
| *Dur1KEMeanHR_beats_min* | 75.1512 | 79.8884 | 67.1538 | 81.9615 | 90.2195 | 86.52 | 81.8134 | 78.6801 |
| *Dur2KEMeanHR_beats_min* | 80.2681 | 83.0149 | 66.921 | 86.1799 | 84.6691 | 88.0996 | 83.4937 | 80.298 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *PostKEMeanHR_beats_min* | 68.943 | 80.3149 | 62.6154 | 78.9213 | 78.5955 | 77.392 | 85.8046 | 78.1916 |
| *PreRCMeanHR_beats_min* | 86.5772 | 78.0869 | 70.6052 | 76.4704 | 89.7229 | 73.8613 | 85.3462 | 69.6611 |
| *Dur1RCMeanHR_beats_min* | 88.2241 | 76.6767 | 66.9037 | 77.772 | 94.1137 | 76.9054 | 89.0643 | 68.2685 |
| *Dur2RCMeanHR_beats_min* | 78.5974 | 76.5847 | 67.9715 | 80.5766 | 93.0484 | 75.3129 | 88.4151 | 65.9626 |
| *PostRCMeanHR_beats_min* | 65.7533 | 66.3076 | 73.3333 | 79.9271 | 93.0484 | 72.6068 | 86.5003 | 71.7362 |
| *PreREMeanHR_beats_min* | 80.6382 | 75.5445 | 76.4704 | 82.2625 | 76.9185 | 90.2385 | 64.9663 | 69.4834 |
| *Dur1REMeanHR_beats_min* | 79.9391 | 76.5888 | 77.772 | 85.2142 | 86.4352 | 89.1878 | 77.3863 | 70.4641 |
| *Dur2REMeanHR_beats_min* | 79.6603 | 79.9475 | 80.5766 | 90.4724 | 87.1477 | 90.5718 | 78.336 | 74.7928 |
| *PostREMeanHR_beats_min* | 74.4159 | 76.8531 | 79.9271 | 79.6648 | 76.2257 | 86.4072 | 75.3147 | 69.319 |

## APPENDIX-2 PHOTGRAPHS



SuperDry
FREESTYLE


FOREVER