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Exploration of Ayurveda blueprint on clinical physiology of *Meda* (adipose tissue) and *Majja* Dhatu (bone marrow) in context to obesity

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Abstract

The state of health depends on the functional state of *Dosha*, *Dhatu*, *Mala*, *Srotas*, and *Agni*. The concept of functional and nutritional interdependence of *Dhatu* as well as a physiological and pathological aspect of all the seven *Dhatu* has been described by Ayurveda scholars. The metabolic effect of *Meda* and *Majja Dhatu* on other tissues like a muscle (*Mamsa Dhatu*), bone (*Asthi Dhatu*), and reproductive tissue (*Shukra Dhatu*) show their functional interdependence. The Ayurveda compendia, as well as recent research data, shows that obesity is the disorder of nutrition, which depends on lifestyle and diet. The obesity has been discussed in relation to *Medovaha Srotodushti* and *Meda Dhatu Vriddhi*. Although the physiology of *Vasa*, *Meda*, and *Majja* tissue has not been elaborated much, their clinical physiology has been described. This article aims to comprehend the pathophysiology of obesity as well as manifestations on the disturbed functional state of *Meda* and *Majja Dhatu,* as depicted by Ayurveda scholars in light of contemporary science. This article will be helpful in developing a vision regarding the clinical physiology of *Meda* and *Majja*, which will be further helpful in the exploration of pathophysiology and the management of obesity and associated disorders manifested by them. On exhaustive study, it was observed that the clinical physiology of *Meda* and *Majja Dhatu* shares quite a resemblance with the outcomes of contemporary researches on adipocytes, but still, some of these are still under the research.

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INTRODUCTION

Ayurveda scholars have discussed both physiological as well as a pathological aspect of all the seven *Dhatu* i.e., *Rasa* (Plasma), *Rakta* (blood cells), *Mamsa* (muscle), *Meda* (adipose tissue), *Asthi* (bone), *Majja* (bone marrow/brain marrow), *Shukra* (reproductive tissue). Among these *Dhatu*, physiological aspect of *Meda* and *Majja Dhatu* containing mainly different adipocytes have not been extensively discussed, but their clinical physiology have been elaborated in different contexts like etiology of vitiation, pathophysiology, characteristics, and management of obesity or *Sthoulya* and other disorders.

Obesity is an important component of the global

Syndemic, including undernutrition and climate change that affect the health and wellbeing of the people worldwide (Swinburn *et al.*, 2019). The present epidemiological studies have reported that obesity pandemic has shifted the pattern of malnutrition in the past 40 years, which is a major risk factor for NCDs. However, after the perusal of Ayurveda literature, it seems that the obesity (*Sthaulya*) and disorders of fat metabolism (*Meda Dushti*), its impact on the functional state of other tissues and subsequent development of clinical metabolic syndrome causing Diabetes (*Prameha*) and NCDs have been documented in a comprehensive manner. This shows that obesity and its related disorders are not the newly emerged health problem; rather, it was present in ancient time as well. The Ayurveda, as well as recent research data, shows that this is the disorder of nutrition, which depends on lifestyle and diet.

Recent researches have given significant evidence of an association between chronic inflammation (*Shopha*), obesity (*Sthaulya*), and its subsequent disorders like diabetes, CVD, cancer, etc. The sub-inflammatory markers (cytokines) may be understood as *Aama* that refers to the products produced due to improper metabolism of *Dhatu*. Recent researches have also established various mechanisms showing how the disturbed metabolism of adipocytes affects the physiology of other tissues like bones, reproductive tissue, muscles, etc. Ayurveda scholars have also discussed these under the clinical physiology of *Meda Dhatu*, *Majja Dhatu*, and their *Srotas*. Thus an attempt has been done to understand the pathophysiology aspects of *Meda* and *Majja* as described in Ayurveda in light of contemporary medicine.

MATERIALS AND METHODS

Ayurveda literatures were meticulously reviewed for the description of *Vasa*, *Meda*, and *Majja Dhatu* in different contexts like functions in different states i.e., normal, increased, decreased and vitiated, causes and features of vitiated *Srotas, the* pathophysiology of *Sthoulya*. For contemporary descriptions, most recent review articles related to the role of distinguished adipocytes in physiological as well as pathological state have been included from the electronic resources like PubMed. This article is an attempt to understand the clinical physiology of *Meda* and *Majja Dhatu* and *Srotodushti* in light of recent contemporary science researches.

RESULTS AND DISCUSSION

The concept of functional and nutritional interdependence of *Dhatu* has been described by Ayurveda scholars (Dwivedi *et al.*, 2016b). The metabolic effect of *Meda* and *Majja Dhatu* on other tissues like a muscle (*Mamsa Dhatu*), bone (*Asthi Dhatu*), and reproductive tissue (*Shukra Dhatu*) shows their functional interdependence (Agrawal *et al.*, 2019). Ayurveda scholars have not only described the physiological functions of *Rasadi Dhatu* and the mechanism of tissue nutrition (*Dhatu Poshan*) but also mentioned the manifestation of signs and symptoms in case of disturbed physiology. The obesity has been discussed in relation to *Medovaha Srotodushti* and *Meda Dhatu Vriddhi* (Thakarar, 2017c) .

Although the physiology of *Vasa*, *Meda*, and *Majja* tissue have not been elaborated much but their clinical physiology have been described i.e., the symptoms manifested in their increased or decreased or vitiated state, factors causing vitiation of their *Srotas*, description of *Srotasmoola*, etc. (Table 1). These symptoms can be interpreted through the recent advancement in the field of adipocytes to understand the role of these tissues in the maintenance of homeostasis and manifestation of pathology.

Consideration of kidney (*Vrikka*), omental/visceral fat (*Vapavahana*), waist area (*Kati*) and *Mamsa* (muscle) as *Srotomoola* of *Medavaha Srotas*

The *Srotomoola* are the primary sites of onset of pathogenesis or the organ through which disease signs and symptoms of a particular *Srotas* get manifested (Dwivedi *et al.*, 2016k; Verma and Gehlot, 2014). These organs, too, have an important role in pathophysiological conditions related to adipose tissue. The possible reasons behind consideration of these as *Srotomula* of *Medavaha Srotas* are described in Table 2 . *Meda* has also been considered as *Moola* of *Asthivaha Srotas* while *Majja* as *Moola* of *Shukravaha Srotas*. Recently, it has been found that osteoclastin secreted by bone affects fat metabolism and insulin sensitivity (Karsenty G et al., 2016), thus affecting the functions of adipose tissue. (Thakarar, 2017a; Dwivedi *et al.*, 2016j; Acharya, 2008a)

Manifestations of an abnormal state of *Meda Dhatu*

Features of *Sthoulya*, *Meda Vriddhi*, and *Meda Dushti* have been mentioned to describe the pathophysiology of the abnormal functional state of *Meda.* Obesity has been defined as a cluster of symptoms of increased *Meda* and *Mamsa Dhatu*, increased adiposity in buttock, breast, and abdomen, decreased

Table 1: Describing Clinical physiology of *Meda* and *Majja* and *Srotodushti* i.e., pathophysiological aspect as described in Ayurveda

	Meda	Majja
Features of increased state	Unctuousness (Snigdhangata), increase in visceral fat (Udaraparshavvriddhi), cardiovascular and respiratory disorders producing breathlessness (Shwas), cough (Kasa), foul smell (Daurgandhaya), breathlessness on mild exertion, disorders of Shlesma, Rakta, and Mamsa (Thakarar, 2017c; Kunte and Navare, 2009a; Acharya, 2008d)	Heaviness in the whole body including eyes (Sarvanaganetragauravam), a manifestation of deep-seated eruption (Thakarar, 2017c; Kunte and Navare, 2009a).
Features of decreased status	Splenomegaly (Pleehaabhivriddhi), emptiness in joints (Sandhishunyata) roughness in the body (Roukshayam), (Thakarar, 2017b). Cracking of joints, fatigue in eyes on exhaustion, emaciation in the abdomen (Udara) (Dwivedi *et al.*, 2016f), loss of sensation over the pelvis, the desire of having fleshy meat, features of Mamsa Kshaya, desire for unctuous flesh (Medaourmamashprathana) (Kunte and Navare, 2009b; Acharya, 2008c)	Low fertility (Alpashukrata), joint pain (Parvabheda), bone pain (Asthinistoda), the lightness of bone, osteoporosis (Asthishunyata) (Thakarar, 2017b). Thinness, weakness, and lightness of the bones, affliction with Vata disorders continuously, fainting (Dwivedi *et al.*, 2016g; Kunte and Navare, 2009c)
Srotas and Moola	Pelvis (Kati), kidney (Vrikka), muscles (Mamsa), omentum (Vapavahana). Meda is Moola of Asthivaha Srotas (Thakarar, 2017b; Dwivedi *et al.*, 2016j; Acharya, 2008a)	Bones (Asthi), joints (Sandhi), Moola of Shukravaha Srotas (Dwivedi *et al.*, 2016k; Acharya, 2008a)
Causes of vitiation of Srotas	Lack of exercise, excessive day sleep excessive intake of fatty things, and alcoholic drink (Varuni) (Dwivedi *et al.*, 2016i).	Crushing, injury, compression of bone marrow (Dwivedi *et al.*, 2016i).
Features of Srotovaigunya/ injury	Sweating, unctuousness in the injured area, dryness of palate (Taalushosha), obesity (Sthulata), inflammation (Shopha), thirst (Pipasa) Prodromal symptoms of Prameha (Dwivedi *et al.*, 2016a; Thakarar, 2017a).	Joint pain, giddiness, fainting, feeling of entering into the darkness, manifestation of deep-seated eruptions (Dwivedi *et al.*, 2016h).

body strength (Dwivedi *et al.*, 2016d). It manifests eight peculiar features i.e., short life span, early aging, sexual dysfunction, debility, profuse sweating, foul smell, feeling of excessive hunger, and thirst (Dwivedi *et al.*, 2016d). The features of increased *Meda* include increased waist circumference (increased visceral fat in abdominal region), cardiorespiratory disturbance and foul smell due to excessive sweating (Thakarar, 2017c) while vitiated *Meda* includes excessive sweating (*Atisweda*), inflammation (*Shopha*), prodromal symptoms of diabetes (*Prameha poorvaroop*) and thirst dysregulation (excessive thirst and dryness in palate)

Thakarar (2017a); Dwivedi *et al.* (2016a), These might be included under different clusters of symptoms of metabolic syndromes, which also depicts disease advancement. (NCEP, 2001) has defined metabolic syndrome as a cluster of three or more of the following: abdominal obesity, elevated blood pressure, impaired fasting glucose, elevated triglyceride, and decreased high-density lipoprotein (HDL) cholesterol level. It is linked with an increased

Table 2: Probable reasons behind consideration of following organs as *Srotomoola* of *Medavaha Srotas*

1.	Kidney (Vrikka)	Adipo renal axis is established by various autocrine and endocrine secretions i.e., adpinonectines and pro-inflammatory factors released by adipocytes. It affects the normal functioning of the kidney as well as its response to injury and inflammatory factors (Zhu and Scherer, 2018). Chronic kidney diseases are said to be linked with obesity and is one of the risk factors to aggravate primary renal disease (Amann and Benz, 2013).
2.	Muscle (Mamsa)	Myokines released by contracting muscles form a cross-talk between skeletal muscle and adipose tissue. These myokines not only affect the functioning of skeletal muscle but also other tissues like Adipose tissue (Leal *et al.*, 2018; Rodríguez *et al.*, 2017).
3.	Omental fat and waist (Vapavahana and Kati)	Main sites for the deposition of visceral fat. In the case of obesity, the adipocytes present in omentum release adiponectine, which is responsible for chronic sub-inflammatory reactions in the body, leading to metabolic disorders (Bastard and Fève, 2013; Amato and Giordano, 2014). According to Ayurveda description too, the main sites of deposition of fat in obesity are buttocks, abdomen, and breast (Dwivedi *et al.*, 2016c). Considering waist (Kati) as Moola of Medavaha Srotas has clinical significance in determining the grade of obesity. Hip-waist ratio is considered one of the best determinants of obesity (Aronne, 2002).

risk of cardiovascular disease (CVD) and type 2 diabetes (Eckel *et al.*, 2005).

Pathophysiology of *Sthoulya*

Dietary and lifestyle factors causes vitiation of *Medadhatvagni*, which will leads to overproduction of *Meda Dhatu* while disturbing the nourishment of other *Dhatu*, obstruction of channels (*Srotas*) leading to *Vataprakopa* which repetitively augments *Jathragni* (digestive power) making a person more and more desirous for eating. Vitiated *Medo Dhatavagni* will also lead to the productions of *Aama*, which circulates in the whole body, affecting the metabolism as well as nourishment of other *Dhatu*. These factors produce a circumstance of over nourishment of *Meda Dhatu* and undernourishment of other *Dhatu* (Shrikanth *et al.*, 2009; Dwivedi *et al.*, 2016e).

The whole mechanism can be understood from the different manifestation of obesity as described in Figure 1.

(Nagpal *et al.*, 2018; Oussaada *et al.*, 2019; Simonds *et al.*, 2012; Romeo *et al.*, 2012; Akhmedov and Berdeaux, 2013; Patel *et al.*, 2018; Cao, 2011; Jungheim *et al.*, 2012; Mansour *et al.*, 2017; Crujeiras and Casanueva, 2015).

Parameter for assessing obesity

Different parameters like BMI, waist circumference, waist-hip ratio, total body fat, etc. are employed for the assessment of obesity. Among these waist circumferences is mostly used as a reliable method. In Ayurveda, simile of pork has been narrated to refer physique of an obese, as the deposition of fat occurs mainly on trunk region i.e., gluteal, abdomen, and breast; thus, it describes the central obesity, which is assessed through waist-hip ratio circumference. As prevention of obesity has become a global challenge now a days, different obesity models are prepared in laboratories, then altered cellular functions with the help of diverse biochemical parameters are analyzed. In Ayurveda, the overall effect of obesity on human life have been mentioned, which are outcomes of the present researches too. Table 3 summarizes eight peculiar features of obesity as described in Ayurveda with support of findings evidence-based researches and probable hypothesis (Dwivedi *et al.*, 2016e).

Effect of Sthoulaya or Meda Vriddhi on bone metabolism: Ayurveda Scholars have opined that Meda Dhatu in its normalcy state provides nourishment to Asthi Dhatu (Thakarar, 2017b) but when it gets increased it results in Asthi Kshaya (Thakarar, 2017c). Contemporary researches, too have found that secretion of adipocytes maintains the nourish-

Table 3: Depicting the evidence-based researches and probable hypothesis in support of the feature of obesity described in Ayurveda

S.N.	Features of obesity as described in Ayurveda	Possible scientific explanations
1.	Short life span	Obesity has been linked with increased mortality. It may be due to an increased incidence of chronic disorders leading premature death (Crimmins *et al.*, 2011).
2.	Early aging	Obesity has been linked with telomere dysfunction as well as mitochondrial dysfunctions i.e., decreased mitochondrial biogenesis and mitochondrial oxidative capacity, which accelerate the aging process. It also increases the oxidative stress (Mello *et al.*, 2018; Rong *et al.*, 2007; Tzanetakou *et al.*, 2012; Salvestrini *et al.*, 2019).
3.	Lack of enthusiasm	Obesity may be associated with a number of psychological illnesses (Esfahani and Pal, 2018).
4.	Profuse sweating	Increased insulating layer preventing dispersion of heat, resulting in increased core temperature and thus heat loss. Vagbhat has mentioned that due to Vishyandana of Svedavaha Sira Moola, Meda, along with Shleshma, causes profuse sweating (Acharya, 2008b).
5.	Foul smell	Bacterial growth over the excessive sweat causes foul smell (Sharma H and Chandola HM, 2011).
6.	Sexual dysfunction	Obesity has been found to affect the sexual functions negatively (Esfahani and Pal, 2018).
7.	Excessive hunger	Due to leptin resistance, in spite of hyperleptinemia, it is unable to suppress the hunger center and increase energy expenditure (Berger *et al.*, 2018).
8.	Excessive thirst	It may be due to disturbed glucose metabolism leading to hyperosmolar plasma which stimulates the thirst center

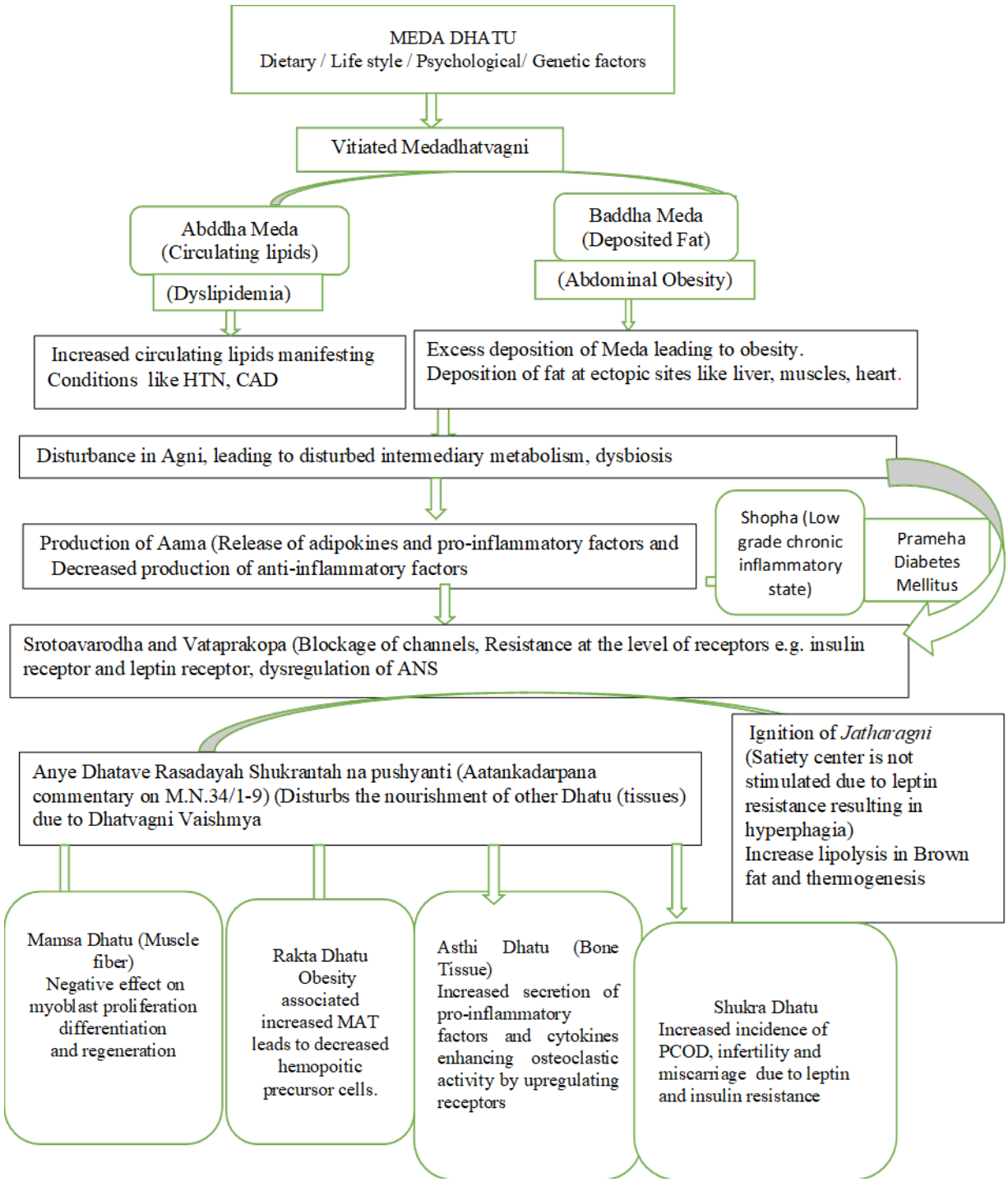

Figure 1: Pathophysiology of *Sthoulya* in Ayurveda in light of contemporary science

ment of bone tissues in normalcy, but in case of obesity, they unfavorably disturb the bone metabolism through several ways (Cao, 2011) as described in Figure 2.

Effect of decreased and increased state of *Majja Dhatu*

Increased status of *Majja Dhatu* results in heaviness in whole body including eyes (*Sarvanaganetragauravam*) (Thakarar, 2017c) while decreased status results in low fertility (*Alpashukrata*), joint pain (*Parvabheda*), bone pain (*Asthinistoda*), lightness, thinness and weakness of the bones, osteoporosis (*Asthishunyata*), affliction with *Vata* disorders continuously (Thakarar, 2017b; Dwivedi *et al.*, 2016g).

Affliction with continuous *Vata* disorders (*Pratata Vatarogani*) might be indicating dysregulated neural activities either due to osteoporotic changes resulting in imbalanced serum calcium ion concentration or loss of lipid covering of neurons resulting

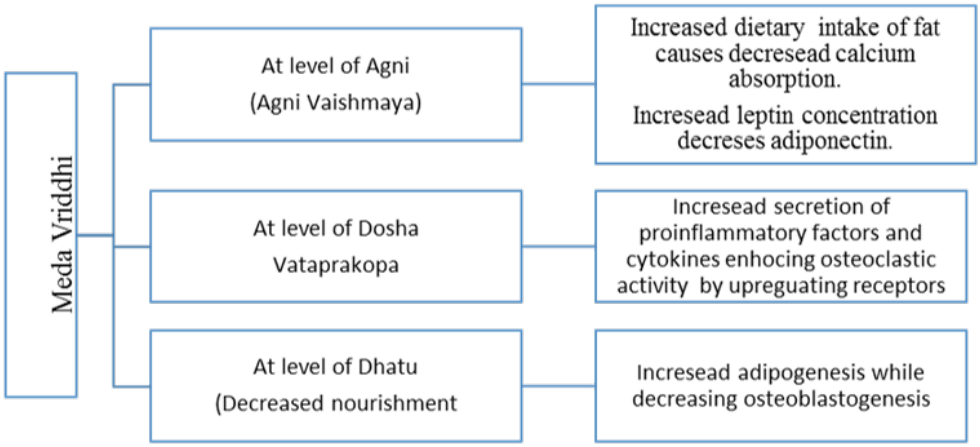

Figure 2: Effect of sthoulya or MedaVriddhi on bone metabolism

in their hyper excitability. Secondly, this description might be pertaining to injury or degeneration of *Mashtaka Majja* under which central and peripheral tracts can be taken, leading to the onset of features like a cramp, paresthesia, etc. The features in the disturbed state of *Majja Dhatu* need more exploration through evidence-based research as some of these are not in consistence with contemporary researches, for example, a study by (Li *et al.*, 2019) have shown that increased bone marrow adipocytes results in the manifestations like osteoporosis, decreased bone mineral density, but it has been described under the increased conditions of bone marrow adipocytes as per Ayurveda (Li *et al.*, 2019; Paccou *et al.*, 2019).

Secondly, a manifestation of heaviness in the whole body including eye in the increased status has been interpreted as an increased amount of circulation RBCs resulting in polycythemia and by some authors but recent researches are not in consistence with the positive correlation of increased bone marrow adipocytes and haemopoisis (Wang *et al.*, 2018). Thirdly bone marrow has been shown to induce spermaetogenesis in azoospermic hamsters (Karimaghai *et al.*, 2018), but its other role in reproductive functions is not clear.

Ayurveda scholars have mentioned that bone marrow adipocytes (*Majja Dhatu*) are responsible for immunity (*Bala*), mental attributes (*Sneha*, *Preeti*), nourishment of reproductive functions, and filler of bone (*Asthipurana*) (Thakarar, 2017b). Recent researchers have shown that bone marrow adipocytes are not only the filler of bone but having a great role in homeostatic functions of the body. However, more studies are required to evaluate the relationship of bone marrow fat with other homeostatic functions of the body, especially mental attributes.

CONCLUSIONS

The concept of functional and nutritional interdependence of *Dhatu* has been described by Ayurveda scholars. Obesity is primarily a disorder of *Meda Dhatu Dushti* that causes malnutrition of other tissues leading to multiple dysfunctions at the level of different tissues. The metabolic effect of *Meda* and *Majja Dhatu* on other tissues like a muscle (*Mamsa Dhatu*), bone (*Asthi Dhatu*), and reproductive tissue (*Shukra Dhatu*) shows their functional interdependence which is consistent with the recent research findings of contemporary science.

The researchers are trying to find out the consequences of obesity, the role of adipocytes in the development of state of metabolic syndrome with various hypotheses. This manuscript will provide to researchers an insight about the Ayurveda understanding about a clinical physiological aspect of *Meda, Majjja Dhatu, Shrotodushti*, obesity, and consequent disorders and may help in further exploration of the role of adipocytes and other tissues in the development of the metabolic syndrome and NCDs. The whole discussion elucidates that Ayurveda scholar had a profound understanding about the clinical physiology of *Meda* and *Majja Dhatu*. Pathophysiology of *Sthoulya* described by them also reflects their deep insights in the manifestation of metabolic syndromes.

Although some views, for example, the effect on bone metabolism, are not consistent with findings of contemporary researches while some likes relation of bone marrow with mental attributes, the occurrence of deep-seated eruptions on vitiated *Majja Dhatu* needs more research for their significance.

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