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# Multidimensional Approach on *Lekhaneya Dashakaya* used in *Athisthaulya* (Overweight and Obesity) - A Review

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## ABSTRACT

*Lekhaneya Dashakaya* is mentioned in *Charaka Samhita* and it has *Lekhana* (scraping /corrosive action) potentials are practiced for reduction of body weight. It consists of ten ingredients as, *Musthaka*, *Kushtha*, *Haridra*, *Daruharidra*, *Vachaa*, *Athivisha*, *Katurohini*, *Chitraka*, *Chirabilwa*. and *Haimawathi*. The present study has been focused to find out Pharmacodynamics and pharmacokinetics potentials of ingredients of *Lekhaneya Dhashakaya* and develop the hypothetical *samprapthi* of *Athisthaulya*. The secondary data was collected by authentic texts of *Charaka Samhita*, *Ayurveda Aushadha Samgrahaya* book series, *Ayurveda Pharmacopeia of India* book series, related web sites and scientific journals. Results revealed that *Tikta* (90%), *Katu* (80%) in *Rasa*, *Laghu* (100%), *Ruksha* (90%) in *Guna*, *Ushna Veery* (90%), *Katu Vipaka* (100%) and *Kaphavatahara* (50%) in *Dosha karma* were prominent pharmacodynamics potentials in *Lekhaneya Dashakaya*. *Lekhana*(100%), *Deepana*,(80%), *Kaphaghna*(70%), *Pachana*(60%), *Krimighna*(60%), *Twak doshahara*(50%), *Shotahara*(50%), *Vedanasthapana*(50%) and *Jwaraghna*(50%) were major pharmacokinetic potentials and hypolipidemic action (100%), anti-inflammatory action(90%), anti-diarrheal action(80%), hepatoprotective action(80%), anti – microbial action(80%) , hypoglycemic action (80%), anti-cancer (70%), anti-oxidant activity(70%), immunomodulatory action (70%) and anti -ulcer (50%) were the prominent pharmacological actions. While, *Ruksha*, *Teekshna* qualities cause to penetrate deeply in tissue level and scrap vitiated excessive accumulated *medas* due to *Lekhana* action, *Kaphaghna* action helps to expel excessive *kapha* and *Amapachana* and *Agnideepana* restore *Jataraghni* and *Dathvagni*. In addition, pharmacodynamic potentials and pharmacological properties of *Lekhaneya Dashakaya* have exhibited characteristic similarities. Thus, it can be concluded that *Lekhaneya Dashakaya* could be used in treating the *Athisthaulya* and it show multidimensional approach.

**Key Words** *Athisthaulya*, *Lekhaneya Dashakaya*, *Overweight*, *Obesity*

## INTRODUCTION

The physical and mental health of people some 50 years back was better than the current era. They had worked hard with physical and mental balance

in their life. But with the rapid modernization and urbanization of the world, people have become accustomed to a sedentary lifestyle with mental and physical stress, irregular diet and sleep



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pattern. As a result of that he or she is prone to series of disorders. *Athisthaulya* that correlated with overweight and obesity is one of the best commonly available examples. In Ayurveda, it has been mentioned under “*Ashtnindithitiya Pursha*” (eight undesirable conditions) by *Charaka acharya*<sup>1</sup>.

According to the modern concept, obesity and overweight are medical conditions that make it a global epidemic. Once obesity and overweight was considered as a high-income country problem, but now a days it is spreading in low- and middle-income countries also. It is characterized by excess accumulation of adipose in the body and leads to adverse metabolic effects on blood pressure, cholesterol, triglyceride, and insulin resistance, and it is a risk factor for coronary heart disease, ischemic stroke, type 2 DM, and cancer of the breast, etc.

Body mass index (BMI) is a simple indicator of weight for height commonly used to classify adult overweight and obesity. It is the weight of a person in kilograms divided by his height in square meters (kg / m<sup>2</sup>). The WHO definition is: BMI is equal to or more than 25 is called overweight and BMI equal to or more than 30, it named obesity<sup>2</sup>.

As per WHO estimate in 2019, 38.2 million of children under 5 years were overweight or obese in 2019. One in five adults and 6.6 million young children under 5 years are estimated currently overweight in South Asia<sup>3,4</sup>.

In Ayurveda, the *Apatharpaniya chikitsa* is used in the treatment principle of *Athisthaulya*. Drugs that have *Lekhana* action (scraping /corrosive

action) are practiced to reduce weight. Those drugs can scrape excessive accumulation of *Kapha* and fats by scraping action.

In *Charaka Samhitha Sutrasthana* 4<sup>th</sup> chapter “*Shatvirechanashrithiya adyaya*”, *Musthaka*, *Kushtha*, *Haridra*, *Daruhari dra*, *Vachaa*, *Athivisha*, *Katurohini*, *Chitraka*, *Ch irabilwa*. and *Haimawathi* are named under “*Krushakaraka /Lekhaneya Dashakaya*”<sup>5,6</sup>.

## AIMS AND OBJECTIVES

- To find out Pharmacodynamics and Pharmacokinetics potentials of ingredients of *Lekhaneya Dhashakaya*.
- To study Pharmacological actions of ingredients of *Lekhaneya Dhashakaya* by using secondary data.
- To develop Hypothetical *Samprapthi* of *Athisthaulya*.
- To develop mode of action of *Lekhaneya Dhashakaya* on *Athisthaulya*.

### **Athisthaulya**

*Athisthaulya* (Overweight and obesity) is a disease that arises due to overnutrition (*Santarpana*), as various scholars have mentioned in their authentic texts. which have mentioned by different scholars in their authentic texts. The word *Sthaulya* is derived from *Mula dhatu* “*Sthula*” with “*Ach*” *pratyaya*, which stands probably for bulky, big, or thick<sup>7</sup>.

In *Charaka Samhitha sutrasthana* 21<sup>st</sup> chapter, “*Ashtaunindithitiya adhyaya*”, the eight type of undesirable constitutions are mentioned. Out of



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the eight types mentioned, *Athisthulya* person has more unwanted distinctive features than others. Such as the pendulous appearance of *Sphika* (buttock), *Udara* (abdomen), and *Stana* (breast) due to excess deposition of *Meda* along with *Mansa Dhatus*<sup>8,9</sup>.

As per the Ayurveda Authentic texts, the aetiological factors of *Athisthulya* are *Athi bhojana* (excessive intake of foods), *Guru Madhura Ahara* (Heavy to digest, sweet foods), *Sheeta Snigdha Ahara* (cooling & unctuous (oily foods), *Avyayama* (lack of exercise), *Avyavaayaath* (abstinence from sexual intercourse), *Divaswapna* (day sleep), *Harsha nithyatvath* (uninterrupted cheerfulness, happy all the time), *Achintha* (lack of mental exercise, lack of thinking) and *Beeja Swabhavat* (heredity)<sup>10,11</sup>.

### **Samprapthi (Patho physiology)**<sup>4,12,13,14,15</sup>

*Samprapti* is the process of disease manifestation. (Figure 1) in *Athisthulya*, all three *doshas* are vitiated, especially *Samana* and *Vyana Vata*, *Kledaka Kapha*, and *Pachaka Pitta*.

According to *Charaka acharya*, the *Kapha* dosha increases due to excessive consumption of the causative factors. It accumulates in *Amashaya* which is a seat of *Kapha dosha*. During the metabolism, the end products of digestion become Sweet. It leads to increase *Medas*. *Medodhatavagnimandaya* (due to unavailability of getting *Poshakansha* of *Medodhatavagni nourished* through *Jataragni*) is also a reason for increasing *Medas*.

Later those vitiated *Medas* circulate all over the body and accumulate in body tissues, especially *Sphika* (buttock), *Stana* (breast), and *Udara* (abdomen).

Increased *Medas* obstruct *Srotas* (channels) which in all over the body. Other *Dhathus* do not produce properly due to reduction of nutrition. Also, the movement of *Vata* is specially confined to *Koshtha* (abdomen viscera) by reasons of obstructed *Srotas*. It is resulting in the stimulation of the digestive power and absorption of food. Because of this condition, the patient digests food quickly and becomes a voracious eater.

If the corpulent does not get food when he needs it, he can be subjected to many diseases of serious natures. *Charaka acharya* has given a good example to illustrate this circumstance. He mentioned that the *Agni* and *Vata* are the two most troublesome factors, they burn corpulent ones as the forest fire burns the forest.

### **Lekhaneya Dashakaya**

“*Lekhana*” meaning is scraping or corrosive. Many scholars have mentioned different plants which have *Lekhana* action in their authentic texts. *Charaka* has given a single group (Table 1) of ten ingredients (Figure 2) which is named as *Lekhaneya/ Krushakaraka dashakaya* in *Charaka Samhitha, Sutrasthana* 4<sup>th</sup> chapter “*Shatvirechanashrithiya Adyaya*”<sup>5</sup>.

### **Pharmacodynamics potentials of Lekhaneya Dashakaya**

Table 2 is presented the summary of Pharmacodynamic potentials of individual ingredients of *Lekhaneya Dashakaya*.



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Table 1 Ingredients of *Lekhaneya Dashakaya*

S.no	Sanskrit name	English Name	Used part	Botanical name	Family
1.	<i>Musthaka</i>	Nut Grass	Rhizome	<i>Cyperus rotundus</i> Linn.	Cyperaceae
2.	<i>Kushtha</i>	Costus	Rhizome	<i>Saussurea lappa</i> (Decne.) Sch.Bip	Asteraceae
3.	<i>Haridra</i>	Turmeric	Rhizome	<i>Curcuma longa</i> L.	Zingiberaceae
4.	<i>Daruharidra</i>	Indian Barberry	Stem	<i>Berberis aristata</i> DC.	Berberidaceae
5.	<i>Vachaa</i>	Sweet flag	Rhizome	<i>Acorus calamus</i> Linn.	Acoraceae
6.	<i>Athivisha</i>	Indian atees	Root	<i>Aconitum heterophyllum</i> Wall. Cat.	Ranunculaceae
7.	<i>Katurohini</i>	Picrorhiza	Rhizome	<i>Picrorhiza kurroa</i>	Plantaginaceae
8.	<i>Chitraka</i>	Ceylon leadwort	Root	<i>Plumbago zeylanica</i> L.	Plumbaginaceae
9.	<i>Chirabilwa</i>	Indian elm	Stems bark	<i>Holoptelia integrifolia</i> (Roxb). Planch.	Ulmaceae
10.	<i>Haimawathi</i>	Orris	Rhizome	<i>Iris germanica</i> Linn.	Iridaceae

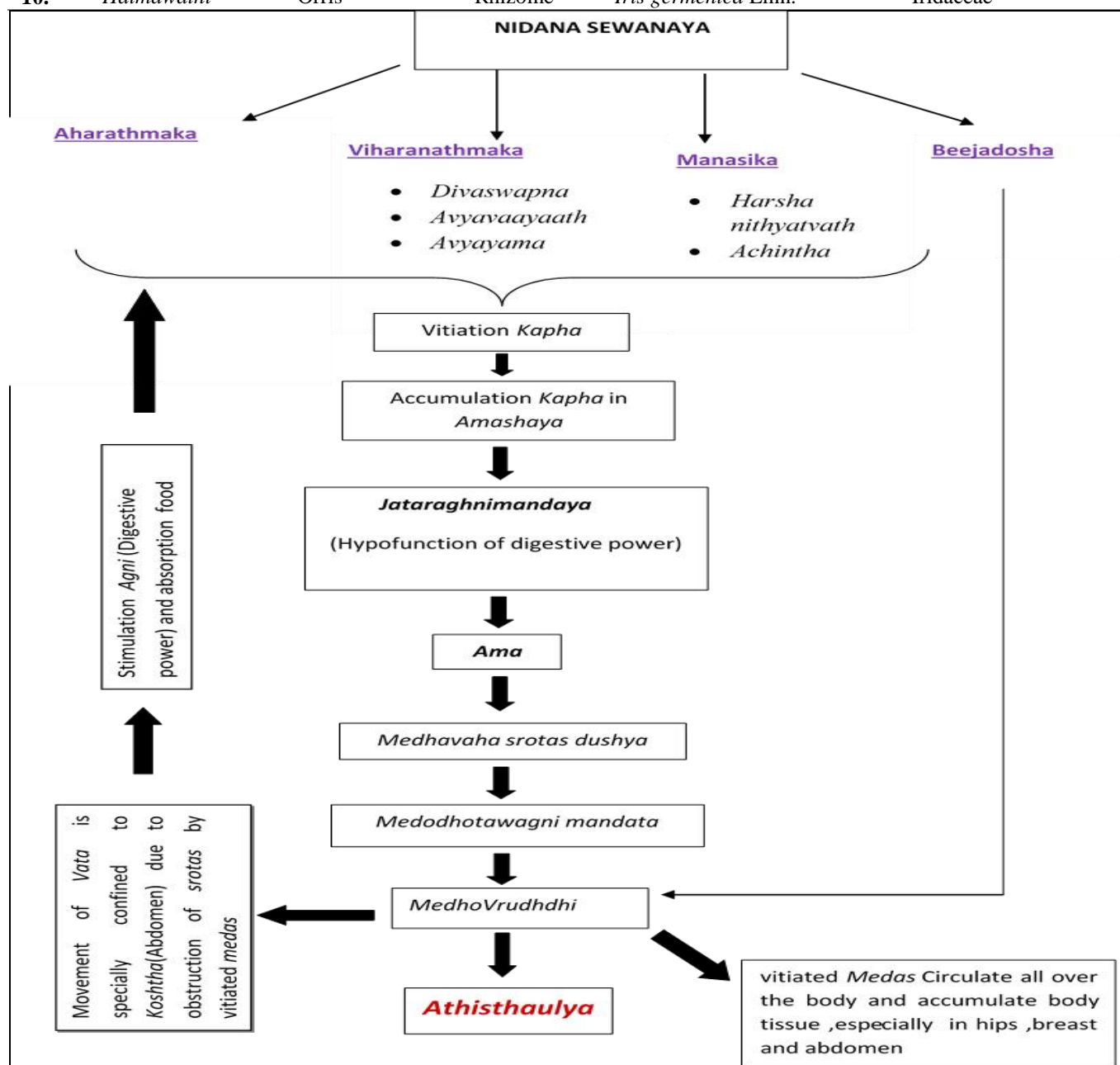


Figure 1 Hypothetical Samprapthi of Athisthaulya (Patho physiology)



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Table 2 Pharmacodynamics potentials of *Lekhaneya Dashakaya*

s.no	Sanskrit name	Rasa	Guna	Virya	vipaka	Prabhava	Dosha karma
1.	<b>Musthaka</b>	Katu, Tikta, Kashaya	Laghu, Ruksha	Sheeta	Katu	-	Kapha pitta shamaka
2.	<b>Kushtha</b>	Tikta, Katu, Madura	Laghu, Ruksha, Teekshna	Ushna	Katu	-	Kapha vata shamaka
3.	<b>Haridra</b>	Tikta, Katu	Laghu, Ruksha	Ushna	Katu	-	Tridosha shamaka
4.	<b>Daruharidra</b>	Tikta, Kashaya	Laghu, Ruksha	Ushna	Katu	-	Kapha pitta shamaka
5.	<b>Vachaa</b>	Katu, Tikta	Laghu, Ruksha	Ushna	Katu	Medhya	Kapha vata shamaka
6.	<b>Athivisha</b>	Katu, Tikta	Laghu, Ruksha	Ushna	Katu	-	Tridosha shamaka
7.	<b>Katurohini</b>	Tikta	Laghu, Ruksha	Sheeta	Katu	-	Kapha pitta shamaka
8.	<b>Chitraka</b>	Katu	Laghu, Ruksha, Teekshna	Ushna	Katu	-	Kapha vata shamaka
9.	<b>Chirabilwa</b>	Katu, Tikta, Kashaya	Laghu, Tekshna	Ushna	Katu	-	Kapha vata Shamaka
10.	<b>Haimawathi</b>	Katu, Tikta	Laghu, Ruksha	Ushna	Katu	-	Kapha vata shamaka

Table 3 Pharmacokinetic potentials of *Lekhaneya Dashakaya*

s.no	Name of the plant	Pharmacokinetic properties
1.	<b>Musthaka</b>	Lekhana, Sthanya Janaka, Sthanya shodaka, Medhya, Kaphaghna, Rakthaprasada, Deepana, Pachana, Grahi, Krimighna, Trushna Nigrahana, Garbhasha sankochaka, Swedajanaka, Jwaraghna, Vishaghn, Thvag doshahara
2.	<b>Kushta</b>	Lekhana, kasahara, shvaasahara, Hikkahara, Shukrala, Tvag doshahara, Jwarahara, Trushna nigrahana, Kandughna
3.	<b>Haridra</b>	Lekhana, Vedanasthapana, Kaphaghna, Rakta prasada, Rakta sthambana, deepana, virechaniya, Krimighna, Mutra sangrahaniya, Sthanya janaka, Garbhasha shodhaka, Tvag doshahara
4.	<b>Daruharidra</b>	Lekhana, Shothahara, Chakshushya, Vedanasthapana, Kaphaghna, Rakta Sthambha, Yakruith Uttejaka, Grahi, Trushna nigrahana, Varnya, Svedajanaka, Jwaraghna, Tvag doshahara
5.	<b>Vacha</b>	Lekhaniya, Medhya, Unmadahara, Rakshoghna, Bhutaghna, Kantya, Vedanasthapana, Pachana, Deepana, Vamaka, Vatanulomana, Virechaniya Garbha sankochaka, Vakpradara, Janthughna
6.	<b>Athivisha</b>	Lekhana, Vishaghna, Kaphaghna, Rakta stambhana, Shothahara, Deepana, Pachana, Grahi, Krimighna, Sthanya shodaka, Jwaraghna, Vajikarana

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7.	<b>Katurohini</b>	Lekhana, Kaphaghna, Hrudyā, ,Shotahara, Bhedhaniya, Deepana, Yakruṭh Uttejaka, Virechaka, Krimighna, Vata anulomana, Sthanya shodaka
8.	<b>Chitraka</b>	Lekhana, Vishphotajanaka, ,Kaphaghna, Shotahara, Deepana ,Pachana, Grahi, Krimighna, Garbhasha sankochaka, Jwaraghna,Swedajanaka ,Vajikarana.
9.	<b>Chirabilva</b>	Lekhana, Janthughna, Kandughna, Shothahara, Vedanasthapana, Kaphaghna, Kasahara, Raktaprasadana, Deepana, Pachana, Bedhanna, Krimighna, Yakruṭh Uttejaka, Mutra sangrahana, Garbhasha shodaka.
10.	<b>Haimavathi</b>	Lekhaniya, Medhya, Rakshoghna, Bhutaghna, Kantya, Vedanasthapana, Pachana, Deepana,Vamaka, Vatanulomana, Unmadahara, Virechaniya ,Garbha sankochaka, Vakpradara, Janthughna



Musthaka (*Cyperus rotundus* Linn.) Rhizomes



Kushtha (*Saussurea lappa* (Decne.) Sch.Bip) Rhizomes



Haridra (*Curcuma longa* L) Rhizomes



Daruharidra (*Berberis aristata* DC.) Stems



Vacha (*Acorus calamus* Linn.) Rhizomes



Athivisha (*Aconitum heterophyllum* Wall. Cat.) Roots



Katurohini (*Picrorhiza kurroa*) Rhizomes



Chitraka (*Plumbago zeylanica* L) Roots



Chirabilwa (*Holoptelia integrifolia* (Roxb). Planch., Stem bark



Haimawathi (*Iris germanica* Linn.) Rhizomes

Figure 2 Ingredients of Lekhaneya Dashakaya



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**Table 4** Pharmacological potentials of *Lekhaneya Dashakaya*

s.no	Name of the plant	Pharmacological potentials
1.	<b>Musthaka</b>	Anti-oxidant, Anti-inflammatory, Wound healing activity, Anti-diarrheal activity, Anti-ulcer, Hepatoprotective activity, Hypoglycemic activity, Anti-microbial activity, Hypolipidemic activity, Analgesic Activity, Anti-convulsant, Anti-allergic, Anti-arthritic
2.	<b>Kushta</b>	Anti-inflammatory, Anti-cancer, Anti-ulcer, Hepatoprotective, Hypolipidemic activity, Anti-diarrheal, Anti-epileptic action, Immunomodulator activity, Hypoglycaemic activity, Anti-microbial activity, CNS depressant, Anti-parasitic activity,
3.	<b>Haridra</b>	Hypoglycemic activity, Anti-inflammatory, Anti-diarrheal, Hepatoprotective, Anti-asthmatic, Anti-cancer, Anti-oxidant, Hypolipidemic activity, Chemoprotective, activity, Anti-dermatophytic activity
4.	<b>Daruharidra</b>	Hepatoprotective, Anti-oxidant, Hypoglycemic activity, Anti-cancer, Anti-microbial activity, Anti-inflammatory, Anti-diarrheal activity, Anti-dysenteric activity, Anti-depressant, Immunomodulatory activity, Hypolipidemic activity.
5.	<b>Vacha</b>	Anti-convulsion, Anti-inflammatory, Anti-microbial, Memory enhancing effect, Anti-diarrheal, CNS depressant activity, Hypoglycemic activity, Anti-cancer, Anti-oxidant, Hypolipidemic activity, Diuretic, Anti-ulcer, Immunomodulatory activity
6.	<b>Athivisha</b>	Anti-inflammatory, Anti-convulsant, Hypolipidemic action, Anti-flatulents, Anti-diarrheal, Anti-oxidant activity, Anti-microbial activity, Diuretic action, Hepatoprotective action, Anti-phlegmatic activity, Immunomodulatory action
7.	<b>Katurohini</b>	Hepatoprotective, Anti-inflammatory action, Anti-cancer activity, Immunomodulatory activity, Anti-arthritic activities, Hypolipidemic action, Hypoglycemic activity, Anti-asthmatic action
8.	<b>Chitraka</b>	Hepatoprotective activity, Immunomodulatory action, Hypolipidemic action, Cardioprotective action, Anti-cancer activity, Anti-arthritic activity, Anti-diarrheal activity, Anti-microbial activity, Anti-fertility activity, Hypoglycemic activity, Anti-convulsion action, Wound healing action, anti-allergics
9.	<b>Chirabilva</b>	Anti-inflammatory, Anti-oxidant, Anti-microbial action, Hypoglycemic activity, Anti-diarrheal action, Hepatoprotective activity, Hypolipidemic action, Anti-cancer activity, Anti-ulcer, CNS depressant, Anti-emetic action, Wound healing action, Analgesic activity
10.	<b>Haimavathi</b>	Anti-oxidant, Anti-inflammatory, Hypolipidemic action, Immunomodulatory activity, Anti-microbial activity, Anti-malarial action, Diuretic action, Anti-cancer.

### Pharmacokinetic and Pharmacological potentials of *Lekhaneya Dashakaya*.

The compilation of Pharmacokinetic and Pharmacological potentials of ten ingredient are respectively presented in Table 3 and 4.

### MATERIALS AND METHODOLOGY

The Ayurveda authentic texts with their respective commentaries and peer reviewed index journals have been reviewed as materials for the data

collection. Gathering data were analysed based on main objectives.

### OBSERVATIONS AND RESULTS

All the results of the finding are summarized in the following figures

As a compilation of the ten ingredients of *Lekhaneya Dashakaya* Figure 3 has been presented the distribution of Pharmacodynamic potentials of *Lekhaneya Dashakaya*. Finally, *Rasadi Panchaka* are analyzed as,



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Rasa - Tikta (90%), Katu (80%), Kashaya (30%),  
Madhura (10%)

Guna - Laghu (100%), Ruksha (90%), Teekshna  
(30%)

Veerya - Ushna (80%), Sheeta (20%)

Vipaka – Katu (100%)

Dosha Karma - Kapha vata shamaka (50%),  
Kapha pitta shamaka (30%), Tridoshaha shamaka  
(20%)

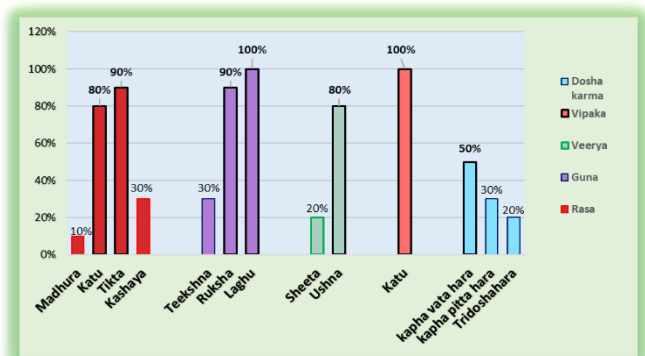


Figure 3: Distribution of Pharmacodynamic potentials of Lekhaneya Dashakaya

As shown in Figure 4, all ingredients of *Lekhaneya Dashakaya* have potentiated with *Lekhana Guna* (100%) and other than potent with Pharmacokinetic properties of *Deepana* (80%), *Pachana* (60%), *Krimighna* (60%), *Thvakhoshahara* (50%), *Shothahara* (50%), *Vedanasthapana* (50%), and *Jvaraghna* (50%) properties.

Based on the clinical evidence of *Lekhaneya Dashakaya*, the abundance of Pharmacological potentials were analyzed (Figure 5). As per the evidences *Lekhaneya Dashakaya* has proved Hypo lipidemic property (100%), Anti-oxidant activity (70%), Anti-inflammatory action (90%), Anti-diarrheal action (80%), Hepatoprotective action (80%), Hypoglycemic action (80%), Anti-

microbial action (80%), Anti-cancer (70%), Immunomodulatory action (70%) and Anti-Ulcer (50%) properties.

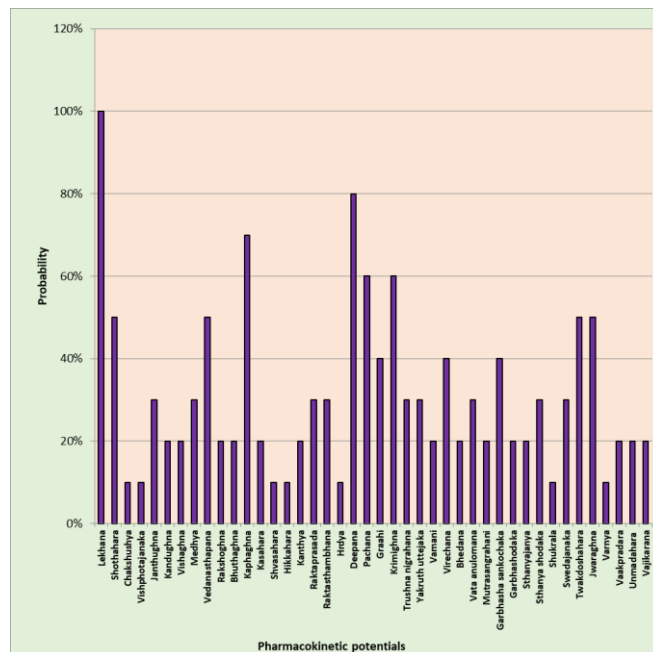


Figure 4 Distribution pharmacokinetic potentials of Lekhaneya Dashakaya

DISCUSSION

Athisthauha is mainly due to Agnimandata (hypofunction of digestive power) that produces Ama in Koshta and tissue level by the result of vitiated Kapha. According to Ayurveda perception Katu, Tikta, Kashaya rasa pacifies Kapha dosha,

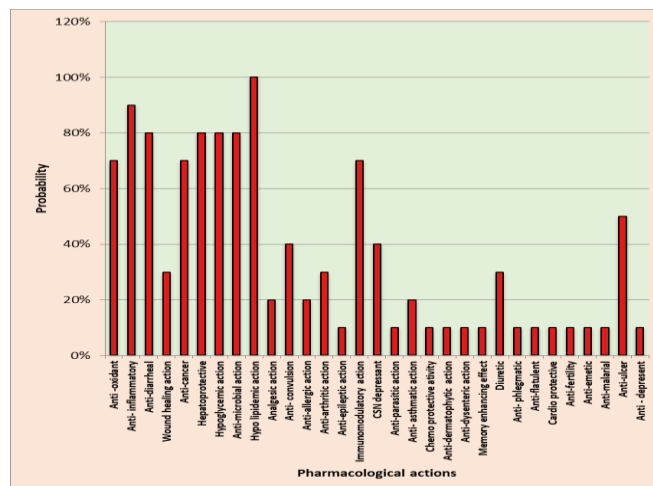


Figure 5: Distribution of Pharmacological actions of Lekhaneya Dashakaya





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Laghu, Ruksha, Teekshna in Guna, and Ushna Veerya responsible for Lekhaniya action, support to penetrate Srotas (body channels) and Dhatu (tissue) level scraping the Ama (undigested toxic) and vitiated Medas and expel out from the body. It supports to clear blockage and has facilitated Amapachnaya and Agnideepanaya in Koshta and Dhatu level. Those actions restore Jataraghi and Dhatavaghi, expel excessive Kapha and re-establish the body with its normal functions. In Athisthaulya, all three Doshas are involved and vitiated, especially both Kapha and Vata doshas. Charaka Acharya has mentioned in the Chikitsasutra (treatment principles) of Athisthaulya that diet and drinks which alleviate Vata and Kapha should be consumed. Majority of Dosha karma that consists of Lekhaneya Dashakaya is Kapha Vata Shamaka (50%). Others are Kapha pitta Shamaka (30%), and Tridosha Shamaka (20%). Therefore, those drugs help to pacify tridosha, especially Kapha and Vata and re-establish the normal function of tissues and organs.

Among pharmacokinetics potentials, Lekhana action indicated in all plants (100%). Due to the Kapahgna (70%) action help to pacify Kapha dosha. Other mostly identified pharmacokinetics potentials of Lekhaneya Dashakaya were Deepana (80%), Pachana (60%), Krimighna(60%), Thvakdoshahara(50%), Shothahara(50%), Vedanasthapanana(50%) and Jvaraghi (50%).

Among pharmacological actions, all ingredients can identify hypolipidemic actions (100%). It is the ability to reduce high lipid level in blood

serum. Hypoglycemic action (80%) helps to reduce high blood sugar and both actions are cause to reduce fat deposition. Anti-oxidant activity (70%), anti-inflammatory action (90%), anti-diarrheal action (80%), hepatoprotective action (80%), hypoglycemic action (80%), hypolipidemic actions (100%), anti-microbial action (80%) anti -cancer (70%), immunomodulatory action (70%) and anti- Ulcer (50%) actions are proved pharmacological potentials in Lekhaneya *Dashakaya*. Furthermore, its specialty is the manifestation of the characteristic similarity between the pharmacokinetic and pharmacological properties.

## CONCLUSION

In *Lekhaneya Dashakaya* is a combination of ten ingredients and it reveals the excellence of which is that all ingredients have *Lekhana* and *Kaphaghi* properties. It gives support to *samprapthi vighatanaya*. Thus, it is applicable for treating *Medoroga* such as *Athisthaulya* and diseases which manifest due to increased *Kapha dosa* and also it can be used in *Agnimandata*. Besides, ingredients of *Lekhaneya Dashakaya* promote *Ama pachanaya*, *Agni deepana*, restore *Jataraghi* and *Dhatvaghi* in *Koshta* and *Dhatu* level. Pharmacological actions show that *Lekhaneya Dshakaya* can indicate management in hyperlipidemia and hyperglycemia. Besides, *Lekhaneya Dashakaya* can also be used for most of the current health issues based on its significant pharmacological actions as anti-oxidant, anti-



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inflammatory, anti-diarrheal, anti-cancer, hepatoprotective, anti-microbial, anti-ulcer, hypoglycemic, hypolipidemic and immunomodulatory actions. The Pharmacodynamic potentials and pharmacological properties of *Lekhaneya Dashakaya* have exhibited characteristic similarities and the result of this review could be useful for future research.



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