Pharmacogn. Res., 2024; 16(1):72-81.
https://www.phcogres.com

Original Article

Comparative Therapeutic Evaluation of Insuwin and Insuwin Forte Polyherbal Formulation on Streptozotocin and Nicotinamide Induced Diabetic Rats

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ABSTRACT

Background: The clinical exploration and regulatory approval of herbal formulations requires authenticated preclinical studies. **Objectives:** This study objective is to assess the therapeutic effectiveness of Insuwin and Insuwin forte polyherbal tablet formulation (Manufactured by SKM Siddha and Ayurveda Company (India) Pvt. Ltd.,) in diabetic rats. **Materials and Methods:** Hypoglycemic effect of Insuwin and Insuwin forte tablets were evaluated in normal fasted, oral glucose challenged, and diabetes-induced rats. Diabetes mellitus was induced by intraperitoneal administration of streptozotocin (45 mg/kg and nicotinamide 110 mg/kg). Glimepiride (5 mg/kg orally) was used as standard, Insuwin 194 mg/kg, and Insuwin forte 188 mg/kg test doses were administered for 21 days. After the treatment period, fasting blood glucose levels, serum HbA_{1c} levels, lipid profiles, and biochemical parameters were assessed using standard laboratory techniques. The pancreas histopathology was also carried out. **Results:** The treatment of Insuwin and Insuwin forte significantly reduces the fasting blood sugar levels in both the normal control and diabetic rats, also Insuwin forte treatment significantly improves the glucose uptake in OGTT, and the abnormal lipid profile like increased total cholesterol, LDL, TG, and decreased HDL in diabetic rats were significantly normalized. Also decreased the elevated serum HbA_{1c}, AST, ALT, and creatinine, additionally Insuwin forte decrease the elevated serum urea in diabetic rats. In histopathology, all the treatments showed better improvement in beta cell regeneration. **Conclusion:** Based on our results Insuwin and Insuwin forte was effective in diabetes mellitus. In comparison Insuwin forte showed a superior hypoglycemic effect, improve glucose uptake by induced insulin releases, regularize lipid abnormality, better liver and kidney protection, and improve the islet of Langerhans in beta cells. Hence Insuwin forte might be an effective alternative oral hypoglycemic agent for diabetes mellitus.

Keywords: Diabetes mellitus, Insuwin, Insuwin forte, Oral hypoglycemic agent, Polyherbal tablets.

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Received: 21-05-2023;
Revised: 11-07-2023;
Accepted: 09-09-2023.

INTRODUCTION

One of the most common metabolic illnesses, Diabetes Mellitus (DM), is characterized by excessive blood sugar levels brought on by decreased insulin secretion and/or sensitivity. Hyperglycemia leads to damage of tissues and impairment of organs in chronic conditions.[1] Worldwide, about 4% of the population is affected DM, and in India the number is proposed to increase by 54 million by 2025.[2] The current pharmacotherapy for DM includes the administration of insulin and/or intake of many synthetic oral hypoglycemic agents like thiazolidine, sulfonylureas, biguanides, Sodium-Glucose Transporter-2 (SGLT-2) inhibitors, and α-glucosidase inhibitors, etc. The uses of these synthetic drugs are reported to be associated with serious adverse effects such as hypoglycemia, hematological effects, weight gain, abdomen enlargement, GI discomfort, disturbed liver and kidney functions, and hypoglycemic coma.[3-5] Hence medicinal practitioners and patients are looking for the safest and most potent alternative medication for diabetes mellitus. Ayurveda is the Indian system of alternative medicine reported to be less toxic and more efficacious in diabetes treatment.[6] According to the World Health Organization (WHO), traditional plant-based therapies are safe, efficient, and have few to no side effects when used orally to treat diabetes mellitus.[7]

Insuwin is the herbo-metallic tablet preparation indicated for type-II DM treatment prepared based on the Siddha formulary of

DOI: 10.5530/pres.16.1.10

India part-1. Each tablet of Insuwin contains *Tinospora cordifolia*. St. 8%, *Terminalia chebula*. Fr. R. 8%, *Emblica officinalis*. Fr. R. 8%, *Murraya koenigii*. Lf. 8%, *Aegle marmelos*. St. 8%, *Curcuma longa*. Rz. 8%, *Trigonella foenum-graecum*. Sd. 4%, *Coccinia indica*. Lf. 4%, *Berberis aristata*. St.4%, Kungiliya parpam (P.M) 4%, Kantha chendooram (P.M) 4%, Meganarayana chendooram (P.M) 4%, and Silasathu parpam (P.M) 10%, are the major ingredients. Insuwin forte is the polyherbal extract-based tablet preparation indicated for type-II diabetes management; it increases insulin secretion, has alpha-glucosidase inhibitory properties, and regularizes the enzymes involved in carbohydrate metabolism. Insuwin forte is prepared based on the Ayurvedic Formulary of India (AFI) Part-1 and Ayurvedic Pharmacopoeia of India (API) Part-1.

This investigation sought to determine the efficacy of the Insuwin and Insuwin forte polyherbal tablets preparation on the streptozotocin and nicotinamide-induced type-II diabetic rats. This study results can support the clinical implementation of Insuwin and Insuwin forte as an effective alternative for the management of type -II diabetes mellitus.

MATERIALS AND METHODS

Drug profile

Insuwin is the Siddha proprietary medicine of Herbo-metallic polyherbal tablet preparation and Insuwin forte is the Ayurvedic proprietary medicine of polyherbal extract-based polyherbal tablet preparation of SKM Siddha and Ayurveda Company (India) Pvt. Ltd, Tamil Nadu.

Dose selection

The recommended adult clinical dose of Insuwin is 2 tablets twice daily (Strength of 468 mg active ingredients per tablet). Insuwin forte is 2 tablets twice daily (Strength of 454 mg active ingredients per tablet). Hence based on the body surface area the human clinical dose was converted into a rat dose of Insuwin 194 mg/kg and Insuwin forte 188 mg/kg.[8]

Experimental animals

The mature albino wistar rats (200-250 g) from a healthy colony were housed in polypropylene cages and kept in controlled environments with a 12/12 light/dark rhythm, controlled ambient temperature (23 ± 2°C), and relative humidity of 60% ±10%. The animals were provided with a pellet diet and water *ad libitum*. Three individual-sex rats were housed in each cage along with a husk for bedding. Experimental procedures were performed according to the guidelines of the Committee for Control and Supervision of Experiments on Animals (CCSEA).

Hypoglycemic Study in normal fasted rats

The impact of polyherbal formulations (Sample) on normal glycemia was studied in normal fasted rats. Twenty-four rats were split up into four groups of six each. Group I rats were treated with 0.5% Carboxymethylcellulose (CMC), whereas groups II-IV were treated with glimepiride (5 mg/kg), Insuwin (194 mg/kg), and Insuwin forte (188 mg/kg) respectively. Baseline and at 1, 2, 4, and 8 hr after drug treatments fasting blood glucose level was estimated by tail vein blood samplings.[9]

Oral Glucose Tolerance Test in normal fasted rats

The 18 hr fasted normal glycemic rats underwent the Oral Glucose Tolerance Test (OGTT). The rats were split up into four groups of six animals each. Group I rat were treated with 0.5% CMC, whereas groups II-IV were treated with glimepiride (5 mg/kg), Insuwin (194 mg/kg), and Insuwin forte (188 mg/kg) respectively. After drug treatments oral glucose (2 gm/kg) was administered to all the groups. Following the oral glucose challenge, blood samples were withdrawn from the tail vein 30 min, 60 min, and 120 min later. Blood glucose levels were measured with a single-touch glucometer (ACCU-CHECK Active, Roche Diabetes Care GmbH, Germany).[9]

Anti-diabetic activity evaluation in non-insulin-dependent diabetic rats

Induction of type 2 diabetes mellitus

A single intraperitoneal dose of nicotinamide (110 mg/kg; prepared in normal saline), followed by a 15 min infusion of streptozotocin (45 mg/kg; prepared in 0.1 M citrate buffer, pH 4.5), was used to induce Non-Insulin-Dependent Diabetic Mellitus (NIDDM) in overnight fasted rats. 6 hr after administration of STZ and nicotinamide, a 10% glucose solution was provided through drinking water to prevent the occurrence of hypoglycemic shock. Induction of diabetes was confirmed by measuring blood glucose levels after 72 hr. The rats with elevated Fasting Blood Glucose level (FBG) ≥ 250 mg/dL were considered diabetic rats and included in further studies.[10]

Experimental design

The rats with FBG levels ≥ 250 mg/dL were included and randomly assigned into five groups of six each.

Group-I: Normal control (received 0.5% CMC *p. o.* for 21 days).

Group-II: Diabetic control received for a single dose of nicotinamide (110 mg/kg *i. p.*)+STZ (45 mg/kg *i. p.*).

Group-III: Diabetic animals received Glimepiride (5 mg/kg of b. w. *p. o.*) for 21days.

Group-IV: Diabetic animals received Insuwin (194 mg/kg of b. w. *p. o.*) for 21 days.

Group-V: Diabetic animals received Insuwin forte (188 mg/kg of b. w. *p. o.*) for 21 days.

Measurement of body weight changes, feed, and water consumption

Changes in body weight were weighed periodically (Once a week), and the feed and water consumption per treatment was measured daily and computed as weekly changes.

Estimation of fasting blood glucose level

Baseline and 7th, 14th, and 22nd days after induction of diabetes mellitus the FBG levels were measured by using a single touch glucometer (ACCU-CHECK, Active, Roche Diabetes Care GmbH, Germany) through tail vein blood samplings.

Estimation of HbA_{1c} level

The value of glycosylated hemoglobin (HbA_{1c}) of the treatment was determined after 21 days of treatment from a whole blood sample using commercially available test kits (NycoCard HbA_{1c}, Abbott Diagnostics Technologies AS, Norway).

Serum biochemical parameter estimation

On the 22nd day of the study, blood samples were taken from the overnight fasting animals under light anesthesia by puncture of the retro-orbital plexus. Serum was separated from the collected blood samples and centrifuged at 3500 rpm for 10 min to determine biochemical parameters such as serum Low-Density Lipoprotein (LDL), High-Density Lipoprotein (HDL), Triglycerides (TG), and Total Cholesterol (TC), Alanine Aminotransferases (ALT), Aspartate Transaminases (AST), serum urea and creatinine using established kit procedures and the automated VITROS 5.0/ FS analyzer.

Determination of absolute organs weight

The animals were sacrificed on day 22 by an overdose of anesthesia, and the liver, kidney, and spleen organs were isolated and weighed with standard scales.

Histopathological analysis

After the experimental period, the pancreas was isolated from the sacrificed animal of each group for histological analysis. The isolated pancreases were sectioned at 2 mm thickness using a microtome, fixed in 10% formalin, and stained with eosin and hematoxylin. The photomicroscopic images were taken at 45x and observed.[11]

Statistical analysis

The results were provided as the mean and Standard Error of the Mean (SEM) of six sample replicates. Using SPSS V.17, raw data were analyzed using one-way Analysis of Variance (ANOVA) followed by post hoc Dunnett's multiple comparison tests. $p<0.05$ was defined as statistically significant.

Animal study ethics statement

The Institutional Animal Ethics Committee (IAEC) of Swamy Vivekanandha College of Pharmacy, Tamil Nadu, India, reviewed and approved the protocol of this study. The care and use of the study animals were following CCSEA guidelines (889/PO/Re/S/05/CCSEA).

RESULTS

Effect of Insuwin and Insuwin forte on blood glucose levels in normal fasted rats

Table 1 represents the effect of Insuwin and Insuwin forte on fasting blood glucose levels in normal rats. When compared to the normal control, all treatments exhibited a significant reduction in blood glucose levels as early as the 4th hr after drug treatments. The treatment of glimepiride showed moderate significance ($p<0.01$) at the 4th hr and the most significant decrease in FBG level at the 8th hr after treatment in normal fasted rats. The treatment of Insuwin and Insuwin forte showed similar hypoglycemic effects on normal fasted rats from mild significant ($p<0.05$) hypoglycemia at the 4th hr and moderate significant ($p<0.01$) hypoglycemia at the 8th hr of post-treatment.

Effect of Insuwin and Insuwin forte on blood glucose levels in glucose-loaded hyperglycemic rats

The results in Table 2 show that Fasting Blood Glucose (FBG) levels were elevated in all groups after 30 min of glucose loading, then there was a significant ($p< 0.05$) decrease in FBG levels in groups II and IV compared to group I. The onset of an antihyperglycemic action was observed from 60 min of post-drug treatment and a study state in the action continued up to 120 min. It indicates the enhanced glucose utilization property of glimepiride and Insuwin forte treatments in glucose-challenged rats. Insuwin treatment does not have a significant anti-hyperglycemic effect on glucose-loaded rats than the normal control.

Effect of Insuwin and Insuwin forte on body weight changes in diabetic rats

The effects of Insuwin and Insuwin forte on body weight changes in diabetic rats are shown in Table 3. When compared to normal control rats, diabetic control rats showed a moderately significant ($p<0.01$) decrease in body weight gain. In addition, when glimepiride and Insuwin treatments were compared to normal rats, there was a mildly significant ($p<0.05$) decrease in body weight increase. Hence there is no significant weight changes were observed in the Insuwin forte treatment.

Effect of Insuwin and Insuwin forte on feed and water intake in diabetic rats

The results in Tables 4 and 5 showed the effect of Insuwin and Insuwin forte on feed and water intake changes in diabetic rats. When compared to normal control rats, diabetic rats consumed

Table 1: Effect of Insuwin and Insuwin forte on blood glucose levels in normal fasted rats.

Treatment	Fasting blood glucose level (mg/dL)				
	Baseline (0 hr)	1 hr	2 hr	4 hr	8 hr
Group-I (Normal Control)	86.33 ± 9.67	89.67 ± 7.84	85.67 ± 13.05	93.00 ± 6.56	95.33 ± 6.96
Group-II (Glimepiride)	83.00 ± 9.97	79.33 ± 9.26	74.33 ± 8.57	61.67 ± 7.80**	57.67 ± 6.06***
Group-III (Insuwin)	80.00 ± 4.16	85.33 ± 4.81	77.33 ± 2.91	74.33 ± 2.72*	71.33 ± 2.33**
Group-IV (Insuwin forte)	82.67 ± 6.77	81.00 ± 7.94	72.33 ± 3.18	68.67 ± 3.53*	67.00 ± 2.52**

Values are expressed as mean ± SEM, n=6. Symbols represent statistical significance: *** p<0.001, ** - p <0.01, *- p<0.05. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's test multiple comparisons. The comparison was made between Group-I Vs II, III, and IV.

Table 2: Effect of Insuwin and Insuwin forte on blood glucose levels in glucose-loaded hyperglycemic (OGTT) rats.

Treatment	Fasting blood glucose level (mg/dL)			
	0 min	30 min	60 min	120 min
Group-I (Normal Control)	86.67 ± 8.05	131.67 ± 7.80	118.67 ± 7.13	100.00 ± 9.87
Group-II (Glimepiride)	84.00 ± 9.85	108.67 ± 6.01	88.33 ± 7.31*	75.67 ± 5.37*
Group-III (Insuwin)	78.33 ± 4.10	115.33 ± 5.93	100.00 ± 4.58	85.00 ± 7.23
Group-IV (Insuwin forte)	80.67 ± 7.22	111.33 ± 8.76	90.00 ± 9.21*	76.00 ± 5.51*

Values are expressed as mean ± SEM, n=6. Symbols represent statistical significance: *** p<0.001, ** - p <0.01, *- p<0.05. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's multiple comparison tests. The comparison was made between Group-I Vs II, III, and IV.

Table 3: Effect of Insuwin and Insuwin forte on body weight changes in diabetic rats.

Treatment	Bodyweight (g)				Changes in Bodyweight
	Initial body weight	First week	Second week	Third week	
Group-I (Normal Control)	237.5±16.52	250±14.72	256.3±14.77	261.3±12.81	(+)23.8±7.18
Group-II (Diabetic Control)	237.5±23.94	207.5±21.36	203.8±23.83	197.5±23.23*	(-)40.0±20.62**
Group-III (Glimepiride)	233.8±17.00	228.8±19.83	213.8±23.84	213.8±20.14	(-)20.0±18.23*
Group-IV (Insuwin)	240.0±16.83	225.0±16.58	210.0±15.41	211.3±15.05	(-)28.8±4.7*
Group-V (Insuwin forte)	230.0±10.80	215.0±9.57	211.3±12.48	223.8±11.62	(-)6.3±5.15

Values are expressed as mean ± SEM, n=6. Symbols represent statistical significance: *** p<0.001, ** - p <0.01, *- p<0.05. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's multiple comparison test. The comparison was made between Group-I Vs II, III, and IV.

Table 4: Effect of Insuwin and Insuwin forte on feed intake in diabetic rats.

Treatment	Feed intake (g)		
	First week	Second week	Third week
Group-I (Normal Control)	58.57 ± 5.95	47.14 ± 4.06	52.14 ± 10.74
Group-II (Diabetic Control)	61.43 ± 5.53	72.86 ± 4.86[c]	73.57 ± 3.89[a]
Group-III (Glimepiride)	50.00 ± 4.76	51.43 ± 5.00[f]	49.29 ± 4.81[d]
Group-IV (Insuwin)	51.43 ± 5.53	43.57 ± 3.89 [f]	47.85 ± 6.97 [d]
Group-V (Insuwin forte)	48.57 ± 5.53	50.71 ± 2.97 [f]	50.00 ± 5.35 [d]

Values are expressed as mean ± SEM, *n*=6. Symbols represent statistical significance [a]$p<0.05$; [b]$p<0.01$; [c]$p<0.001$ Vs Group I. [d]$p<0.05$; [e]$p<0.01$; [f]$p<0.001$ Vs Group II. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's multiple comparison test.

Table 5: Effect of Insuwin and Insuwin forte on water intake in diabetic rats.

Treatment	Water intake (mL)		
	First week	Second week	Third week
Group-I (Normal Control)	67.00 ± 5.13	71.57 ± 7.74	63.14 ± 9.33
Group-II (Diabetic Control)	126.57 ± 7.85[c]	150.57 ± 15.49[c]	193.43 ±13.92[c]
Group-III (Glimepiride)	96.71 ± 5.34[be]	96.71 ± 6.56[e]	92.71 ± 5.17[af]
Group-IV (Insuwin)	98.71 ± 4.83[be]	92.71 ± 5.91[e]	105.43 ± 11.69[bf]
Group-V (Insuwin forte)	91.86 ± 9.13[ae]	89.14 ± 3.41[e]	90.57 ± 5.18[f]

Values are expressed as mean ± SEM, n=6. Symbols represent statistical significance [a]$p<0.05$; [b]$p<0.01$; [c]$p<0.001$ Vs Group I. [d]$p<0.05$; [e]$p<0.01$; [f]$p<0.001$ Vs Group II. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's multiple comparison test.

considerably more feed and water. All the treatments significantly normalized the increased feed and water intake in diabetic rats.

Effect of Insuwin and Insuwin forte on blood glucose levels in diabetic rats

Fasting blood glucose levels in diabetic rats were 262-283 mg/dL before therapy, which was significantly ($p<0.001$) higher than in normal rats. On day 21 of the study, it continued to rise to 454 mg/dL. Treatment with glimepiride, Insuwin, and Insuwin forte significantly lowered blood glucose by 202.5 mg/dL (23%) with glimepiride, 248.5 mg/dL (8%) with Insuwin and 213.5 mg/dL (21%) in Insuwin forte on day 14 and 154.75 mg/dL (41%) in glimepiride, 210.5 mg/dL (22%) in Insuwin and 163.0 mg/dL (40%) in Insuwin forte on day 21 (Table 6).

Effect of Insuwin and Insuwin forte on serum lipid profile and HbA_{1c} levels in diabetic rats

When compared to the normal control, the serum lipid profile in diabetic control showed significant abnormalities such as increased serum total cholesterol, triglyceride, and LDL, and decreased HDL values. All the treatments significantly normalize the lipid abnormality induced by diabetes, except serum LDL level there were no significant changes in the glimepiride and Insuwin treatments and a significant ($p<0.05$) reduction in serum LDL level was noted in Insuwin forte-treated rats when compared to diabetic control. In diabetes controls, serum HbA_{1c} levels were significantly ($p<0.001$) higher. The entire drug-treated groups significantly ($p<0.001$) reverse the increased serum HbA_{1c} level (Table 7).

Table 6: Effect of Insuwin and Insuwin forte on blood glucose levels in diabetic rats.

Treatment	Fasting blood glucose level (mg/dL)			
	Day 0	Day 7	Day 14	Day 21
Group-I (Normal Control)	81.5 ± 5.25	82.75 ± 3.88	86.00 ± 4.60	84.50 ± 3.12
Group-II (Diabetic Control)	282.75 ±12.51^{c}	362.75 ± 8.68 ^{c}	427.50 ± 44.77^{c}	454.50 ± 37.89^{c}
Group-III (Glimepiride)	261.75 ± 24.51^{c}	247.50 ± 12.74^{cf}	202.50 ± 29.80^{bf} (23%)	154.75 ± 13.53^{bf} (41%)
Group-IV (Insuwin)	270.50 ± 10.20 ^{c}	255.25 ± 20.16^{cf}	248.50 ± 28.82^{cf} (8%)	210.50 ± 17.66^{cf} (22%)
Group-V (Insuwin forte)	270.50 ± 11.73 ^{c}	250.75 ± 17.29^{cf}	213.50 ± 19.52^{bf} (21%)	163.00 ± 15.40^{bf} (40%)

Values are expressed as mean ± SEM, n=6. Symbols represent statistical significance $^{a}p<0.05$; $^{b}p<0.01$; $^{c}p<0.001$ Vs Group I. $^{d}p<0.05$; ^{e} $p<0.01$; ^{f} $p<0.001$ Vs Group II. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's multiple comparison test.

Table 7: Effect of Insuwin and Insuwin forte on serum lipid profile and HbA_{1c} levels in diabetic rats.

Treatment	Lipid Profile (mg/dL)				HbA_{1c} (%)
	Total cholesterol	Triglyceride	LDL	HDL	
Group-I (Normal Control)	164.00 ± 14.00	136.00 ± 13.06	82.00 ±5.03	44.33 ± 1.20	4.37 ± 0.12
Group-II (Diabetic Control)	214.67 ± 10.48^{b}	179.67 ± 7.83^{b}	113.00 ± 8.96^{b}	26.00 ± 3.61^{a}	9.77 ± 0.58^{c}
Group-III (Glimepiride)	156.67 ± 14.11^{e}	139.33 ± 9.33^{e}	99.00 ± 7.00	66.67 ± 6.12^{bf}	5.03 ± 0.38^{f}
Group-IV (Insuwin)	149.67 ± 17.32^{e}	129.33 ± 9.83^{e}	93.67 ± 7.45	72.00 ± 3.06^{cf}	5.43 ± 0.79^{f}
Group-V (Insuwin forte)	146.67 ± 15.70^{e}	127.00 ± 10.79^{e}	86.33 ± 6.17^{d}	72.33 ± 6.36^{cf}	4.77 ± 0.66^{f}

Values are expressed as mean ± SEM, n=3. Symbols represent statistical significance $^{a}p<0.05$; $^{b}p<0.01$; $^{c}p<0.001$ Vs Group I. $^{d}p<0.05$; $^{e}p<0.01$; $^{f}p<0.001$ Vs Group II. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's multiple comparison test.

Effect of Insuwin and Insuwin forte on liver function test and kidney function test in diabetic rats

When compared to the normal control, diabetes control serum Aspartate Aminotransferase (AST) and Alanine Transaminase (ALT) levels were significantly ($p<0.001$) higher. Glimepiride, Insuwin, and Insuwin forte therapy significantly ($p<0.001$) reduce the elevated AST and ALT levels in diabetic rats. When compared to the normal control, the diabetic control had a mildly significant ($p<0.05$) rise in serum urea and the most significant ($p<0.001$) increase in creatinine levels. Glimepiride and Insuwin treatment did not result in any significant changes in serum urea levels, however, Insuwin forte treatment significantly ($p<0.05$) reduced the elevated serum urea levels in diabetic rats. Though, all therapies significantly (p 0.01) lower increased serum creatinine levels in diabetic rats (Table 8).

Effect of Insuwin and Insuwin forte on absolute organs weight in diabetic rats

Table 9 data represents the effect of Insuwin and Insuwin forte on absolute organ weights in diabetic rats. In diabetes control, the weight of the liver and kidneys was considerably ($p<0.01$) reduced. When compared to the normal control, no significant changes in spleen weight were seen in the diabetes control or any of the other treatments. Insuwin forte therapy considerably ($p<0.05$) improves kidney weight near normal control rat kidney weight.

Histopathological changes in the pancreas

The histology of a normal control pancreas shows normal pancreatic ducts, exocrine components, and blood vessels, numerous large intact islets of langerhans, and a few reactive lymph nodes. Diabetic control rat pancreas shows dilated

Table 8: Effect of Insuwin and Insuwin forte on liver function test and kidney function test in diabetic rats.

Treatment	Liver function test		Kidney function test	
	AST (U/L)	ALT (U/L)	Urea (mg/dL)	Creatinine (mg/dL)
Group-I (Normal Control)	19.67 ± 1.76	32.67 ± 2.03	18.00 ± 1.73	0.70 ± 0.12
Group-II (Diabetic Control)	78.00 ± 6.35[c]	104.00 ± 9.87[c]	25.67 ± 3.53[a]	1.73 ± 0.29[c]
Group-III (Glimepiride)	33.33 ± 4.49[f]	34.33 ± 3.76[f]	21.00 ± 2.08	0.93 ± 0.15[e]
Group-IV (Insuwin)	34.33 ± 6.17[f]	38.33 ± 3.76[f]	19.33 ± 1.89	0.77 ± 0.09[e]
Group-V (Insuwin forte)	23.67 ± 4.63[f]	37.30 ± 5.84[f]	18.67 ± 2.03[d]	0.73 ± 0.09[e]

Values are expressed as mean ± SEM, n=3. Symbols represent statistical significance [a]p<0.05; [b]p<0.01; [c]p<0.001 Vs Group I. [d]p<0.05; [e]p<0.01; [f]p<0.001 Vs Group II. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's multiple comparison test.

Table 9: Effect of Insuwin and Insuwin forte on absolute organs weight in diabetic rats.

Treatment	Absolute organ weight (g)			
	Liver	Kidney		Spleen
		Right	Left	
Group-I (Normal Control)	6.95 ± 0.98	1.01 ± 0.04	1.05 ± 0.03	0.56 ± 0.04
Group-II (Diabetic Control)	4.61 ± 0.64[a]	0.74 ± 0.05[b]	0.77 ± 0.04[b]	0.46 ±0.05
Group-III (Glimepiride)	5.28 ± 0.48	0.85 ± 0.05	0.89 ± 0.05	0.49 ±0.04
Group-IV (Insuwin)	6.47 ± 0.85	0.90 ± 0.08	0.94 ± 0.08[d]	0.53 ±0.05
Group-V (Insuwin forte)	6.30 ± 0.45	0.93 ±0.03[d]	0.96 ± 0.03[d]	0.57 ±0.06

Values are expressed as mean ± SEM, n=3. Symbols represent statistical significance [a]p<0.05; [b]p<0.01; [c]p<0.001 Vs Group I. [d]p<0.05; [e]p<0.01; [f]p<0.001 Vs Group II. Data were analyzed by one-way ANOVA followed by post hoc Dunnett's multiple comparison test.

pancreatic ducts, the exocrine component with stromal edema, very tiny clusters of necrotic islet cells, and a few reactive lymph nodes. Insuwin-treated rat pancreas shows mildly edematous exocrine component, islet cell aggregates with around 50% of the aggregate size of normal non-diabetic rats, and a few reactive lymph nodes. Insuwin forte treated rat pancreas shows mildly edematous exocrine component, islet cell aggregates with around 80% of the aggregate size of normal non-diabetic rats, and a few reactive lymph nodes. Glimepiride-treated pancreas shows mildly edematous exocrine component, ·islet cell aggregates with around 85% of the aggregate size of normal non-diabetic rats and a few reactive lymph nodes (Figure 1).

DISCUSSION

Insuwin and Insuwin forte are the polyherbal Siddha and Ayurvedic tablet preparation indicated for type-II diabetes mellitus, the primary goal of this study was to assess the efficacy of Insuwin and Insuwin forte in Streptozotocin (STZ) and nicotinamide-induced type II diabetic rats. The streptozotocin and nicotinamide-induced diabetic model is the widely accepted model which mimics most of the clinical features of human diabetes mellitus.[12]

The treatment of glimepiride, Insuwin, and Insuwin forte produce significant hypoglycemia in the normal fasted rats 4 hr after administration and steadily reduce up to 8 hr. The treatment of glimepiride produced more significant hypoglycemia than the Insuwin and Insuwin forte treatments. Glimepiride's

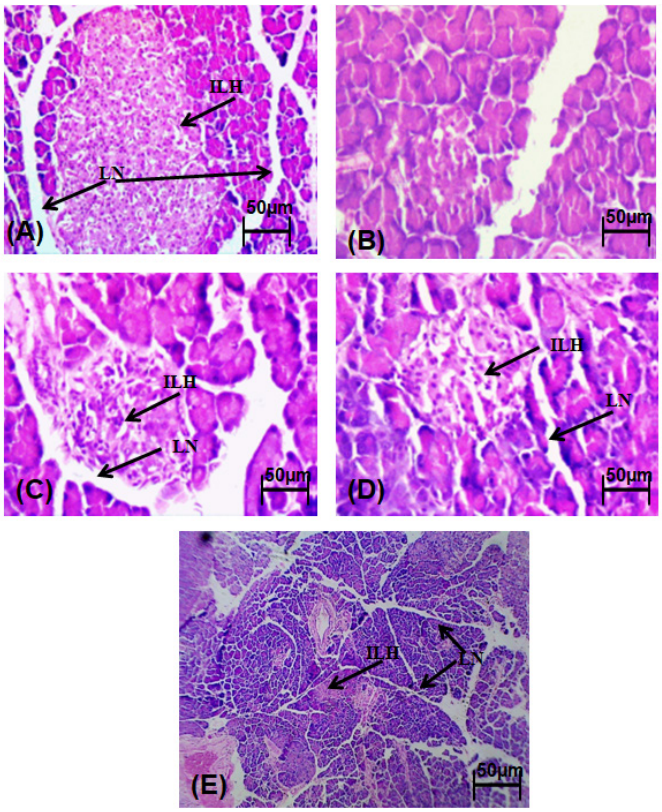

Figure 1: Effect of Insuwin and Insuwin forte on pancreas histopathological changes in diabetic rats. Effect of Insuwin and Insuwin forte on pancreas histopathological changes in diabetic rats. A) Normal Control; B) Diabetic Control; C) Insuwin treatment D) Insuwin forte treatment; E) Standard treatment (Glemipiride). ILH- Islet of langerhans, LN-Lymph nodes.

hypoglycemic impact in normal fasting rats is attributed to enhanced insulin release by activating pancreatic β cells.[13,14] Besides the hypoglycemic effect of Insuwin and Insuwin forte might be also due to the insulin-releasing effect.

In normal fasting rats, the Oral Glucose Tolerance Test (OGTT) was used to assess the effect of Insuwin and Insuwin forte on insulin after a glucose challenge. OGTT is a key parameter to measure insulin resistance.[15] Our findings indicated that the rate of glucose clearance was significantly higher in glimepiride and Insuwin forte-treated normal fasting rats from 60 to 120 min after the oral glucose challenge. It also confirms the blood glucose lowering property of Insuwin forte treatment might be due to the pancreatic β cells stimulatory effect of insulin release and promotes glucose utilization.

Diabetes mellitus is related to a loss of body weight due to muscle wasting, loss of tissue protein, and breakdown of accessible fat and is used as a secondary energy source in diabetic circumstances due to a lack of glucose utilization.[16,17] Our findings also show that diabetic control rats have a significant loss in body weight. In comparison, body weight changes were improved with Insuwin forte treatment, which may be due to its hypoglycemic property through improved glucose utilization. Polyphagia, polyuria, and polydipsia are the foremost diagnostic feature of diabetes mellitus.[18,19] The feed intake and water intake were significantly increased in the diabetic control rat, and these clinical conditions were significantly reversed in all the treatments in diabetic rats.

In our study, diabetes mellitus was induced by the administration of streptozotocin and nicotinamide through the mechanism of partial destruction of insulin-producing pancreatic beta cells, making beta cells less active.[20] Fasting blood glucose (FBG) levels were considerably higher in diabetic rats after induction and gradually increased in diabetic control rats for up to 21 days. All the treatments significantly reduced the FBG in the diabetic rats; in comparison between the treatments the hypoglycemic effect of Insuwin forte is almost equal to the treatment of glimepiride. Excess blood glucose combines with hemoglobin to create glycated hemoglobin (HbA_{1c}), which has been reported to be elevated in diabetes patients.[21,22] The treatment of Insuwin, Insuwin forte, and glimepiride significantly decreased the HbA_{1c} level in diabetic rats. The treatment of Insuwin forte reduce the HbA_{1c} level almost nearer to the normal control value, it indicates the superior effect of Insuwin forte on hyperglycemia in chronic diabetic condition.

Diabetes mellitus is usually associated with impaired lipid profiles characterized by elevated serum triglyceride, VLDL, and LDL levels and decreased HDL levels, which may confer an increased risk of coronary heart disease. Diabetes-related lipid abnormalities are primarily caused by insulin insufficiency and/or insulin resistance.[23] This study's findings also revealed that STZ-induced diabetes caused hyperlipidemia by raising serum total cholesterol, triglyceride, and LDL levels while reducing HDL levels. Except for LDL, the glimepiride and Insuwin therapies significantly reversed the STZ-induced increases in TC, TG, and lower levels of HDL. The treatment of the Insuwin forte sample alone completely normalizes the altered lipid profile nearer to the normal value.

Hyperglycemia leads to affect hepatic and renal function in diabetic conditions. Increased blood AST and ALT levels in diabetic rats indicate liver injury, which has been linked to augmented gluconeogenesis and ketogenesis.[24] Also, the elevated level of serum urea and creatinine is considered to be an indicator of renal dysfunction in diabetic conditions.[25] Results of our study also confirm the elevated level of serum AST, ALT, urea, and creatinine indicates hepatic and renal damage in diabetic control. Significant changes in the weight of the liver and kidneys in diabetic control also confirm the abnormality in liver and kidney function. The treatment of Insuwin and Insuwin forte significantly reduce the elevated AST, ALT, and serum creatinine levels, the treatment of Insuwin forte also significantly reduce elevated serum urea level in diabetic rats. Hence the treatment of Insuwin forte treatment showed a superior effect on improving both the hepatic and renal function in diabetic rats. Histopathological analysis of the pancreas also confirms the treatment effectiveness of Insuwin forte in diabetes mellitus,

when compared to Insuwin treatment the treatment of Insuwin forte superiorly improves the beta cells density in diabetic rats which is almost equal to standard glimepiride treatment.

CONCLUSION

In conclusion, the results of our data suggested that the treatment of Insuwin and Insuwin forte possesses anti-diabetic properties in STZ and nicotinamide-induced diabetes mellitus. As the treatment of Insuwin and Insuwin forte tablets reduce the fasting blood glucose level in both normal and diabetic rats, and also in the oral glucose challenged rats by improving glucose uptake, both treatments improve weight loss, altered lipid profile, and reduce the HbA_{1c} level. When comparing the Insuwin and Insuwin forte treatments Insuwin forte possesses superior hypoglycemic, hypolipidemic, reduces glucose tolerance, and improves beta cell regeneration, and hepatic and renal production in diabetic rats. These beneficial effects of Insuwin forte might be due to its potential polyherbal combinations. Our study results provide scientific evidence that Insuwin forte could be a safe and effective alternative oral hypoglycemic agent for diabetes mellitus.

ACKNOWLEDGEMENT

The authors are thankful to Mrs. Kumutaavalli Shivkumar, Managing Director and Mr. S. K. Sharath Ram, Executive Director of SKM Siddha and Ayurveda Company (India) Private Limited for all the necessary support and financial assistance.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

AFI: Ayurvedic Formulary of India; **ALT:** Alanine aminotransferases; **ANOVA:** Analysis of variance; **API:** Ayurvedic Pharmacopoeia of India; **AST:** Aspartate transaminases; **CCSEA:** Committee for Control and Supervision of Experiments on Animals; **CMC:** carboxymethylcellulose; **DM:** Diabetes Mellitus; **FBG:** Fasting blood glucose level; **HbA1c:** Glycosylated hemoglobin; **HDL:** High-density lipoprotein; **IAEC:** Institutional Animal Ethics Committee; **LDL:** Low-density lipoprotein; **NIDDM:** Non-insulin-dependent diabetic mellitus; **OGTT:** Oral Glucose Tolerance Test; **SEM:** Standard error mean; **SGLT-2:** Sodium-glucose transporter-2; **STZ:** Streptozotocin; **TG:** Triglycerides; **WHO:** World Health Organization.

SUMMARY

Insuwin is a herbo-metallic based preparation and Insuwin forte is an extract-based polyherbal tablet preparation indicated for type-II diabetes mellitus. In this study, the comparative antidiabetic efficacy of Insuwin and Insuwin forte was investigated using streptozotocin-nicotinamide-induced rat model. The results revealed that both the preparations were effective in type-II diabetes mellitus, with Insuwin forte showing superior hypoglycemic effect by improving glucose uptake through induced insulin release. It also normalized lipid abnormalities, protected the liver and kidneys, and improved the number of beta cells in the islet of Langerhans. The results of this study suggest that Insuwin forte may be a safe and effective alternative oral hypoglycemic agent for diabetes mellitus.

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Cite this article: Thangavel G, Murugesan S, Pachiappan S, Gopal M. Comparative Therapeutic Evaluation of Insuwin and Insuwin Forte Polyherbal Formulation on Streptozotocin and Nicotinamide Induced Diabetic Rats. Pharmacog Res. 2024;16(1):72-81.